Indirect Assessment of Practical Skills Working Group Report

Exemplifying the indirect assessment of practical skills in AS/A level biology, chemistry and physics

ofqual

Contents

Executive Summary

The reformed A levels have seen the assessment of practical skills formalised in Ofqual's requirements for the first time. To support the ongoing development and delivery of this assessment, we convened a meeting of subject experts from Ofqual and the exam boards to consider the indirect assessment of practical skills in the written assessments for the A levels in biology, chemistry and physics. The discussions provided a rich source of evidence, and the resulting report provides some common principles for good practice in the assessment of these skills, reflecting the content requirements, assessment objectives and other regulatory requirements.

Introduction

New assessment arrangements relating to practical skills in A level physics, chemistry and biology have been in place since these subjects were reformed for teaching in 2015.

The assessment of practical skills can be *direct* or *indirect*[1]. *Indirect* assessment relates to any form of assessment in which a student's competency in terms of a specific or generic skill, including those gained through the manipulation of real objects, is inferred from their data and/or reports of the practical work they undertook. The assessment can include, in this context, written examination papers taken by students.

The assessment of practical skills can also be *direct*, where students, are required, through the manipulation of real objects, to directly demonstrate a specific or generic skill in a manner that can be used to determine their competence in that skill. For the reformed A level[2] qualifications, direct assessment is carried out by teachers observing their students in the laboratory against criteria agreed between the exam boards. The outcome of the direct assessment forms the Practical Endorsement, a separately reported result alongside the main A level grade. Students can achieve either a 'pass' where they have demonstrated competency against the criteria, or they are 'not classified'.

To support the development and delivery of the *indirect* assessment of practical skills, we convened a meeting of subject experts from Ofqual and the exam boards to agree some common principles for good practice in designing questions that address this area of assessment.

This report is the output of that meeting and contains examples of questions from all three subject areas which the subject experts agree address the principles well. The report is intended as a source of information for exam boards to consider in designing their assessments but may also be interesting to those involved in delivering the courses of study.

---

[1] Reiss, M., Abrahams, I. & Sharpe, R. (2012). *Improving the Assessment of Practical Work in School Science.* London: Gatsby Charitable Foundation. Available at: http://www.gatsby.org.uk/uploads/education/reports/pdf/improving-the-assessment-of-practical-work-in-school-science.pdf

[2] Students taking an AS qualification are expected to have carried out practical work but the assessment is through the indirect route in the examination papers only.

We will consider the report as we develop additional guidance on the indirect assessment of practical skills. The examples used in this document are provided for illustrative purposes, and the questions and mark schemes provided might not have gone through the full review process for use in live examinations. The examples have been drawn from across the exam boards, and so reflect a variety of different legitimate approaches to assessment. The questions and mark schemes are those written by the exam boards and are reproduced with their permission.

The working group has provided a rich source of evidence on the indirect assessment of practical skills in different subject contexts. In doing so, the group recognises the overlap that exists between the delivery of curriculum aspirations and the delivery of reliable assessments on a national scale. For example, in physics there is an inevitable overlap between practical and mathematical skills and, in some cases, it is appropriate that calculations are firmly classed as meeting both the requirements for mathematical skills and those for indirectly assessing practical skills. This overlap is mentioned in the principles for good practice.

The principles provided in this document (below) demonstrate that subject experts agree on the focus and purpose of the assessment within an examination context. They provide some common ground for assessment developers. The principles also highlight the need for mark schemes to support the reliable and consistent reward of candidates for demonstrating the application and understanding of practical skills in a manner appropriate to the focus of the question.

Indirect assessment of practical skills requirements

The practical skills to be assessed indirectly in GCE AS and A level biology, chemistry, physics and psychology[3] are listed in Appendix 5 of the subject content. The Ofqual GCE Subject Level Guidance for Science[4] states that we expect that at least 15% of the marks available for the assessment by examination in each science (physics, chemistry and biology) will be allocated to questions which indirectly assess a student's practical skills, as described in Appendix 5a.

Appendix 5a is titled "Practical skills identified for indirect assessment and developed through teaching and learning" prior to listing the required skills. This makes clear the expectation that teaching and learning allows students to develop their skills using a wide range of practical experiences, as detailed in each specification offered by the exam boards.

We do not require that the items that indirectly assess practical skills do so in isolation of the other course content. Good practice means that such items should draw on students' wider knowledge of scientific theory, as well as their practical knowledge and skills – assessing science in the broadest sense. This practical

[3] Department for Education (April 2014) GCE AS and A level subject content for biology, chemistry, physics and psychology, DFE-00357-2104, https://www.gov.uk/government/publications/gce-as-and-a-level-for-science

[4] Ofqual (July 2015) GCE Subject Level Guidance for Science (Biology, Chemistry, Physics)

knowledge will be rooted in the practical activities highlighted as the minimum requirements within specifications. These cover the use of apparatus and development of skills specific to each subject as listed in Appendix 5c.

The subject experts agreed that it is important that the identification of questions and items that indirectly assess practical skills is accurate to support valid assessment and consistent understanding. This means that the identification has to be carefully considered at item level and not just whole questions. The indirect assessment of practical skills should not be over or under assigned e.g. when most of a question is theory based but there is an item that does indirectly assess practical skills, it should be identified as such. Likewise, if most of a question is assessing practical skills, any theory only items should be identified as such. This approach will provide clarity and avoid ambiguity about the focus of the assessment for users of the specifications.

Common principles for good practice in the indirect assessment of practical skills

The principles outlined below are intended as a guide for good practice, and reflect the requirements and expectations of the content, assessment objectives and regulatory requirements outlined above.

1. Questions that indirectly assess practical skills should be indicated in mark schemes, examiner reports and assessment grids in order to facilitate understanding of this part of the assessment. It is not expected that question papers will separately identify questions in which practical skills are indirectly assessed.
2. Exam boards should indicate **all** questions and items that indirectly assess practical skills. There is no maximum weighting restriction and, therefore, an exam board should not limit its identification of this type of assessment to 15% of the marks.
3. When indirectly assessing practical skills, the term ‘practical’ means “an activity that students could undertake in a school laboratory/fieldwork or that could be demonstrated to them by a teacher”.[5]
4. Where practical skills are indirectly assessed, there is legitimate variation in the types of questions and tasks that can be used.
5. Overlap between practical and mathematical skills –
    a) where mathematical skills overlap with the requirements for the indirect assessment of practical skills, the marks can be attributed to the regulatory requirements for both mathematical skills and the indirect assessment of practical skills.

[5] There are some experiments that it is not feasible for students to do for health and safety reasons. However, where it is possible for teachers to demonstrate such experiments it is reasonable for students to be indirectly assessed on these activities in the written examinations.

b) where mathematical skills are assessed but not in a practical context the marks can be attributed to the regulatory requirements for mathematical skills but not the indirect assessment of practical skills[6].

The subject experts were confident that where exam boards assign more marks to the indirect assessment of practical skills than the minimum expected in the Ofqual Guidance document (15%), this will not be to the detriment of the overall assessment, presuming the principles are followed. As A level science subjects have an inherently practical context, a higher than required weighting of marks for the indirect assessment of practical skills will not detract from the effective assessment of knowledge and understanding.

Users of the qualifications, teachers and students, should know that a varied experience of practical work, covering all relevant parts of the Subject Content, should benefit students when they are faced with these questions that indirectly assess practical skills.

Conclusions

The exemplar questions provided show that it is possible to design questions that meet Ofqual's regulations and complement the subject content in an appropriate way.

The approach to the assessment of practical skills has changed considerably from that in the legacy qualifications. The indirect assessment of practical skills, as described in this report and as exemplified in the questions above, is a way of encouraging teachers to embed practical skills in A level science courses so that practical work forms an integral part of the teaching and learning in these subjects.

The questions and commentaries above show that it is possible to indirectly assess these skills in a variety of ways. The approaches taken to this form of assessment by the exam boards in these exemplars meet the principles described on page 5 of this report.

The traditional approach to the development of a student's practical skills has always been based on first hand practical experience by the student and this remains the case. However, the questions that indirectly assess these skills are an important part of the overall assessment and this report indicates that teachers should be encouraged to underpin their A level courses with a practical approach.

Exemplar questions, mark schemes & commentaries

The exemplars below are taken from assessment materials from the exam boards offering qualifications in the A level sciences. The questions represent the indirect assessment of practical skills at both AS and A level and cover a range of different

---

[6] Appendix 5a of the subject content requires the 'application of mathematical concepts in a practical context'.

content areas and question types. Each exemplifies effective ways of indirectly assessing practical skills and is accompanied by a short commentary that explains the approach taken for each question, the aspects of Appendix 5a addressed and the rationale for the marks attributed to the indirect assessment of practical skills together with some observations about good practice in the delivery of the course.

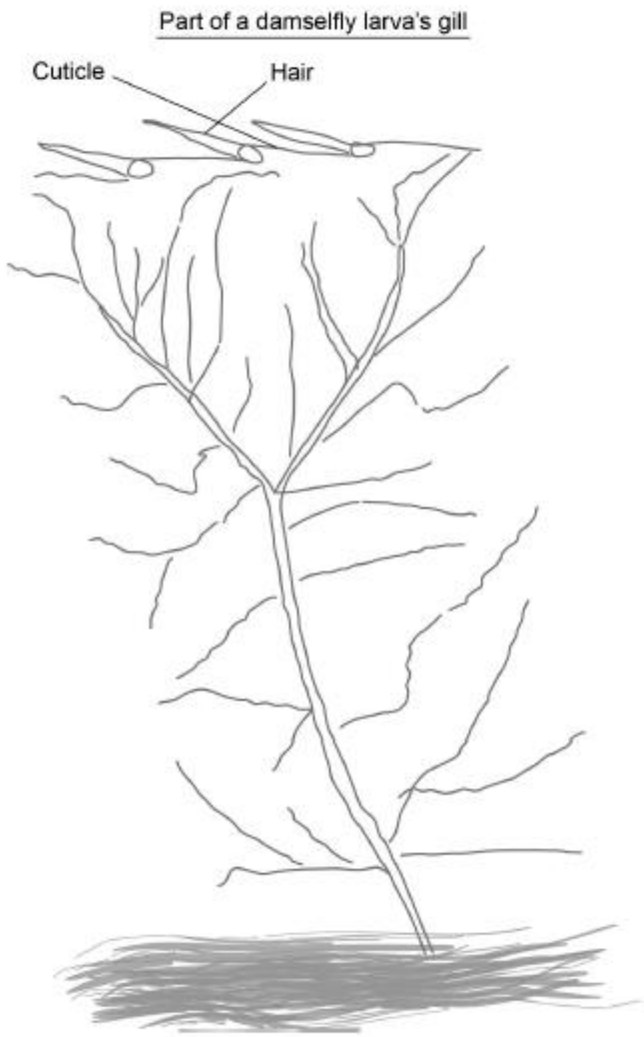
Biology

Example B1

0 9 . 4 A student used an optical microscope to observe part of a damselfly larva gill.

Figure 5 shows the drawing the student produced.

Figure 5



box

Suggest two ways the student could improve the quality of her scientific drawing of this gill.

[2 marks]

1 ______________________________

____

____

2 ______________________________

____

____

10

Example B1 mark scheme

9.4	1. Don't use shading; 2. Only use single lines/don't use sketching (lines)/ensure lines are continuous/connected; 3. Add further labels/annotations; 4. Don't cross label lines; 5. Add magnification/scale (bar);	2 max	Reject 'colour in'. Reject 'use of electron microscopes' Ignore 'use a sharp pencil'

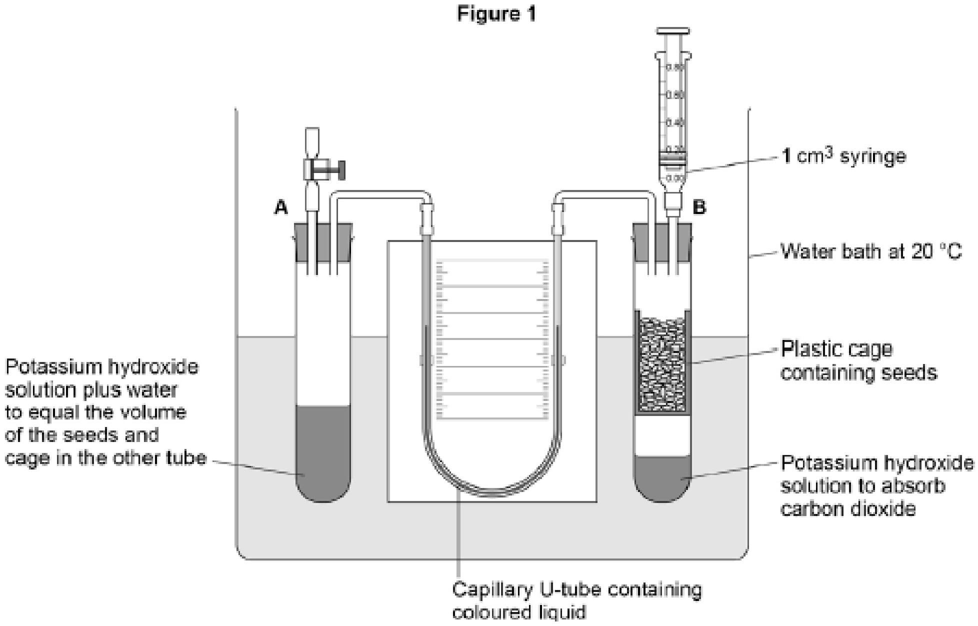
Example B1 Commentary

Description	This question asks students to suggest improvements to a biological drawing of a damselfly larva gill.
Appendix 5a skills assessed	• 'Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification'
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • It demonstrates how the skill from Appendix 5c to the Content 'produce scientific drawing from observation with annotations' can be assessed in a written examination. • This question shows the importance of students developing good biological drawing skills over their 2 year A level course.

Example B2

1 **Figure 1** shows the apparatus used for measuring the rate of oxygen consumption in aerobic respiration by seeds.

Figure 1



0 1 . 1 For the first 10 minutes, the tap attached to tube **A** was left open and the syringe from tube B was removed.

Suggest **three** reasons why the apparatus was left for 10 minutes.

[3 marks]

1 ____

____

2 ____

____

3 ____

____

0 1 . 2 Suggest and explain why the chosen temperature was 20 °C for this experiment.

[2 marks]

After 10 minutes, the tap attached to tube **A** was closed and the syringe was attached to tube B. Every minute, the syringe plunger was moved until the levels in the U-tube were the same. The reading on the syringe volume scale was then recorded.

The results are shown in **Table 1**.

Table 1

Time / minutes	Reading on syringe volume scale / cm^3
0	0.84
1	0.81
2	0.79
3	0.76
4	0.73
5	0.70
6	0.68
7	0.66
8	0.63
9	0.62
10	0.58

0 1 . 3 During the experiment, the coloured liquid in the tubing moved towards tube B. Explain what caused this.

[3 marks]

___

___

___

___

___

___

[Extra space] ___

___

___

0 1 . 4 The mass of the seeds was 1.6 g. Use the information in **Table 1** to calculate the rate of oxygen consumption in $cm^3 g^{-1} hour^{-1}$ by the seeds.

Show your working.

[2 marks]

Rate = ____________________________ $cm^3 g^{-1} hour^{-1}$

Example B2 mark scheme

Question	Marking Guidance	Mark	Comments
01.1	1. Equilibrium reached; 2. Allow for expansion/pressure change in apparatus; 3. Allow respiration rate of seeds to stabilise;	3	1. Accept equilibrate 3. Ignore seeds acclimatise
01.2	1. Optimum temperature/temperature for normal growth of seeds; 2. (Optimum temperature) for enzymes involved in respiration;	2	
01.3	1. Oxygen taken up/used by seeds; 2. CO_2 given out is absorbed by KOH (solution); 3. Volume/pressure (in B) decreases;	3	
01.4	0.975/0.98;	2	If incorrect, 0.26 × 6 / or incorrect numbers divided by 1.6 for 1 mark

Example B2 Commentary

Description	Parts 1.1 and 1.2 require students to provide explanations for the way in which apparatus was set up to measure the rate of oxygen consumption in aerobic respiration in seeds. Part 1.3 asks for an explanation of the experimental results. Part 1.4 is a calculation of the rate of oxygen consumption by the seeds.
Appendix 5a skills assessed	• ‘Comment on experimental design and evaluate scientific methods’. • ‘Apply scientific knowledge to practical contexts’. • ‘Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students will have a material advantage when approaching this question as a result of completing the related required practical activity. • Parts 1.1 and 1.2 require students to demonstrate that they understand why parts of the procedures are carried out. • Part 1.3 would only be accessible to students who have fully understood how the practical activity is linked to the relevant biological theory. • It demonstrates how the skill from Appendix 5c to the Content ‘use appropriate apparatus to record a range of quantitative measurements’ can be assessed in a written examination.

Example B3

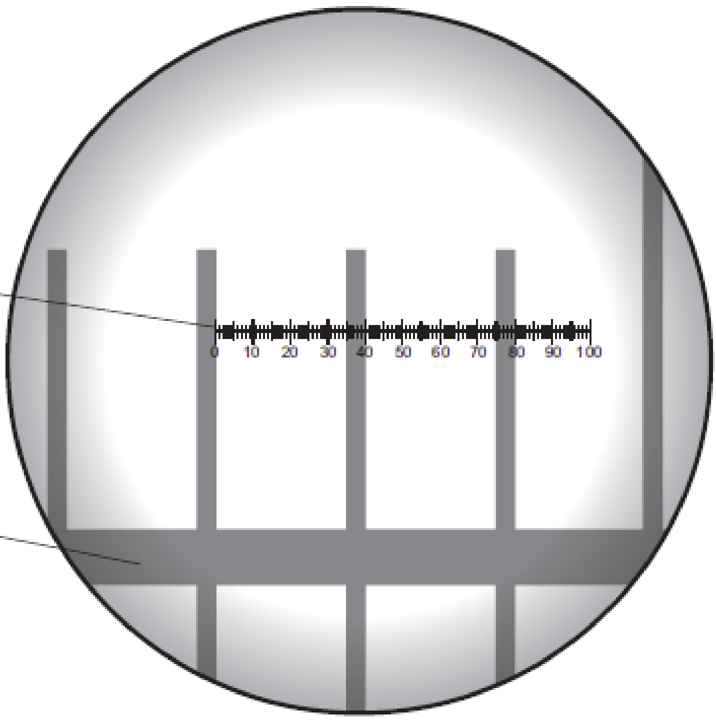
E

2. It is possible to germinate pollen grains *in vitro* by placing them in a suitable solution containing a mixture of mineral salts. One technique involves hanging a droplet of the mixture from the underside of a coverslip and suspending the coverslip above a microscope slide using petroleum jelly. The pollen grains may then be observed directly through a microscope.

(a) The photomicrograph below shows part of a stage micrometer and the eyepiece graticule.

Eyepiece graticule scale

Stage micrometer scale

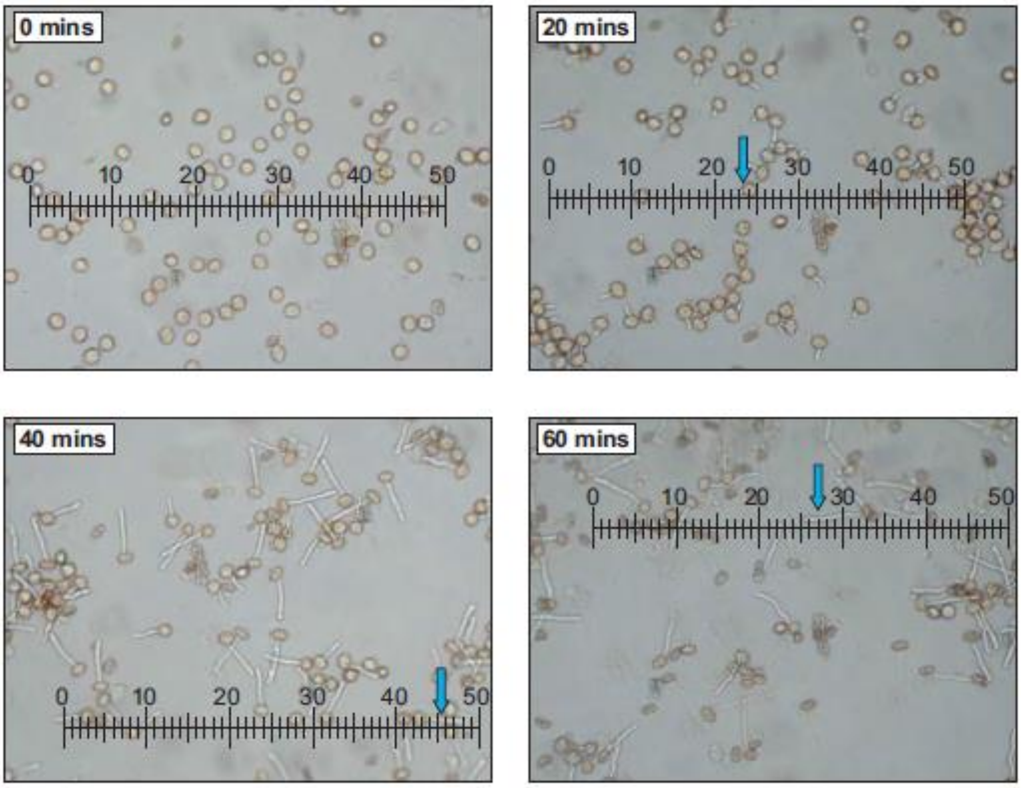


The smallest divisions on the stage micrometer measure 100 µm.

(i) Calibrate the eyepiece graticule. Express your answer to one decimal place. [2]

1 eyepiece unit = ... µm

The photomicrographs below were taken at time intervals of 20 minutes from placing the pollen in the solution.



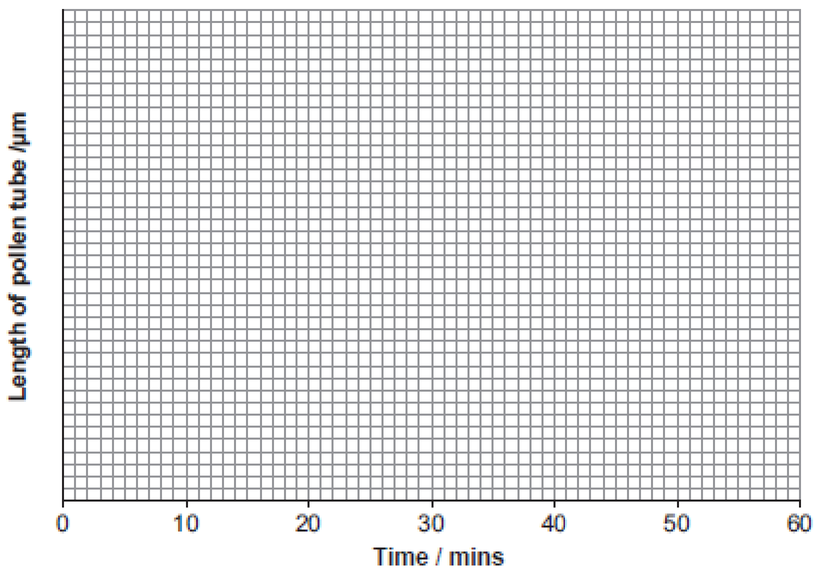
Exa

(ii) Use the eyepiece graticule to measure the length of the pollen tube indicated by an arrow from each photomicrograph. Measure each pollen tube to the nearest whole number. **Enter the values in the table below.** [2]

Time / mins	Length of pollen tube / eyepiece graticule units	Actual length of pollen tube /µm
0	0	0
20	....	....
40	....	....
60	....	....

(iii) Calculate the actual length of the pollen tubes in µm. **Write your answers in the table above.** [2]

(iv) Plot a graph of the results using a suitable scale for the y-axis. [3]



(v) How could you make the data more reliable? [1]

....

Exa
o

(b) Using the technique described on page 5, design an experiment to investigate the effect of pH on the growth of pollen tubes.

Give a brief description of your method. [4]

....

....

....

....

....

....

....

....

....

....

Example B3 mark scheme

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	(a)	(i)		2.5 µm = 2 marks If incorrect allow 1 mark for: 80 eyepiece units=2 x 100 µm 40 eyepiece units=1x 100 µm 1epu = 200/80 1epu = 100/40		2		2	2	2
		(ii)		1,5,7 2marks for 3 correct ,1 for 2 correct	2			2		
		(iii)		2.5, 12.5/ 15.0, 17.5 Accept rounding up 3, 13, 18 2marks for 3 correct ,1 for 2 correct **ecf from ai and aii**		2		2	2	2
		(iv)		**Ecf from aiii** Scale – linear, include 0 at origin, sensible scale(1) 1mark for plots +/- ½ small square tolerance(1) 1 mark for line dot to dot through centres/ good curve of best fit ; (1)		3		3	3	
		(v)		{Measure more tubes/ repeat} **and** calculate a {mean/ average};			1	1		1
	(b)			Place pollen grains in range of {pH (solutions)/ pH (buffers)/ pHs by adding acid or alkali} (1) measure lengths at a set time/ time intervals/every 20 min (1) NOT different time intervals **Any 2 (x1) from:** same (species/ type of) plant (1) same concentration of solution (1) {same/ control} temperature (1) Same {mass/ volume/ amount/ age} of pollen grains (1) Light intensity (1)			4	4		4

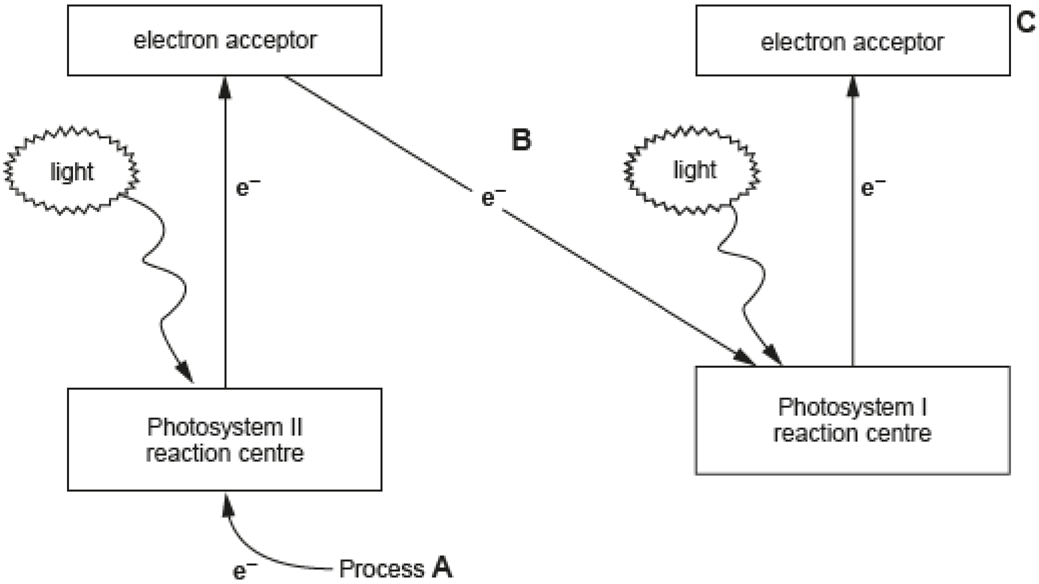
Example B3 Commentary

Description	(a) (i) requires students to use given data to calibrate an eyepiece graticule. (a) (ii) and (iii) ask students to use their calibration from part (i) to provide an actual size for pollen tubes shown in photomicrographs. (a) (iv) is a graph question where students are asked to provide a scale for the data that has already been plotted. (a) (v) assesses the understanding that the student has of 'reliability'. Part (b) requires students to extend the practical activity and to develop the method provided in order to investigate a different variable.
Appendix 5a skills assessed	• 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'. • 'Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification'. • 'Plot and interpret graphs'. • 'Comment on experimental design and evaluate scientific methods' • 'Solve problems set in practical contexts' • 'Identify variables including those that must be controlled'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students who have undertaken similar practical activities will be better prepared for questions of this type (use of light microscope including use of a graticule is a practical requirement). • This is an example of where mathematics skills are being assessed within a practical context. • Students who had taken the opportunity to discuss why they were carrying out practical activities would be better able to provide an answer to this question. A wide variety of opportunities to develop their own practical work would have been an ideal preparation for this type of question.

Example B4

Exa

4. The light dependent stage of photosynthesis can be represented by a diagram called the Z-scheme, shown below.



(a) (i) **Describe** the process at **A** which replaces the electrons lost from photosystem II and explain how electrons are used at **B** and **C**. [3]

....

....

....

....

....

....

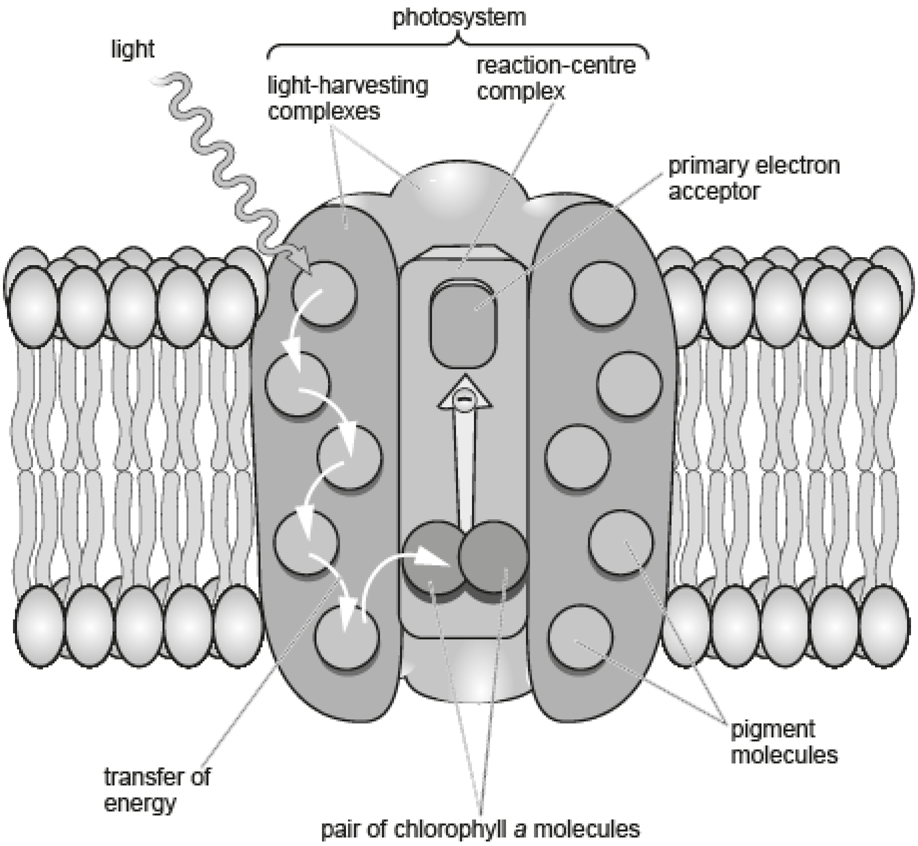
....

....

(ii) **Draw a clear line** labelled **X** on the Z-scheme diagram above, to indicate the movement of electrons in cyclic photophosphorylation. [1]

Ex

(b) The modern representation of a photosystem is shown in the diagram below.



(i) Apart from chlorophyll *a*, name **three** *other* pigments you would expect to be present in a photosystem. [2]

....

....

....

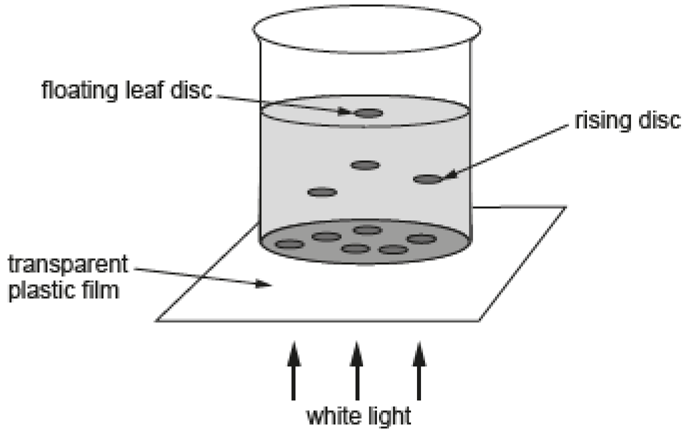
(ii) State precisely where a photosystem would be found in a plant cell. [1]

....

Ex

(c) An experiment was carried out to investigate the effect of leaf colour on the rate of photosynthesis. Leaves placed in water naturally float, but if small discs of leaves are punched out of the leaves and the air in the discs is replaced by hydrogen carbonate solution (a CO_2 source), they will sink.

The time taken for 15 light green leaf discs to float to the top of the solution when illuminated from below can be determined and gives an estimate of the rate of photosynthesis. This was repeated for dark green leaf discs.



The results of such an experiment are shown below.

Order of leaf discs rising	Time taken for each leaf disc to rise / seconds	
	Dark green colour discs	Light green colour discs
1st	102	296
2nd	157	324
3rd	186	358
4th	201	360
5th	240	420
6th	260	422
7th	287	665
8th	317	666
9th	396	805
10th	404	1000
11th	474	1108
12th	535	1173
13th	622	1674
14th	808	1821
15th	898	2388
Mean time	....	898.7

E

(i) Calculate the mean time taken for the 15 dark green discs to float and **insert your answer in the table**. [1]

(ii) Explain what caused the discs to rise in the solution. [2]

....

....

....

(iii) Explain why the darker green leaf discs rose faster than the lighter green discs. [4]

....

....

....

....

....

....

....

....

....

....

....

....

....

Examiner only

(d) (i) Describe how would you use the technique described in *(c)* to investigate the effect of light wavelength on photosynthesis. [4]

....

....

....

....

....

....

....

....

....

....

....

(ii) Predict the results that you would expect from this experiment. [2]

....

....

....

....

20

Example B4 mark scheme

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
4	(a)	(i)		A. Water is split to release electrons , protons and oxygen (1) reject reference to enzymes splitting water Accept equation B. ATP synthesis/ ADP + P(i) -→ ATP/ fuel proton pumps (1) C. $NADP^+ + 2e^- + 2H^+ \rightarrow NADPH + H^+$ (Accept $NADPH_2$) / reduction of NADP (1)	3			3		
		(ii)		Line from electron acceptor above photosystem1 to diagonal line	1			1		
	(b)	(i)		Chlorophyll b/c Carotene Xanthophyll **3 correct = 2 marks** **2 correct = 1 mark** **0/1 correct = 0 marks**	2			2		
		(ii)		Thylakoid (membrane) in a chloroplast	1			1		
	(c)	(i)		392.5 seconds		1		1	1	
		(ii)		Oxygen produced from {photosynthesis/ photolysis of water}(1) (O_2 fills the airspaces in the leaf so) the leaf is {less dense/ lighter/ more buoyant} (and so rises) (1)(must be in correct context)		2		2		2
		(iii)		**Any 4 (x1) from:** A. (the darker leaves rise more quickly because they have) more {chloroplasts/chlorophyll/ pigment} (in the palisade mesophyll) (1) B. So more {photons will be trapped/ light (energy) absorbed} /more energy transferred to high energy electrons (1) Ignore more wavelengths C. More light dependent stage/ or description of (1) D. More photolysis of water (1) E. More O_2 production (1)			4	4		4
	(d)	(i)		A. Change light wavelength/ or description e.g. using filters/ bulbs (1) B. Record the time taken for discs to rise (1) C. Keep hydrogen carbonate concentration constant/ temperature constant/ light intensity/ height of solution (1) D. same colour leaf/ {area/diameter/ size} discs/ species of plant (1)			4	4		6
		(ii)		{Less time/ faster} to rise at the {blue/ violet/ short/ approx. 350nm} **and** {red / longer/ approx. 650nm} wavelengths (1) {Slower to /More time to/ does not } rise in the {yellow/green/ approx. 500nm} wavelengths (1)		2		2		
				Question 4 total	**7**	**5**	**8**	**20**	**1**	**12**

Example B4 Commentary

Description	Parts (a) and (b) are not indirectly assessing practical skills and are based on the theory of the light dependent reaction of photosynthesis. Part (c) (i) requires students to calculate a mean from data generated from a leaf disc experiment. Parts (c) (ii) and (iii) ask students to explain the results seen in the experiment. Part (d) extends the experiment and asks students to think about a further photosynthesis investigation to consider the effect of light wavelength.
Appendix 5a skills assessed	• 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'. • 'Apply scientific knowledge to practical contexts'. • 'Solve problems set in practical contexts' and 'identify variables including those which must be controlled'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question illustrates how different parts of the same question can be used to assess theory and indirectly assess practical skills. • This distinction of practical and non-practical parts of the question may be helpful to teachers and students in understanding the integrated nature of the indirect assessment of practical skills. • It demonstrates how the skill from Appendix 5b to the Content 'apply investigative approaches and methods to practical work' can be assessed in a written examination.

Example B5

35 *Miscanthus* and reed canary grass are crops that are reported to promote species diversity.

A field trial was carried out to determine which crop promotes the greater diversity of bird species:

- two fields (**M** and **R**) were sampled
- *Miscanthus* was grown in field **M**
- reed canary grass was grown in field **R**
- the number of each bird species (***n***) was recorded for both fields
- the Simpson's Index of Diversity was calculated for both fields.

(a) **(i)** Explain what is meant by the term species diversity.

....

....

....

.... **[2]**

(ii) State **two** variables that should have been controlled to ensure a **valid** comparison between fields **M** and **R**.

1 ....

....

2 ....

....
[2]

(b) The incomplete results for field **M** are shown in Table 35.

Bird species	*n*	*n* / *N*	$(n/N)^2$
Dunnock	3	0.03	0.0009
Song thrush	40	0.40	0.1600
Reed bunting	23	0.23	0.0529
Meadow pipit	12		
Willow warbler	4		
Common redstart	18		
	N =		$\sum(n/N)^2$ =
			$1 - (\sum(n/N)^2)$ =

Table 35

(i) Complete Table 35 and use the formula below to calculate the Simpson's Index of Diversity (D) for field **M**.

$D = 1 - (\sum(n/N)^2)$

Where:
n = number of individuals of each species
N = total number of individuals in all species

Simpson's Index of Diversity (D) = ... **[3]**

(ii) The Simpson's Index of Diversity for field **R** is 0.54.

Using this information and your answer to **(b)(i)**, conclude which crop promotes the greater diversity of bird species. Justify your conclusion.

....

.... **[1]**

(c) Modern agricultural methods involve the use of chemical fertilisers added to the soil to increase crop yield.

However, the use of chemical fertilisers can have an impact on organisms within aquatic ecosystems such as ponds and streams.

The lifecycle of a dragonfly is shown in Fig. 35.

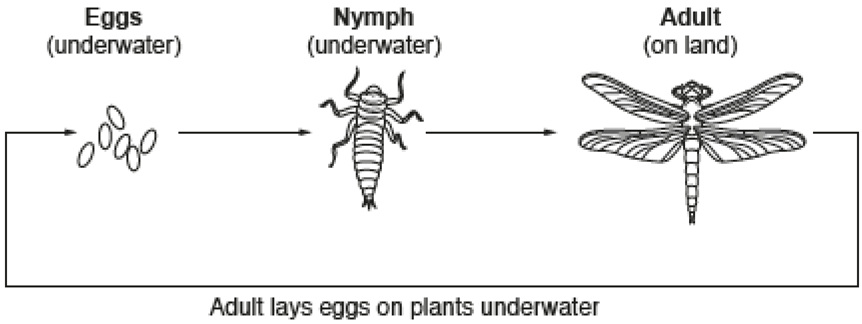


Fig. 35

Explain how the use of chemical fertilisers on agricultural land may threaten the survival of dragonflies.

....

....

....

....

....

.... **[3]**

Example B5 mark scheme

Question			Answer	Mark	Guidance
35	**(a)**	**(i)**	number of species in habitat / species richness ✓ relative abundance of each species / species evenness ✓	**2**	
		(ii)	**any 2 from**: equal size of, field / sampled area ✓ same soil, quality / type / hydration ✓ same season for observations ✓ same time of day for observations ✓ same method of sampling ✓ same climate ✓ same time period for observations ✓	**max 2**	
	(b)	**(i)**	*N* = 100 **AND** ***n/N***: 0.12, 0.04, 0.18 ✓ **$(n/N)^2$**: 0.0144, 0.0016, 0.0324 ✓ $\Sigma(n/N)^2 = 0.2622$ $1-(\Sigma(n/N)^2) = 0.7378$ ✓	**3**	ECF ECF **ALLOW** 0.26 or 0.262 **ALLOW** 0.74 or 0.738
		(ii)	M **AND** greater value of, *D* / Simpson's Index of Diversity ✓	**1**	**ECF** (i.e. R **AND** lower value of, *D* / Simpson's Index of Diversity, if *D* calculated as < 0.54) **ALLOW** M **AND** 0.738 is greater than 0.54
	(c)		fertiliser moves (from soil) into lake / stream / aquatic ecosystem ✓ algae bloom / rapid growth of algae ✓ plants (underneath), cannot photosynthesise / die ✓ bacteria / microorganisms, break down / decompose, dead matter ✓ bacteria / microorganisms consume all oxygen / decrease in oxygen concentration ✓ **at least 1 from:** (adult) dragonflies may not be able to lay eggs (because of lack of plants) ✓ eggs / nymph die from lack of oxygen ✓	**max 3**	Must link idea of eutrophication to interruption of dragonfly life cycle for 3 marks
			Total		

Example B5 Commentary

Description	Part (a) (i) does not indirectly assess practical skills. Part (a) (ii) requires students to identify control variables when comparing the effect of a particular crop on bird species diversity. Parts (b) and (c) do not indirectly assess practical skills.
Appendix 5a skills assessed	• 'Identify variables including those that must be controlled'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question illustrates how different parts of the same question can be used to assess theory and indirectly assess practical skills. • A wide practical experience, including regular discussion of the variables relating to practical activities, will allow students to be well prepared to approach a question of this type, even if the actual context of the question is not directly related to an activity that they have completed themselves.

Example B6

6* A student investigated the heart rates of smokers and non-smokers.

- Each test subject had their resting heart rate measured using an electronic heart rate monitor.
- They ran 1 km on a running track and their heart rate after running 500 m was recorded.
- Their heart rate was recorded for a third time 3 minutes after the completion of the exercise.

All test subjects were 18 years old. Subjects were tested between 9 am and 4 pm on one day, one at a time. Each test lasted approximately 20 minutes in total. The tests were repeated one week later using the same method. Mean heart rates were calculated for each subject.

The student's plan was to compare the heart rates of smokers and non-smokers using Student's *t*-test.

The student's results are shown in Table 6.

Student	Smoker?	Gender	Resting heart rate (bpm)	Heart rate during exercise	Heart rate after exercise
1	Y	Male	60.5	130.0	66.5
2	N	Female	67.0	145.5	73
3	Y	Male	70.0	120	77.0
4	Y	Male	65.5	100	69
5	Y	Male	66.0	128.5	75.5
6	Y	Female	65.5	115.5	74.5
7	Y	Female	73.5	120.5	81
8	N	Female	63.0	118	66
9	N	Female	71.0	95.5	80.5
10	N	Female	65.5	110	71
11	N	Male	64.0	145.5	68
12	N	Male	52.5	140.0	58.5
13	N	Male	54.0	137.5	63
14	N	Female	73.0	130.5	81
15	N	Female	61.5	124	67
16	N	Female	71.0	130	81.5
17	N	Male	60.0	122.5	63
18	N	Female	64.5	118	69
19	N	Female	67.5	130.5	73.5
20	Y	Male	72.0	135	82
21	Y	Female	69.5	110	75.5

Table 6

© OCR 2017

Suggest and explain improvements that the student could make to his experimental method **and** his presentation of data.

In your answer you should explain the benefits of your suggested improvements.

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[6]**

Example B6 mark scheme

6			***Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*** ***In summary:*** *Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)* *Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors,* ***Level 1****,* ***Level 2*** *or* ***Level 3****, best describes the overall quality of the answer.* *Then, award the higher or lower mark within the level, according to the* **Communication Statement** *(shown in italics):* o *award the higher mark where the Communication Statement has been met.* o *award the lower mark where aspects of the Communication Statement have been missed.* ***• The science content determines the level.*** ***• The Communication Statement determines the mark within a level.*** ***A level annotation should be used where all marks for a level have been achieved eg for 6 marks*** **L3** ***If a candidate has achieved 5 marks then they have reached level 3 but with one mark omitted*** **e.g L3** ^ ***The same principal should be applied to level 2 and level1*** ***No marks (0) should have a cross***			
			Level 3 (5-6 marks) Describes **and** explains some improvements to the method **and** the presentation. *There is a well-developed line of reasoning, which is clear and logically-structured and uses scientific terminology at an appropriate level. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Describes some improvements to the method **and** the presentation, **and** explains improvements to **either** method **or** presentation *There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented in the most part relevant and supported by some evidence.* **Level 1 (1-2 marks)** Describes some improvements to either method **and / or** presentation. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**		**Indicative scientific points may include** *Method:* • sample sizes should be increased to improve the accuracy and repeatability of the results • same number of subjects for, smokers/non-smokers/gender, to make comparisons more valid • gender should be controlled/tested separately because heart rate may show an overall difference between genders • other subject factors (e.g. diet, exercise history, other health issues) should be controlled/taken into account because these can influence heart rate • the level of smoking (e.g. casual vs 20 per day) should be controlled because this is likely to be a continuous variable rather than the discrete variable the student has implied • time of day should have been standardised because this may influence heart rate • subjects should have been given an exercise that required a particular intensity (e.g. treadmill running) because effort will have varied • more repeats before calculating mean to identify anomalies *Presentation:* • smokers and non-smokers should have been presented as separate columns to make comparisons easier • units should be include for the final two columns to show that the three heart rate measurements were made using the same method • the number of significant figures/decimal places should be the same for each measurement to standardise the level of precision • present data graphically to spot trends more easily • label heart rates as mean heart rates for clarity

Example B6 Commentary

Description	This question assesses the quality of an extended response and requires students to suggest and explain improvements that could be made to the way that data has been presented following an investigation into the heart rates of smokers and non-smokers.
Appendix 5a skills assessed	• 'Present data in appropriate ways'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students who have carried out a range of practical activities over their 2 year A level course and have had opportunities to record data in tables, will be well prepared to see ways in which the data presented in this question could be improved. • The opportunity to discuss the reasons for appropriate data presentation, means students will also be better able to explain why it would be more appropriate to present data in the ways suggested by the mark scheme.

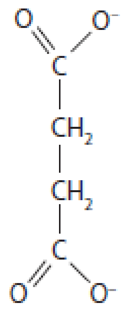
Example B7

9 Succinate dehydrogenase is an enzyme found in mitochondria.

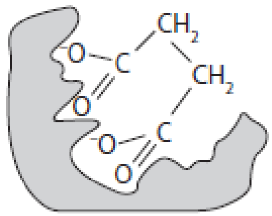
Succinate dehydrogenase converts succinate to fumarate.

The diagrams show the structure of succinate, succinate binding to the active site of succinate dehydrogenase and the structure of fumarate.

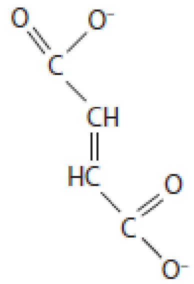
Structure of succinate



Succinate binding to succinate dehydrogenase



Structure of fumarate

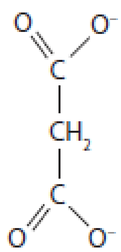


(a) Explain the role of the active site in the conversion of succinate to fumarate.

(3)

(b) The activity of succinate dehydrogenase is inhibited by malonate.

The diagram shows the structure of malonate.



(i) Explain why malonate inhibits the activity of succinate dehydrogenase.

(2)

....

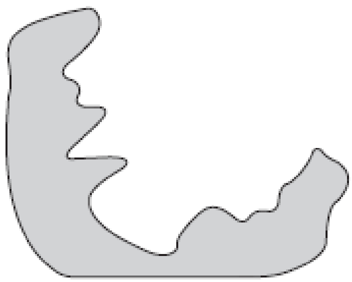
....

....

....

(ii) On the diagram, draw malonate binding to succinate dehydrogenase.

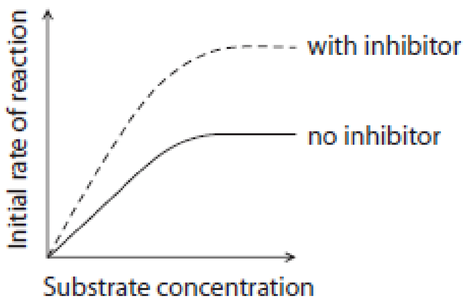
(1)



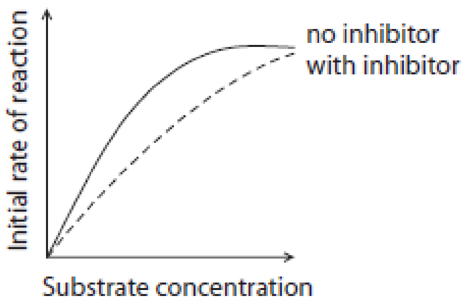
(iii) Which of the following graphs represents the effect of this type of inhibitor?

(1)

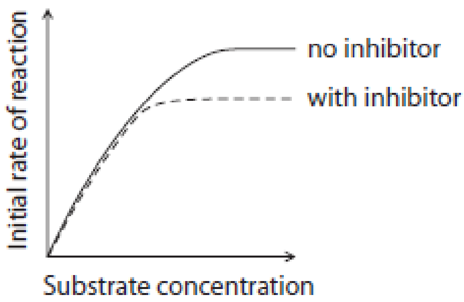
☒ **A**



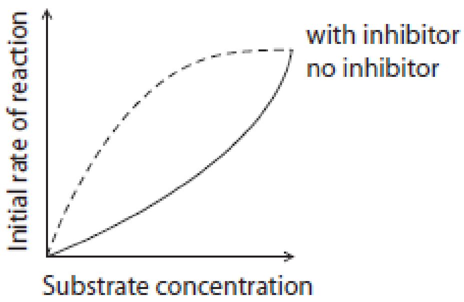
☐ **B**



☒ **C**



☒ **D**



*(c) The rate of reaction of succinate dehydrogenase can be measured using a methylene blue solution.

Methylene blue starts off blue but changes to colourless as succinate is converted to fumarate.

A student investigated the effect of malonate on the rate of reaction of succinate dehydrogenase.

The student used the following steps.

Step 1. Succinate solution was poured into a beaker up to the 25 cm^3 mark.

Step 2. Ten drops of succinate dehydrogenase solution and three drops of methylene blue solution were added.

Step 3. The beaker was left on the bench until the methylene blue became colourless and the time for this change was recorded.

Step 4. Steps 1 to 3 were repeated using two different concentrations of succinate solution.

The whole procedure was repeated with the addition of 15 cm^3 of malonate solution with the succinate solution in **Step 1**.

Criticise the method used in this investigation.

(6)

Example B7 mark scheme

Question Number	Acceptable Answer	Additional Guidance	Mark
9(a)	An explanation that makes reference to the following: • specific shape to fit the {substrate / succinate} (1) • lowers the activation energy (1) • so two hydrogens can be removed / a double bond formed between the carbons (1)	Allow complementary in shape / interaction of R groups and substrate / conformational change / induced fit Allow forms an {enzyme substrate complex / stable intermediate compound}	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to the following: • because it has a similar {structure / shape} / both ends of the molecule have a COO^- group (1) • therefore it can {fit / bind} into the active site / act as a competitive inhibitor (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
9(b)(ii)	A drawing that shows the following: • the four oxygens drawn in the active site in the correct position (1)	Two must be =O and two must be $-O^-$ in the same position as the succinate binding i.e. $-O^-$ then =O then $-O^-$ then =O all joined by CH_2 (see original diagram on page 28)	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)(iii)	B		**(1)**

Question Number	Indicative content
9(c)	Answers will be credited according to candidates' deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. • concentrations of solutions not controlled / volume not controlled eg beaker • measuring cylinders used to measure volumes of succinate / 15 cm^3 of water should have been added to the beaker in the experiment without inhibitor • concentration will affect rate of reaction because of collisions between substrate and enzyme active site • temperature not controlled • use a water bath to keep the temperature constant • enzyme could be denatured or rate of reaction changes with kinetic energy • pH not controlled • use a buffer • pH affects shape of active site and therefore rate of reaction • initial rate of reaction should have been measured • add methylene blue before adding the dehydrogenase / use colorimeter • substrate concentration will fall with time therefore rate will be lower • measuring end point is subjective • use a colorimeter • improve the accuracy of the quantitative data • only one concentration of malonate was used • at least four concentrations of malonate should have been used • so that the type of inhibition can be identified • only three concentrations of succinate used • at least five concentrations of succinate should have been used • so that an accurate line could be drawn onto the graph • separate experiments not repeated • repetition of each experiment • so you can {calculate a mean average / deal with anomalies / statistical analysis}

Level	Marks	
0	0	No awardable content
1	1-2	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures.
2	3-4	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures.
3	5-6	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures.

Additional Guidance

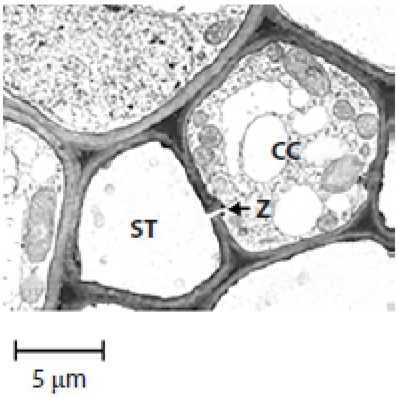
Level 1 response = two issues that could affect validity identified OR two suggestions made on how to improve the validity which are not related to any issues identified [e.g. two random points from indicative contents met]
Level 2 response = at least three suggestions made on how to improve the validity related to specific issues identified [e.g. at least three pairs from the indicative content]
Level 3 response = a range of suggestions made on how to improve the validity related to specific issues identified with some appreciation on the impact of the {issue / improvement} on the data obtained [e.g. at least two triplets with some additional indicative content]

Example B7 Commentary

Description	The first two parts of the question are based on enzyme theory and do not indirectly assess practical skills. Part (c) is a question where students are rewarded for their ability to structure their answer logically showing how the points made are related or follow on from each other where appropriate. This part requires students to criticise the method used to investigate the rate of an enzyme controlled reaction.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students will be better prepared to answer this type of question as a result of undertaking a range of practical work and having considered why methods are carried out in the way that they are. The use of appropriate instrumentation to record quantitative measurements is a practical requirement. • If teachers have discussed and explored steps in procedures with their students, they will be in a stronger position to have a full understanding of the experimental design which is the focus of this question.

Example B8

2 The electron micrograph shows a cross-section through part of a vascular bundle, containing phloem tissue.



A sieve tube element is labelled '**ST**'. A cell called a companion cell is labelled '**CC**'.

(a) Calculate the magnification of this image.

(1)

Answer: × ....

(b) The wall of the sieve tube element contains

(1)

☒ **A** cellulose, lamellae and lignin

☒ **B** cellulose, lignin and pectin

☒ **C** hemicellulose, microfibrils and pectin

☒ **D** hemicellulose, peptidoglycan and pectin

4

(c) There is no nucleus in a mature sieve tube element.

Give **two** reasons why a sieve tube element does not require rough endoplasmic reticulum and ribosomes.

(2)

(d) Companion cells are found next to sieve tube elements.

(i) Describe the structure labelled **Z** that connects the cytoplasm of the companion cell to the sieve tube element.

(2)

(ii) The electron micrograph shows a difference in the number of mitochondria in the sieve tube element and in the companion cell.

Explain the difference in the number of mitochondria.

(3)

(Total for Question 2 = 9 marks)

Example B8 mark scheme

Question Number	Answer	Additional Guidance	Mark
2(a)	• correct calculation of magnification (1)	Example of calculation 14mm = 14000μm 14000 ÷ 5 = 2800 **x 2800**	(1)

Question Number	Answer	Mark
2(b)	**C** hemicellulose, microfibrils and pectin	(1)

Question Number	Answer	Additional Guidance	Mark
2(c)	An answer that makes reference to the following: • there will be no { transcription / mRNA } (therefore ribosomes not required for translation) (1) • no proteins will be synthesised to be processed in endoplasmic reticulum (1)	ALLOW proteins are provided by/from the companion cell	(2)

Question Number	Answer	Additional Guidance	Mark
2(d)(i)	A description making reference to the following: • a pit (in the cell wall) / plasmodesma (1) • the cell wall has only one layer / only primary cell wall present / a strand of cytoplasm (1)	ALLOW plasmodesmata ALLOW a narrow channel through the cell wall description must match structure named	(2)

Question Number	Answer	Additional Guidance	Mark
2(d)(ii)	An explanation making reference to three of the following: • (the micrograph shows that) the CC has many mitochondria whereas the ST has { few / none } (1) • the role of the ST is to provide a channel, so cellular contents are kept to a minimum (1) • the ST has { limited / no } ability to carry out (aerobic) respiration (1) • { ATP / energy } is supplied to the ST from the CC (1)	ALLOW CC has **more** mitochondria / ST has fe**wer** mitochondria ALLOW CC is able to respire more ALLOW use of { ATP / energy } for active transport for phloem loading / described	(3)

Example B8 Commentary

Description	Part (a) of this question requires students to calculate the magnification of an image of phloem tissue shown in an electron micrograph.
Appendix 5a skills assessed	• ‘Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question indirectly assesses the application of mathematical concepts in a practical context and students will need to have had a range of practical experiences to develop the associated mathematical skills to feel confident when faced with this type of question.

Example B9

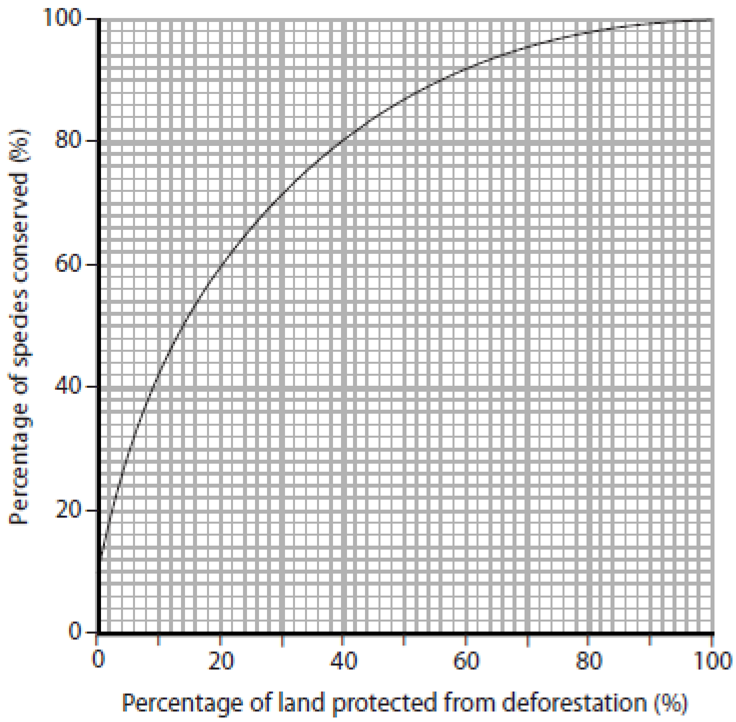
5 The World Wide Fund For Nature (WWF) is the largest conservation organisation in the world.

The WWF recently claimed that 'some 46 000 to 58 000 square miles of forest are lost each year. This is equivalent to 36 football fields every minute'.

This level of deforestation affects biodiversity.

Scientists studied the relationship between protecting land from deforestation and the percentage of species conserved.

The graph shows the results of the study.



(a) Analyse the data in the graph to explain how protection of land affects the percentage of species conserved.

(4)

(b) The number of species in a forest is one factor that affects biodiversity.

Some scientists use the following formula to calculate biodiversity.

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Describe how scientists could collect the data needed for this formula in order to calculate biodiversity.

(3)

Example B9 mark scheme

Question Number	Answer	Additional guidance	Mark
5(a)	An explanation that makes reference to the following: • increase in land protection increases species conserved (1) • because (trees) provide {niches / habitat / food / shelter} (1) • when no land protected (10 to 12%) species still exist (1) • because these species {live in soil / not in trees} (1)		**(4)**

Question Number	Answer	Additional guidance	Mark
5(b)	A description that makes reference to the following: • use of a stated sampling method (1) • (count N = total) number of organisms of all species (1) • (count n = total) number of organisms of {a particular species / each species} (1)	Eg. quadrat / sweep net / tree beating / light trap Ignore species richness / evenness / abundance	**(3)**

Question Number	Indicative content
*5(c)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. <u>Reasons against deforestation:</u> • conservation of biodiversity is important for medicines / wood products / sustainable products / prevent extinction / gene preservation • forests provide livelihood / homes / food for indigenous people and recreational opportunities for non-indigenous people • deforestation contributes to greenhouse effect / global warming / climate change / raised carbon dioxide • deforestation results in soil erosion / landslides / flooding / desertification <u>Reasons for deforestation:</u> • deforestation has economic implications for employment / national income • deforestation needed for wood products used in building of houses / fuel • deforestation needed for cattle farming / crop growth • deforestation results in habitat destruction / reduction of biodiversity / extinction

Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	Demonstrates isolated elements of biological knowledge and understanding to the given context with generalised comments made. Vague statements related to consequences are made with limited linkage to a range of scientific ideas, processes, techniques and procedures. The discussion will contain basic information with some attempt made to link knowledge and understanding to the given context. ***Explains one reason for AND one reason against deforestation =2*** ***Explains two reasons for = 2 OR explains two reasons against deforestation =2***
Level 2	3-4	Demonstrates adequate knowledge and understanding by selecting and applying some relevant biological facts/concepts. Consequences are discussed which are occasionally supported through linkage to a range of scientific ideas, processes, techniques and procedures. The discussion shows some linkages and lines of scientific reasoning with some structure. ***Explains two reasons for and one against = 3 Explains one reason for and two against = 3*** ***Explains two reasons for and two against = 4***
Level 3	5-6	Demonstrates comprehensive knowledge and understanding by selecting and applying relevant knowledge of biological facts/concepts. Consequences are discussed which are supported throughout by sustained linkage to a range of scientific ideas, processes, techniques or procedures. The discussion shows a well-developed and sustained line of scientific reasoning which is clear and logically structured. ***Explains two or three reasons for and two or three against with some evidence of detail = 5*** ***Offers an opinion / summary / conclusion of which reflects evidence presented = 6***

Example B9 Commentary

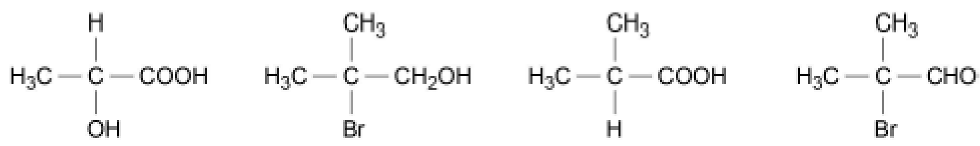
Description	Part (b) of this question asks students to consider the formula that is used to calculate biodiversity and then asks them to describe the data that would need to be collected to allow the calculation of biodiversity in this way.
Appendix 5a skills assessed	• ‘Apply scientific knowledge to practical contexts’. • ‘Comment on experimental design and evaluate scientific methods’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • All of the marks in part (b) of this question are appropriate for the indirect assessment of practical skills and this way of asking about the biodiversity index is different to a calculation. • Students who have carried out the practical activity (required in the specification) and understood which parts of the collected data are related to specific parts of the formula will perform better on this question.

Chemistry

Example C1

0 7 Test-tube reactions can be used to identify the functional groups in organic molecules.

0 7 . 1 You are provided with samples of each of the four compounds.



K **L** **M** **N**

Describe how you could distinguish between all four compounds using the minimum number of tests on each compound.

You should describe what would be observed in each test.

[6 marks]

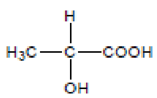
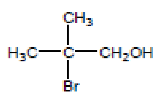
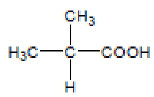
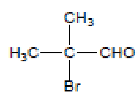
6

Example C1 mark scheme

Question	Answers		Mark	Additional Comments/Guidance
07.1	This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.			**Indicative Chemistry content** **Stage 1**: An initial test to separate into two groups (2 groups of 2 OR 1 group of 3 and 1 group of 1) **Stage 2**: An second test to distinguish within a group or to separate into two further groups **Stage 3**: A third test leads to a set of results/observations which distinguishes between all 4 compounds **Tests must include reagent and observation which identifies compound(s)** -COOH a) $NaHCO_3$ / Na_2CO_3 (or correct alternative) b) effervescence /gas turns limewater milky c) K and /or M but not L and/or N -OH and -CHO d) acidified $K_2Cr_2O_7$ e) solution turns green f) K and/or L and/or N but not M -CHO g) Fehlings OR Tollens h) red ppt OR silver mirror i) N only but not K and/or L and/or M -Br j) Silver nitrate k) cream ppt l) L and/or N but not K and/or M **Isolated tests on individual compounds - max LEVEL 2** **Isolated tests not linked to any compound – max LEVEL 1** **Penalise observation if deduction wrong, but allow observation if deduction incomplete**
	Level 3 5-6 marks	All stages are covered and each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3 to distinguish all the compounds with results for all remaining compounds stated. Describing subsequent organic test on product (unnecessary) - limits to lower mark in level		
	Level 2 3-4 marks	All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete. Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3. Describing subsequent organic test on product (unnecessary) - limits to lower mark in level		
	Level 1 1-2 marks	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order.		
	0 mark	Insufficient correct chemistry to gain a mark.		

Alternative tests

-COOH	-COOH	-OH only
a) named alcohol & H_2SO_4 b) sweet smell (of ester) c) K and /or M but not L and/or N	a) named indicator b) correct colour c) K and /or M but not L and/or N	m) named carboxylic acid & H_2SO_4 n) sweet smell (of ester) o) K and/or L but not M and /or N

					
Test	**Tests for**	**K**	**L**	**M**	**N**
a) $NaHCO_3$ / Mg / Indicator	K M	✓	×	✓	×
d) $K_2Cr_2O_7$ / H^+	K L N	✓	✓	×	✓
g) Fehlings / Tollens	N	×	×	×	✓
j) $AgNO_3$ see Note *	L N	×	✓	×	✓
a) named alcohol & H_2SO_4	K M	✓	×	✓	×
m) named carboxylic acid & H_2SO_4	K L	✓	✓	×	×

Note * allow NaOH then HNO_3, $AgNO_3$ as one test; but treat NaOH, $AgNO_3$ without acid as incomplete,so can mark on.

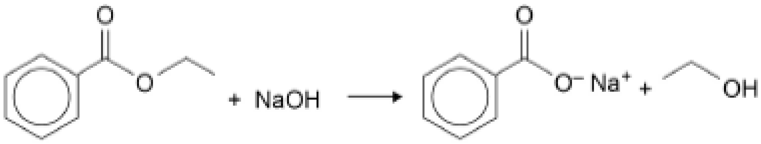
Example C1 Commentary

Description	This is a problem-solving question that requires students to identify the functional groups in organic compounds using their knowledge and understanding of test-tube reactions.
Appendix 5a skills assessed	• 'Solve problems set in practical contexts'. • 'Apply scientific knowledge to practical contexts'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question relates to a required practical (in the specification). • A student who had undertaken and understood the practical would be at an advantage, especially if they have been able to connect the practical to aspects of relevant theory. • Whilst these particular compounds are not in the required practical, students can apply relevant knowledge gained from that practical into this new context (AO2)[7].

[7] "AO" refers to "assessment objective" from Ofqual's Subject Level Guidance for GCE Sciences. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/447167/2015-07-20-gce-subject-level-guidance-for-science.pdf

Example C2

0 3 Benzoic acid can be prepared from ethyl benzoate.
Ethyl benzoate is first hydrolysed in alkaline conditions as shown:



A student used the following method.

Add 5.0 cm^3 of ethyl benzoate (density = 1.05 g cm^{-3}, M_r = 150) to 30.0 cm^3 of aqueous 2 mol dm^{-3} sodium hydroxide in a round-bottomed flask.

Add a few anti-bumping granules and attach a condenser to the flask. Heat the mixture under reflux for half an hour. Allow the mixture to cool to room temperature.

Pour 50.0 cm^3 of 2 mol dm^{-3} hydrochloric acid into the cooled mixture.

Filter off the precipitate of benzoic acid under reduced pressure.

0 3 . 1 Suggest how the anti-bumping granules prevent bumping during reflux.

[1 mark]

____

____

____

0 3 . 2 Show, by calculation, that an excess of sodium hydroxide is used in this reaction.

[2 marks]

Question 3 continues on the next page

0 3 . 3 Suggest why an excess of sodium hydroxide is used.

[1 mark]

0 3 . 4 Suggest why an electric heater is used rather than a Bunsen burner in this hydrolysis.

[1 mark]

0 3 . 5 State why reflux is used in this hydrolysis.

[1 mark]

0 3 . 6 Write an equation for the reaction between sodium benzoate and hydrochloric acid.

[1 mark]

0 3 . 7 Suggest why sodium benzoate is soluble in cold water but benzoic acid is insoluble in cold water.

[2 marks]

0 3 . 8 After the solid benzoic acid has been filtered off, it can be purified.

Describe the method that the student should use to purify the benzoic acid.

[6 marks]

Question 3 continues on the next page

0 3 . 9 In a similar experiment, another student used 0.040 mol of ethyl benzoate and obtained 5.12 g of benzoic acid.

Calculate the percentage yield of benzoic acid.

Suggest why the yield is not 100%.

[3 marks]

Percentage yield ______________ %

Suggestion ____

____

____

18

Example C2 mark scheme

Question	Answers	Mark	Additional Comments/Guidance
03.1	allows smaller <u>bubbles</u> to form / prevents the formation of (very) large <u>bubbles</u>	1	ALLOW provides large surface area for <u>bubbles</u> to form on IGNORE 'air' NOT no bubbles form / prevents bubbles forming
03.2	(Mass of ester = 1.05 x 5.0 = 5.25g) amount of ester = 5.25 / 150.0 = 0.0350 mol amount of NaOH = 30 x 2 / 1000 = 0.06 mol **OR** (Mass of ester = 1.05 x 5.0 = 5.25g) amount of ester = 5.25 / 150.0 = 0.0350 mol Vol of 0.035 mol of NaOH = (0.035/2) x 1000 = 17.5 cm^3 (so 30 cm^3 used is an excess) **OR** amount of NaOH = 30 x 2 / 1000 = 0.06 mol 0.06 mol of ester = 9 g = 8.57 cm^3 (only 5 cm^3 used so NaOH in excess)	 1 1 1 1 1 1 (2 max)	Mark independently
03.3	To ensure that the ester is completely hydrolysed / to ensure all the ester reacts	1	ALLOW to ensure the other reagent has completely reacted
03.4	Many organic compounds / the ester / ethanol are flammable	1	ALLOW prevent ignition of any flammable vapours formed
03.5	Reflux allows reactant vapours (of volatile organic compounds) to be returned to the reaction mixture / does not allow any reactant vapour to escape	1	IGNORE reference to products
03.6	$C_6H_5COONa + HCl \rightarrow C_6H_5COOH + NaCl$	1	Allow ionic equation. ALLOW molecular formulae ($C_7H_5O_2Na$ and $C_7H_6O_2$) ALLOW skeletal benzene ring
03.7	Sodium benzoate soluble because it is ionic Benzoic acid insoluble because: despite the polarity of the COOH group / ability of COOH to form H-bonds, the benzene ring is non-polar.	1 1	IGNORE polar ALLOW 'part of molecule' or 'one end' for COOH
03.8	Dissolve crude product in <u>hot</u> solvent/water of minimum volume Filter (hot to remove insoluble impurities) Cool to recrystallise Filter under reduced pressure / with Buchner/Hirsch apparatus wash (with cold solvent) **and** dry	1 1 1 1 1 1	ALLOW ethanol If no M1 max = 4 ALLOW reference to saturated soln as alternative to 'min vol' IGNORE use of Buchner funnel here apply list principle for each additional process in an incorrect method but IGNORE additional m.pt determination
03.9	5.12 / 122 (= 0.042 mol) (0.042/0.04) x 100 = 105 % Product not dried / impurities present in product	1 1 1	method mark ecf for M1/0.04 or calculation that 0.04 mol of benzoic = 4.88 g (M1) so % yield = (5.12/4.88) x100 = 105% Only allow M3 if M2>100%

Example C2 Commentary

Description	Part 3.8 of this question asks students to describe the method used to purify benzoic acid.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question assesses AO1[8] and requires students to describe a straightforward practical. However, the method is complicated and has many steps that must be described in the right order. • As a result of doing the practical activity, or a similar one showing the technique (purification is a practical requirement), students will have a material advantage when answering the question.

[8] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/447167/2015-07-20-gce-subject-level-guidance-for-science.pdf

Example C3

4. The following method was used to determine the molecular and structural formula of a straight chain alkene **U** of general formula C_nH_{2n-2}. **U** reacts with bromine according to the following equation.

$$C_nH_{2n-2} \quad + \quad 2Br_2 \longrightarrow C_nH_{2n-2}Br_4$$

- Step 1: A 3.50 g sample of **U** was treated with 10.0 cm^3 of liquid bromine (an excess) at 20 °C, the reaction being carried out in a fume cupboard.
  (Density of bromine = 3.10 g cm^{-3} at 20 °C)
- Step 2: After the reaction between alkene **U** and bromine was complete, the unreacted bromine was treated with excess aqueous sodium iodide to form iodine.

$$2NaI(aq) \quad + \quad Br_2(l) \longrightarrow 2NaBr(aq) \quad + \quad I_2(aq)$$

- Step 3: The resulting solution was then made up to 250 cm^3 and the concentration of iodine present in solution determined by titration with a standard solution of sodium thiosulfate of concentration 1.05 mol dm^{-3}.

$$I_2(aq) \quad + \quad 2Na_2S_2O_3(aq) \longrightarrow 2NaI(aq) \quad + \quad Na_2S_4O_6(aq)$$

A 25.0 cm^3 sample of the iodine solution required 17.35 cm^3 of the sodium thiosulfate solution for complete reaction.

(a) Complete the risk assessment for step 1 given below. [1]

Hazard	Risk	Control measure
		Reaction must be carried out in the fume cupboard. Wear eye protection and protective gloves.

(b) Use **all** the information provided to answer parts (i)-(iii).

(i) Calculate the total number of moles of bromine added in step 1. [2]

n(Br_2) added = ... mol

Examiner only

(ii) Calculate the number of moles of bromine that did not react with the alkene and hence the number of moles of bromine that reacted. [4]

$n(Br_2)$ that reacted = ... mol

(iii) Determine the molecular formula of the alkene and hence suggest its structural formula and name. Show your reasoning. [5]

Structural formula

Name ....

12

Example C3 mark scheme

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>4</td><td>(a)</td><td></td><td></td><td>hazard and associated risk required
<table><tr><th>Hazard</th><th>Risk</th></tr><tr><td>bromine is very toxic
or
bromine is corrosive</td><td>bromine produces a vapour which is very toxic if inhaled
or
bromine causes severe burns to the eyes and skin if spilt onto skin or eyes</td></tr></table></td><td>1</td><td></td><td></td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td></td><td>$m = d \times v = 3.10 \times 10 = 31$ (1)
$n(Br_2) = \frac{m}{M_r} = \frac{31}{159.8} = 0.194$ mol (1)</td><td></td><td></td><td>2</td><td>2</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>$n(Na_2S_2O_3) = 1.05 \times 17.35/1000 = 0.01822$ mol (1)
$n(I_2) = \frac{0.01822}{2} = 0.00911$ mol in 25 cm^3 (1)
$n(I_2)$ in 250 cm^3 = 0.0911 mol (1)
$n(Br_2)$ in excess following reaction with alkene = 0.0911 mol
$n(Br_2)$ that reacted = 0.194 – 0.0911= 0.103 mol (1)</td><td></td><td>1
1
1</td><td>1</td><td>4</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>(iii)</td><td></td><td>n(alkene) = $\frac{0.103}{2}$ = 0.0515 mol (1)
M_r(alkene) = $\frac{3.50}{0.0515}$ = 68.0 (1)
therefore molecular formula is C_5H_8 (1)
ecf possible from part (ii)
if incorrect M_r and hence incorrect molecular formula award (1) for stating that alkene is a diene / contains two C=C bonds (ratio of 1U : $2Br_2$)
award (1) for structural formula and (1) for name
any of the following
penta-1,3-diene $CH_3—CH=CH—CH=CH_2$
penta-1,4-diene $CH_2=CH—CH_2—CH=CH_2$
penta-2,3-diene $CH_3—CH=C=CH—CH_3$
penta-1,2-diene $CH_2=C=CH— CH_3—CH_3$</td><td></td><td></td><td>1
1
1
2</td><td>5</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Question 4 total</td><td>1</td><td>3</td><td>8</td><td>12</td><td>3</td><td>1</td></tr>
</table>

Example C3 Commentary

Description	This question involves the use of a range of quantitative data to identify an unknown alkene. Part (a) asks students to complete a risk assessment for part of the practical activity. Parts (b) (i) and (iii) are theory questions and do not indirectly assess practical skills. Part (b) (ii) requires students to apply their understanding of back titrations.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'. • 'Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification'. • 'Solve problems set in practical contexts' and 'apply scientific knowledge to practical contexts'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question illustrates how different parts of the same question can be used to assess theory and indirectly assess practical skills. Parts (b) (i) and (iii) are theory based. • Students will have a material advantage when approaching this question as a result of completing a range of similar practical activities and having the chance to take a problem-solving approach to them (qualitative tests are a practical requirement).

Example C4

13. A class of students is provided with a mixture of the strong base sodium hydroxide and the weak base sodium carbonate. They are asked to carry out an experiment to find the percentage by mass of each in the sample using the following method.

- Prepare a standard solution of the solid mixture in a 250 cm^3 volumetric flask.
- Measure 25.00 cm^3 of this mixture into a conical flask and add a small amount of an appropriate indicator.
- Add 0.105 $mol\,dm^{-3}$ hydrochloric acid from a burette whilst swirling the mixture until a permanent colour change occurs. At this point all the sodium hydroxide has reacted.
- Record the results and calculate the volume required to reach the first end-point (volume **A**).
- Add a few drops of a different indicator.
- Add more of the hydrochloric acid from the burette whilst swirling the mixture until a permanent colour change occurs. At this point all the sodium carbonate has reacted.
- Record the results and calculate the additional volume required to reach the second end-point (volume **B**).

(a) The results of the titrations are shown below.

	1	2	3	4
Initial burette reading / cm^3	0.00	0.00	1.20	5.55
Burette reading at first end-point / cm^3	22.35	22.00	23.25	27.55
Burette reading at second end-point / cm^3	33.55	32.65	33.80	38.00
Volume required to reach first end-point (volume **A**) / cm^3	22.35			
Additional volume required to reach second end-point (volume **B**) / cm^3	11.20			

(i) Complete the table and calculate the mean volume required to reach the first end-point, and the mean additional volume required to reach the second end-point. [3]

Mean volume for first end-point = ... cm^3

Mean additional volume for second end-point = ... cm^3

(ii) The class teacher tells the students that the data show that the value for volume **A** is more reliable than the value for volume **B**. Give **two** reasons for this. [2]

....

....

....

....

(iii) Calculate the mass of sodium carbonate present in the original solid mixture. [3]

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$$

M_r 106.0

Mass = ... g

Example C4 mark scheme

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>13</td><td>(a)</td><td>(i)</td><td></td><td><table><tr><td>volume A / cm^3</td><td>22.35</td><td>22.00</td><td>22.05</td><td>22.00</td></tr><tr><td>volume B / cm^3</td><td>11.20</td><td>10.65</td><td>10.55</td><td>10.45</td></tr></table>all values calculated and give to 4 sig figs (1)
22.02 (1)
10.55 (1) ecf possible throughout</td><td></td><td>3</td><td></td><td>3</td><td>1
1</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td>any two for (1) each
repeat readings in first titration are closer together / concordant / less scatter
smaller percentage error in measurements in first titration as values are larger
two colour changes measured / steps to find volume B but only one to find volume A</td><td></td><td></td><td>2</td><td>2</td><td></td><td>2</td></tr>
<tr><td></td><td></td><td>(iii)</td><td></td><td>moles HCl = 10.55 × 0.105 / 1000 = 1.11×10^{-3} (1)
moles Na_2CO_3 = 5.54×10^{-4} (1)
mass Na_2CO_3 in original sample = 0.587 g (1)
ecf from part (i) and throughout</td><td></td><td>1</td><td>1
1</td><td>3</td><td>1
1</td><td>3</td></tr>
</table>

Example C4 Commentary

Description	This question is based on a double titration. Part (a) asks students to calculate or comment on values to do with the titration.
Appendix 5a skills assessed	• ‘Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science’. • ‘Consider margins of error, accuracy and precision of data’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • As a result of carrying out practical activities of this type (titration is a practical requirement) over the course of their studies, students will be well prepared to approach this question. • If students have had many opportunities to process data and perform the related calculations, this should be straightforward for them.

Example C5

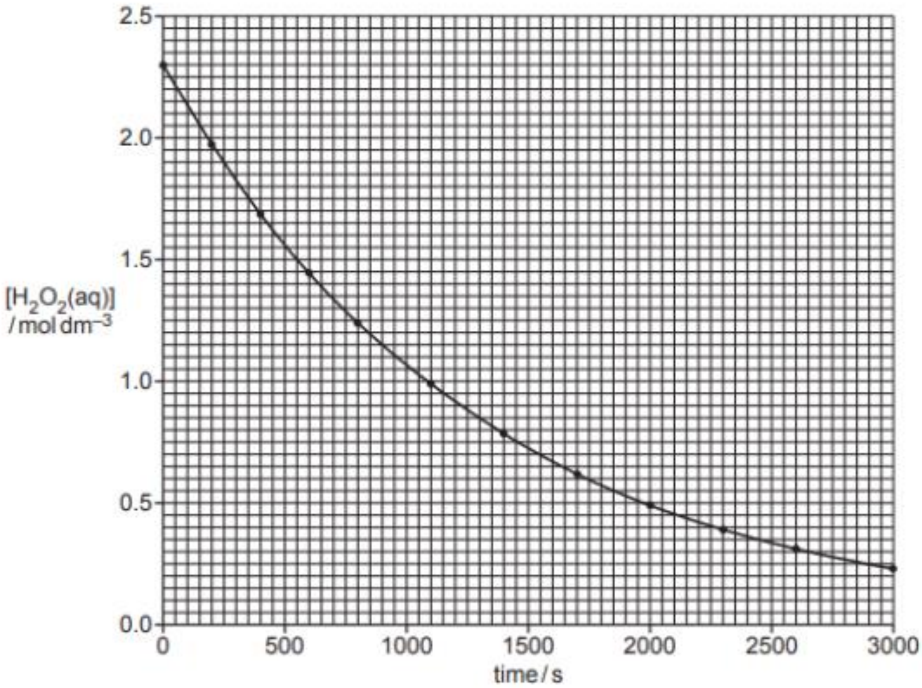
19 Aqueous solutions of hydrogen peroxide, $H_2O_2(aq)$, decompose as in the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A student investigates the decomposition of $H_2O_2(aq)$ by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses $25.0\,cm^3$ of $2.30\,mol\,dm^{-3}$ H_2O_2.

From the results, the student determines the concentration of $H_2O_2(aq)$ at each time. The student then plots a concentration–time graph.



(a) Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.

....

....

....

....

....

.... **[3]**

(c)* Determine the initial rate of reaction, the order with respect to H_2O_2, and the rate constant.

Your answer must show full working on the graph and on the lines below.

.... **[6]**

Example C5 mark scheme

Question			Answer	Marks	Guidance
19	(a)		$n(H_2O_2) = 2.30 \times \frac{25.0}{1000}$ **OR** = 0.0575 (mol) ✓ vol O_2 = $\frac{0.0575}{2} \times 24000$ = 690 cm^3 ✓ Collect in 1000 cm^3/1 dm^3 measuring cylinder ✓	3	**ALLOW** 0.69(0) dm^3 2nd mark subsumes 1st mark **ALLOW** 1000 cm^3/1 dm^3 syringe Needs a **name** of actual apparatus, not just 'container' 'measuring cylinder' without volume is insufficient **DO NOT ALLOW** burette For other possible apparatus, contact Team Leader **ALLOW** volumes from 700–1000 cm^3 but should be realistic apparatus, e.g. 700, 750, 800, 850, 900, 950.

Question			Answer	Marks	Guidance
	(c)*		*Please refer to the marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** A comprehensive conclusion using quantitative data from the graph to correctly determine initial rate **AND** half lives/gradient with 1st order conclusion for H_2O_2 **AND** determination of *k*. *There is a well-developed line of reasoning which is clear and logically structured.* *Clear working for initial rate, half life/gradient and order and k.* *Units mostly correct throughout.* **Level 2 (3–4 marks)** Attempts to describe all three scientific points but explanations may be incomplete. **OR** Explains two scientific points thoroughly with few omissions. *There is a line of reasoning with some structure and supported by some evidence. The scientific points are supported by evidence from the graph.* **Level 1 (1–2 marks)** Reaches a simple conclusion using at least one piece of quantitative data from the graph. Attempts to calculate initial rate **OR** half life. *There is an attempt at a logical structure with a reasoned conclusion from the evidence.* **0 marks** *No response worthy of credit.*	6	**Indicative scientific points may include:** **Initial rate** • Tangent shown on graph as line at t = 0 s • Gradient determined in range: $1.5 - 2.0 \times 10^{-3}$ e.g. $\frac{2.3}{1300} = 1.77 \times 10^{-3}$ • *initial rate* as gradient value with units: mol dm^{-3} s^{-1} *For other methods contact TL* **Evidence for 1st order 2 methods** • 1st order clearly linked to half-life **OR** 2 gradients: **1. Half life** • Half life shown on graph • Half life range 800–1000 s • Two 'constant' half lives ±50 s **2. Two gradients → two rates** • 2 tangents shown on graph at *c* and *c*/2 • Gradient at *c*/2 is half gradient at *c* e.g. *c* = 2.3 mol dm^{-3}, gradient = 1.6×10^{-3} **AND** *c* = 1.15 mol dm^{-3}, gradient = 0.8×10^{-3} • For chosen method, conclusion: H_2O_2 is 1st order **Determination of *k* 2 methods** • *k* clearly linked to rate **OR** half-life: $k = \frac{rate}{[H_2O_2]}$ e.g. $k = \frac{1.6 \times 10^{-3}}{2.3} = 7 \times 10^{-4}$ s^{-1} **OR** $k = \frac{\ln 2}{t_{1/2}}$ e.g. $k = \frac{0.693}{950} = 7.3 \times 10^{-4}$ s^{-1}

Example C5 Commentary

Description	This question is about an investigation into the decomposition of hydrogen peroxide by measuring the volume of oxygen gas produced over time. Part (a) requires students to determine values of variables that would need to be collected and to suggest apparatus that could be used to collect the data. Part (c) assesses the quality of an extended response and asks students to determine a range of values.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'. • 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • As a result of completing this type of experiment (measure rates of reaction is a practical requirement), students will be better able to approach part (a) which requires them to perform a calculation in order to inform the choice of apparatus. • The calculation will give them a volume of gas and the student can use their practical experience to choose the most appropriate apparatus e.g. a syringe. • Students need to have a concept of scale/size and types of apparatus they could use and this would be gained from practical experience (use of appropriate apparatus to record a range of measurements is a practical requirement). • Part (c) is in the context of an experiment and requires data analysis using the appropriate mathematical skills. Four marks from the six available are assigned to the assessment of the mathematical requirements so it is also an example of where the indirect assessment of practical skills and mathematical skills assessment overlap in a practical context.

Example C6

4 This question is about weak acids.

(a) Compound **A** is a weak monobasic acid.

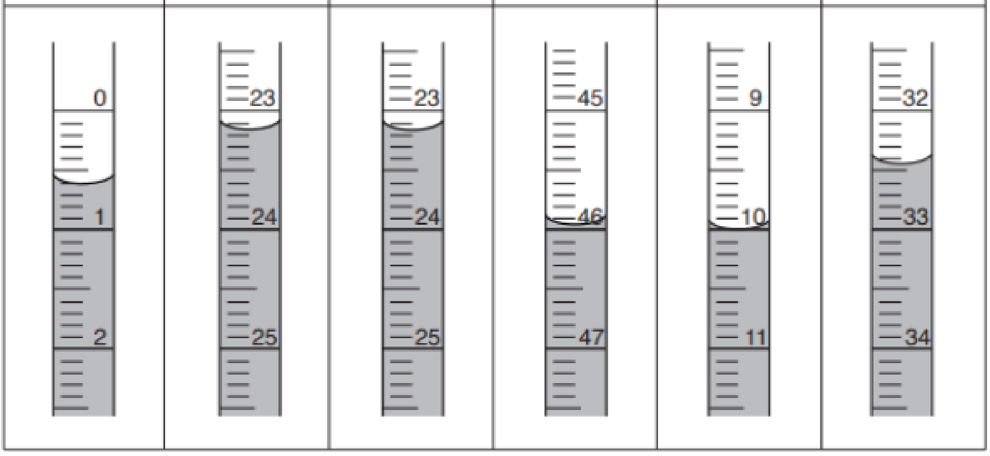
A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

The student titrates 25.0 cm^3 samples of this solution with 0.0840 $mol\,dm^{-3}$ NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 cm^3.

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading



(i) Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

mean titre = ... cm^3 **[4]**

Example C6 mark scheme

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th></th><th>Guidance</th></tr>
<tr><td>4</td><td>(a)</td><td>(i)</td><td>

Burette readings

<table>
<tr><td>Final (reading)/cm³</td><td>23.15</td><td>45.95</td><td>32.45</td><td rowspan="2">✓</td></tr>
<tr><td>Initial (reading)/cm³</td><td>0.60</td><td>23.15</td><td>10.00</td></tr>
</table>

- Correct titration results recorded with initial and final readings, clearly labeled
AND all readings recorded to two decimal places with last figure either 0 or 5

Titres

<table>
<tr><td>Titre/cm³</td><td>22.55</td><td>22.80</td><td>22.45</td><td>✓</td></tr>
</table>

- Correct subtractions to obtain final titres to 2 DP

Units

- Units of cm^3 for initial, final and titres ✓

Mean titre

- mean titre = $\frac{22.55 + 22.45}{2}$ = 22.50 **OR** 22.5 cm^3 ✓
i.e. using concordant (consistent) titres

</td><td>4</td><td></td><td>

Table **not** required

ALLOW initial reading before final reading

ALLOW ECF

ALLOW units with each value
ALLOW brackets for units, i.e. (cm^3)

ALLOW ECF from incorrect concordant titres

</td></tr>
</table>

Example C6 Commentary

Description	Part (a) (i) asks students to record burette readings from a diagram and tabulate them appropriately and to calculate a mean titre.
Appendix 5a skills assessed	• ‘Present data in appropriate ways’. • ‘Process and ‘analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students who had experience of using a burette and carrying out titrations (both practical requirements) should find this question accessible. • In carrying out the required practicals (in the specification) students will have had experience of designing their own results tables. • Selecting titres to calculate the mean requires students to select appropriate data which falls within Appendix 5a ‘Numeracy and the application of mathematical concepts in a practical context’.

Example C7

(c) Which solution produces a white precipitate with acidified barium chloride solution?

(1)

☒ **A** hydrochloric acid

☒ **B** magnesium sulfate

☒ **C** potassium chloride

☒ **D** sodium carbonate

(d) Two of the solutions produce the same result on the addition of dilute nitric acid followed by silver nitrate solution.

State the observation with this test and the **two** solutions that give this result.

(2)

Observation ....

Solutions ....

(e) The hydrochloric acid and the sodium carbonate solution react together. State an observation you would make and write the **ionic** equation for the reaction. State symbols are not required.

(2)

Observation ....

Ionic equation

(Total for Question 4 = 7 marks)

Example C7 mark scheme

Question Number	Answer	Mark
4(c)	**B** (magnesium sulfate)	(1)

Question Number	Acceptable Answers		Additional Guidance	Mark
4(d)	• (Observation) white **and** precipitate	(1)	Do not allow 'off-white' Allow white solid Allow spelling of 'percipitate' Ignore identity of precipitate even if incorrect	(2)
	• hydrochloric acid **and** potassium chloride	(1)	Both names are essential but can be in either order. Accept formulae HCl and KCl. Allow A and C. Mark independently	

Question Number	Acceptable Answers		Additional Guidance	Mark
4(e)	• fizzing/bubbles/effervescence	(1)	Reject 'solid dissolves'/precipitate forms/ references to hydrogen gas Ignore CO_2/ carbon dioxide/ gas given off	(2)
	$2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$	(1)	Ignore state symbols even if correct	

Example C7 Commentary

Description	Part (c) is a multiple-choice question that asks students to identify the solution that produces a white precipitate with acidified barium chloride solution. Parts (d) and (e) require students to know about observations related to tests with the solutions in part (c). The requirement to provide an ionic equation in the second part of (e) does not indirectly assess practical skills.
Appendix 5a skills assessed	• 'Apply scientific knowledge to practical contexts'. • 'Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students who had taken the opportunity to discuss why you do or do not use a particular solution when testing for halide ions would be advantaged (qualitative tests is a practical requirement). • Students would have to understand the connection between chloride and hydrochloric acid and to understand that carbonate ions do not give a precipitate if an acid is also present. This links to the wider scientific knowledge of the student.

Example C8

(b) The following steps were carried out by a student to find the molar mass of a gas. The experiment was carried out at 20 °C and one atmosphere pressure. The dry gas was supplied in a plastic bag fitted with a self-sealing device. The student had a choice of two different gas syringes. The student decided to use a 50 cm^3 syringe.

Step **1.** The 50 cm^3 syringe was fitted with a needle and then emptied of air by pushing in the plunger to zero. The needle was sealed by pushing the needle into a rubber bung and the syringe and bung were then weighed on a balance.

Step **2.** The syringe was checked for leaks by pulling the plunger out by about 10 cm^3 for a few seconds before releasing it.

Step **3.** The rubber bung was removed from the needle which was then inserted through the self-sealing device in the plastic bag of the dry gas.

Step **4.** 50 cm^3 of the dry gas was withdrawn from the plastic bag into the syringe and the needle resealed with the same rubber bung used in step **1**.

Step **5.** The syringe and rubber bung were then reweighed on the balance.

Results

volume of gas used	50 cm^3
initial mass of empty syringe	107.563 g
final mass of syringe + gas	107.655 g

(i) The gas syringe has a total uncertainty of ±0.5 cm^3.
Each reading on the balance has an uncertainty of ±0.0005 g.

Calculate the percentage uncertainty in the measurement of the volume and mass of gas used in this procedure.

(2)

(ii) The student repeated the experiment with 100 cm^3 of the gas using a 100 cm^3 syringe.

The total uncertainty for this larger syringe was also ±0.5 cm^3.

Determine the effect, if any, on the volume and mass uncertainties.

(2)

....

....

....

....

Example C8 mark scheme

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(i)	(% volume uncertainty =)1% **(1)** (% mass uncertainty =)1/1.1/1.09/1.08696 % **(1)**	example of calculation 0.5 cm^3 in 50 cm^3 % uncertainty = $\frac{0.5}{50}$ x 100 = 1% mass of gas = 107.655 – 107.563 = 0.092 g uncertainty = 0.0005 x 2 0.001 g in 0.092 g % uncertainty = $\frac{0.001}{0.092}$ x 100 = 1/1.1/1.09/1.08696 % Ignore uncertainties added together Do not award calculation of uncertainty in each mass reading (often added together +1) eg 0.0004644 + 0.0004648 + 1 = 1.000928	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(ii)	an answer that makes reference to the following points: halves the % volume uncertainty /0.5 cm^3 in 100 cm^3 = 0.5% **(1)** (volume of gas is doubled so mass of gas doubles), % mass uncertainty (also) halves. **(1)**	TE for answer to (b)(i) ÷ 2 TE for answer to (b)(i) ÷ 2 Allow 1 mark for both uncertainties decrease	**(2)**

Example C8 Commentary

Description	Part (b)(i) asks students to calculate the percentage uncertainty in the measurement of the volume and mass of gas when finding the molar mass of a gas. Part (b)(ii) then asks students to determine the effect on the mass and volume uncertainties if the experiment is repeated with a larger gas syringe and a larger volume of gas.
Appendix 5a skills assessed	• ‘Consider margins of error, accuracy and precision of data’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question covers multiple readings so there is more uncertainty than in one reading, linking to the practical requirement to ‘use methods to increase accuracy of measurements’. • This will be straightforward for students who can use their practical experience gained from the completion of the core practical (in the specification).

Physics

Example P1

Section A

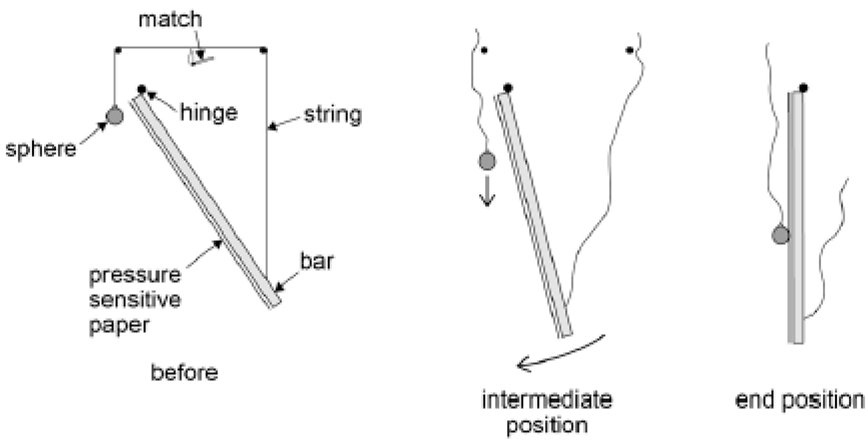
Answer **all** question(s) in this section.

0 1 This question is about measuring the acceleration of free fall g.

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

Question 1 continues on the next page

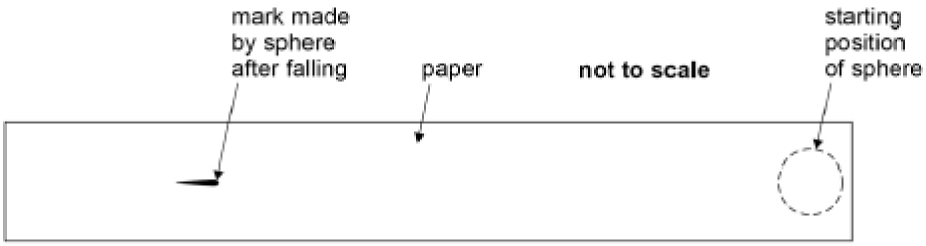
Turn over ▸

0 1 . 1 **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d.

[1 mark]

Figure 2



0 1 . 2 The student repeats the procedure several times.

Data for the experiment is shown in **Table 1**.

Table 1

d / m
0.752
0.758
0.746
0.701
0.772
0.769

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time t for the bar to reach the vertical position.

[1 mark]

time ______________ s

0 1 . **3** Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

[2 marks]

uncertainty = ____________ %

0 1 . **4** Use the data from **Table 1** to calculate a value for d.

[2 marks]

d = ____________ m

0 1 . **5** Calculate the absolute uncertainty in your value of d.

[1 mark]

uncertainty = ____________ m

0 1 . **6** Determine a value for g and the absolute uncertainty in g.

[3 marks]

g = ____________ $m\ s^{-2}$

uncertainty = ____________ $m\ s^{-2}$

Turn over ▸

0 1 . 7 Discuss **one** change that could be made to reduce the uncertainty in the experiment.

[2 marks]

0 1 . 8 The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g.

[3 marks]

Example P1 mark scheme

Question	Answers	Additional Comments/Guidance	Mark
01.1	Clear identification of distance from centre of sphere to right hand end of mark, or to near r.h.end of mark ✓		1
01.2	0.393 (s) ✓	Accept 0.39 (s)	1
01.3	For 10 oscillations percentage uncertainty = $\frac{0.1}{15.7}$ = 0.00637 ≡ 0.64% ✓ same for the ¼ period ✓		2
01.4	Identifies anomaly [0.701] ✓ and calculates mean distance = 0.759 (m)✓	Allow 1 max if anomaly included in calculation giving 0.750 (m)	2
01.5	Largest to smallest variation = 0.026 (m) Absolute uncertainty = 0.013 (m)✓		1
01.6	Use of $g = \frac{2d}{t^2}$ leading to 9. 83 (m s^{-2}) ✓ percentage uncertainty in distance = 1.7%✓ Total percentage uncertainty = 1.7 + 2 x 0.64 = 3.0% Absolute uncertainty = 0.30 (m s^{-2}) ✓ [g = 10.0 ± 0.3 m s^{-2}]	Allow 9.98 (m s^{-2}) if 0.39 used Ecf if anomaly included in mean in 1.4 Expressed sf must be consistent with uncertainty calculations	3
01.7	suggests one change ✓ Sensible comment about change or its impact on uncertainty ✓ eg Use pointed mass not sphere Because this will give better defined mark OR because the distance determination has most impact on uncertainty OR Time more swings/oscillations As this reduces the percentage uncertainty in timing OR longer/heavier bar would take a greater time to swing to the vertical increasing t and s and reducing the percentage uncertainty in each	If data logger proposed, it must be clear what sensors are involved and how the data are used.	2
01.8	[$s = \frac{g}{2}t^2$] plot graph of s against t^2 or $\sqrt{s}$ against t ✓ calculate the gradient ✓ the gradient is $g/2$ or $\sqrt{(g/2)}$ ✓	Accept: plot s against $t^2/2$ or plot $2s$ against t^2: calculate the gradient in both cases gradient gives g Allow 1 max for answer that evaluates g for each data point and averages	3

Example P1 Commentary

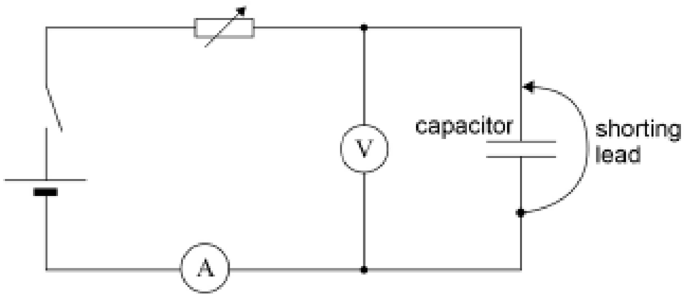
Description	This question is about measuring the acceleration of free fall *g.* Part 1.1 requires students to mark what measurement would be needed to determine *d*. Part 1.2 is a calculation based on the practical data. Part 1.3 requires students to calculate an uncertainty. Part 1.4 requires students to identify that one measurement is likely to be an outlier and therefore may be ignored in determination of the average value for *d.* Part 1.5 requires students to know how to determine the absolute uncertainty in the mean value from a set of different measurements of a variable. Part 1.6 requires an understanding of the need to convert individual uncertainties in *d* and *t* to percentage uncertainties, combine these appropriately to determine the percentage uncertainty in the value for *g* and then determine the absolute uncertainty in the final value for *g*. Part 1.7 asks students to discuss a change to reduce the uncertainty in the experiment. Part 1.8 does not indirectly assess practical skills.
Appendix 5a skills assessed	• ‘Comment on experimental design and evaluate scientific methods’. • ‘Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science’. • ‘Evaluate results and draw conclusions with reference to measurement uncertainties and errors’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • The calculations in this question are viewed in a practical context and require an understanding of the associated practical work in order for students to be able to approach them with confidence. • The mathematical processing in this question overall arises naturally from practical contexts.

Example P2

0 2 This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. **Figure 3** shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.

Figure 3



The student begins the experiment with the shorting lead connected across the capacitor as in **Figure 3**. The variable resistor is then adjusted to give a suitable ammeter reading. The shorting lead is removed so that the capacitor begins to charge. At the same instant, the stop clock is started.

The student intends to measure the potential difference (pd) across the capacitor at 10 s intervals while adjusting the variable resistor to keep the charging current constant.

The power supply has an emf of 6.0 V and negligible internal resistance. The capacitor has a capacitance of 680 μF. The variable resistor has a maximum resistance of 100 kΩ.

0 2 . 1 The student chooses a digital voltmeter for the experiment. A digital voltmeter has a very high resistance.

Explain why it is important to use a voltmeter with very high resistance.

[1 mark]

Question 2 continues on page 9

0 2 . 2 Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

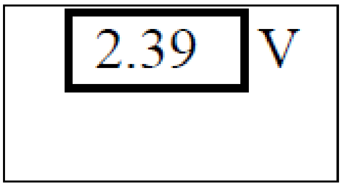
[1 mark]

0 2 . 3 Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

[2 marks]

full scale deflection = ______________

0 2 . 4 The diagram shows the reading on the voltmeter at one instant during the experiment. The manufacturer gives the uncertainty in the meter reading as 2%.



Calculate the absolute uncertainty in this reading.

[1 mark]

uncertainty = ___________ V

Question 2 continues on the next page

0 2 . 5 Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

[3 marks]

number = ______________

0 2 . 6 The experiment is performed with a capacitor of nominal value 680 μF and a manufacturing tolerance of $\pm$ 5 %. In this experiment the charging current is maintained at 65 μA. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 $mV\ s^{-1}$.

Calculate the capacitance of the capacitor.

[2 marks]

capacitance = ______________ μF

0 2 . 7 Deduce whether the capacitor is within the manufacturer's tolerance.

[1 mark]

____

____

____

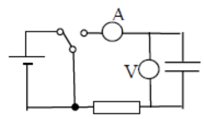
0 2 . 8 The student decides to confirm the value of the capacitance by first determining the time constant of the circuit when the capacitor **discharges** through a **fixed** resistor.

Describe an experiment to do this. Include in your answer:

- a circuit diagram
- an outline of a procedure
- an explanation of how you would use the data to determine the time constant.

[4 marks]

Example P2 mark scheme

02.1	Capacitor must not lose charge through the meter ✓		1
02.2	Position on scale can be marked/easier to read quickly etc ✓		1
02.3	Initial current = $\frac{6}{100000}$ = 60.0 μA ✓ 100 μA or 200 μA ✓ (250 probably gives too low a reading)	Give max 1 mark if 65 μA (from 2.6) used and 100 μA meter chosen	2
02.4	0.05 V ✓		1
02.5	Total charge = 6.0 x 680 x 10^{-6} (C) (= 4.08 mC) ✓ Time = 4.08 x 10^{-3} / 60.0 x 10^{-6} = 68 s ✓ Hence 6 readings ✓		3
02.6	Recognition that total charge = 65 t μC and final pd = 0.098 t so C = 65μ/0.098✓ 660 μF ✓	Allow 663 μF	2
02.7	(yes) because it could lie within 646 – 714 to be in tolerance ✓ OR it is 97.5 % of quoted value which is within 5% ✓		1
02.8	Suitable circuit drawn ✓ Charge C then discharge through R and record V or I at 5 or 10 s intervals ✓ Plot ln V or ln I versus time ✓ gradient is $1/RC$ ✓ OR Suitable circuit drawn ✓ Charge C then discharge through R and record V or I at 5 or 10 s intervals✓ Use V or I versus time data to deduce half-time to discharge ✓ $1/RC = \ln 2/t_{½}$ quoted ✓ OR Suitable circuit drawn ✓ Charge C then discharge through R and record V or I at 5 or 10 s intervals ✓ Plot V or I against t and find time T for V or I to fall to 0.37 of initial value ✓ $T = CR$ ✓	 Either A or V required For 2nd mark, credit use of datalogger for recording V or I.	4

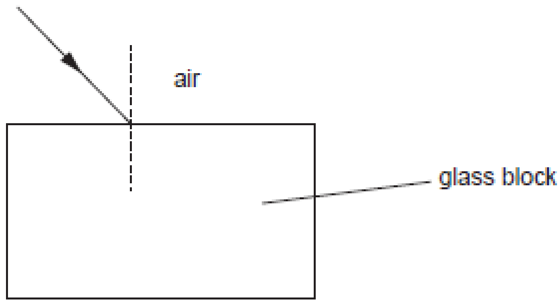
Example P2 Commentary

Description	The context of this question, about capacitor charging and discharging, reflects one of the required practicals (in the specification). Parts 2.1, 2.2 and 2.3 all require students to provide suggestions or reasons for the choice of apparatus to be used in the investigation. Part 2.4 requires an understanding of what is meant by absolute uncertainty. Students would need to appreciate the difference between percentage uncertainty and absolute uncertainty in a reading to answer the question, a skill that is only relevant to practical work. Parts 2.5 – 2.8 do not indirectly assess practical skills.
Appendix 5a skills assessed	• ‘Comment on experimental design and evaluate scientific methods’. • ‘Consider margins of error, accuracy and precision of data’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • The relevant parts of the question are a variation on a required practical (in the specification) and is, therefore, not straight recall. • Students will need a deep understanding of the context of the experimental design in order to be able to approach this question and those who have had the chance to develop this practically will be at an advantage. • Students who had taken the opportunity to discuss why the experiment might be carried out in this way and consider the requirements of the practical would be better placed to do well on this question. • Parts 2.5 – 2.8 mainly involve broad conclusions or assess mathematical skills.

Example P3

Exa
o

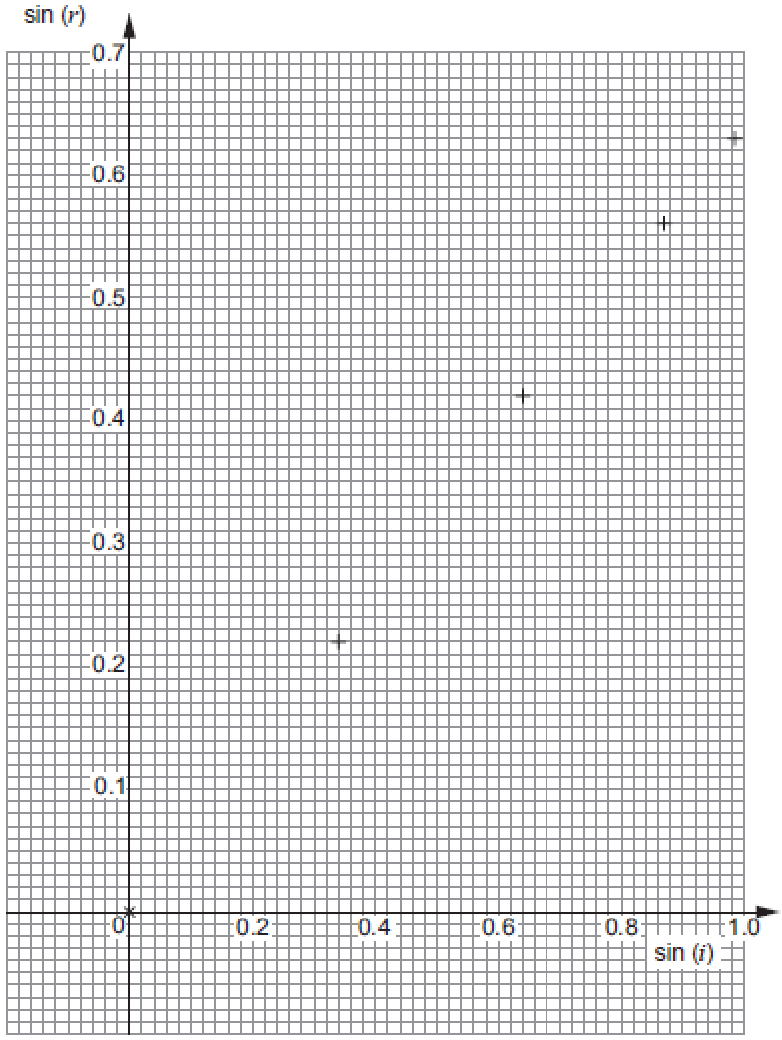
8. An experiment is carried out to investigate Snell's law. Laser light is passed through a glass block and the angles of incidence and refraction are measured using a protractor.



(a) Draw the refracted ray and the ray emerging from the glass block on the above diagram. [2]

(b) The results obtained are collated in the following table and plotted on the grid.

Incident angle (i) / degrees ±1°	Refracted angle (r) / degrees ±1°	sin (i)	sin (r)
0	0	0.00 ± 0.02	0.00 ± 0.02
20	13	0.34 ± 0.02	0.22 ± 0.02
40	25	0.64 ± 0.01	0.42 ± 0.02
60	34	0.87 ± 0.01	0.56 ± 0.01
80	39	0.985 ± 0.005	0.63 ± 0.01



15

Examiner only

(i) **Add error bars** to the data points and also draw the lines of maximum gradient and minimum gradient. [4]

(ii) Determine the refractive index of the block along with a value for its **absolute uncertainty**, quoting your results to an appropriate number of significant figures. [4]

....

....

....

....

....

....

....

....

....

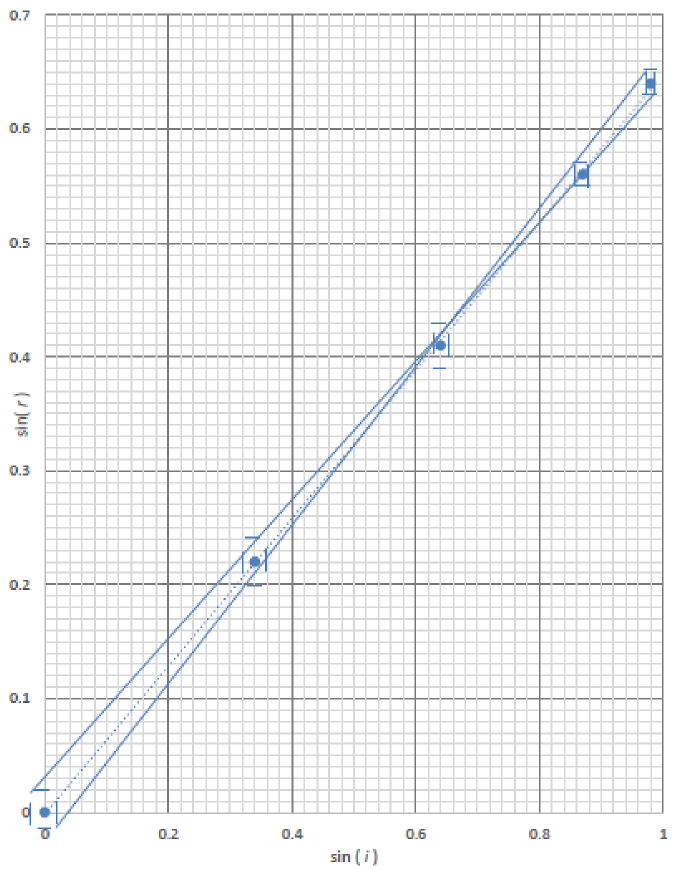
....

A420U301 15

10

Example P3 mark scheme

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Bending toward the normal in the glass (not along normal) (1) Light comes out approximately parallel to original (by eye) (1)	2			2		2
	(b)	(i)	See graph on next page Most y error bars correct (1) Most x error bars correct (1) All error bars correct (1) Drawing maximum and minimum lines (1)		4		4	4	4
		(ii)	Method for calculating gradient (accept inverse if used correctly) (1) At least 2 gradients correct (0.695, 0.648, 0.606) (1) Refractive index = $\frac{1}{\text{gradient}}$ used or implied (1) n = 1.6 ± 0.1 or 1.56 ± 0.12 needs to be with consistent sig figs allow a max of 2 sig figs for the uncertainty (1) **accept** 0.08 - 0.12 for the uncertainty			4	4	4	4
			Question 8 total	**2**	**4**	**4**	**10**	**8**	**10**

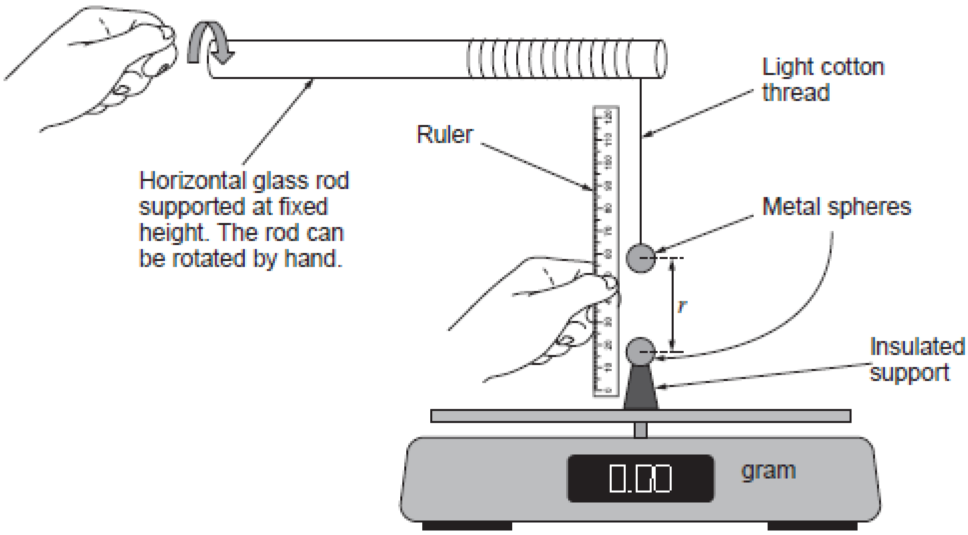


Example P3 Commentary

Description	This question focuses on a practical activity to measure the refractive index of a material. Part (a) is a standard book-work question and does not indirectly assess practical skills. Part (b) requires students to use results from the practical to obtain a value for refractive index together with its absolute certainty.
Appendix 5a skills assessed	• 'Plot and interpret graphs'. • 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'. • 'Consider margins of error, accuracy and precision of data'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question shows the importance of indicating that only part of it indirectly assesses practical skills. Part (a) is based on standard book work. • The part b questions would be accessible as a result of students carrying out this and similar pieces of practical work (using laser or light source to investigate characteristics of light, including interference and diffraction is a practical activity). • The latter parts to the question assess the appropriate use of significant figures which is an important skill, when considering practical data.

Example P4

5. Two students, Ben and Sarah, use the following apparatus to investigate the 'inverse square' nature of Coulomb's law.



The same negative charge is placed on both spheres. The distance, r, between the centres of the spheres is varied and the reading on the top pan balance is noted. Sarah and Ben disagree on the best method to measure r.

Ben favours using a ruler with a resolution of 1 mm to measure it directly.

Sarah suggests measuring the diameter of the glass rod with Vernier calipers, with a resolution of 0.01 mm, to determine the circumference of the rod. The rod can then be rotated by hand, with each complete rotation corresponding to the calculated circumference.

(a) (i) State an advantage and a disadvantage of each method. [4]

....

....

....

....

....

....

....

....

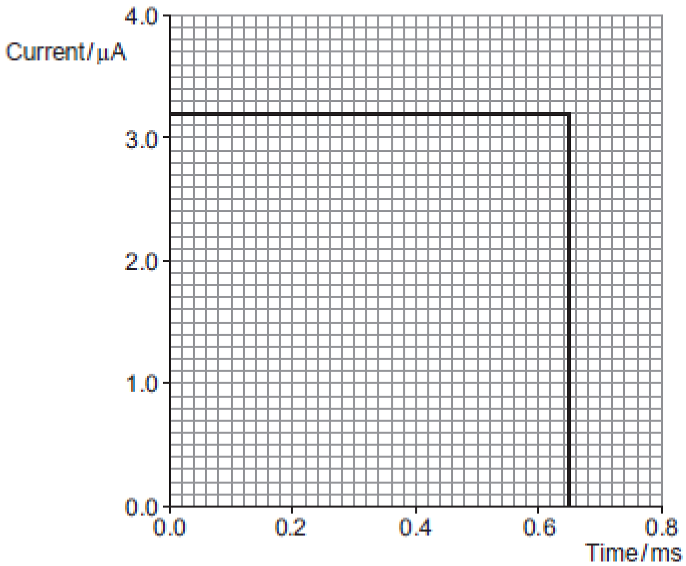
....

(ii) Suggest an improvement to **one** of the techniques which would increase the accuracy of measuring r. [1]

(b) When r = 20 mm, the reading on the top pan balance is 0.01 gram.

(i) Show that the value of Q_1Q_2, the product of the charges on the spheres, when r = 20 mm is approximately $4.4 \times 10^{-18}\ \mathrm{C}^2$. [3]

(ii) One of the spheres is now discharged. The graph shows how the discharge current varies with time.



Show that the values given on the graph are consistent with the product Q_1Q_2 in *(b)*(i). [2]

Examiner only

(iii) Hence, estimate the number of electrons on one sphere when the reading on the balance is 0.01 gram and r = 20 mm. [1]

....

....

....

....

11

Example P4 mark scheme

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th></th><th></th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>5</td><td>(a)</td><td>(i)</td><td>
<table>
<tr><th></th><th>Advantage</th><th>Disadvantage</th></tr>
<tr><td>Ben (ruler)</td><td>Easy to use/convenient / quicker</td><td>Inaccurate [only to ± 1 mm] / reference to parallax errors / difficulty in supporting ruler / may touch spheres</td></tr>
<tr><td>Sarah (rod)</td><td>Diameter measured accurately / greater accuracy</td><td>Diameter/radius of spheres need to be known beforehand / difficult to judge one complete rotation / difficult to measure angle [of rotation] / difficult to set-up / thread overlapping</td></tr>
</table>
4 × 1 mark - one response required from each cell.</td><td></td><td>4</td><td></td><td>4</td><td></td><td>4</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Any ×(1) from:
• Pins/markers on ruler
• Marker on cylinder
• Measure diameter of spheres
• Mark point at centre of each sphere and use a travelling microscope to measure the separation
• Fix the ruler close to spheres
• Smaller diameter rod
• Use of Vernier calipers (for Ben)
Don't accept repeat readings</td><td></td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
</table>

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th></th><th></th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$F = 9.81 \times 10^{-5}$ N (1)
Use of $F = \dfrac{9 \times 10^{9} Q_1 Q_2}{r^2}$ (1)
$Q_1Q_2 = 4.36 \times 10^{-18}$ [C^2] (1)</td><td>
1
</td><td>1

1</td><td></td><td>3</td><td>3</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$Q = (4.36 \times 10^{-18})^{1/2}$ determined (or use of 4.4×10^{-18}) = 2.09×10^{-9} C (1)
Area under graph calculated: $3.2 \times 10^{-6} \times 0.65 \times 10^{-3}$ = 2.08×10^{-9} C (1)
Alternative:
Area, $Q = 2.08 \times 10^{-9}$ (1)
So $QQ = (2.08 \times 10^{-9})^2 = 4.3 \times 10^{-18}$ C^2 (1)</td><td></td><td></td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>$n = \dfrac{2.09 \times 10^{-9}}{1.6 \times 10^{-19}}$ = 1.31×10^{10} electrons ecf on Q</td><td></td><td>1</td><td></td><td>1</td><td>1</td><td>1</td></tr>
<tr><td></td><td></td><td></td><td>Question 5 total</td><td>1</td><td>7</td><td>3</td><td>11</td><td>6</td><td>11</td></tr>
</table>

Example P4 Commentary

Description	This question is based on practical work about Coulomb's Law. Part (a) requires students to discuss the method described and an improvement that would increase the accuracy. Part (b) (i) is a calculation that is linked to the practical activity that has been described. The rest of part (b) does not indirectly assess practical skills.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'. • 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'. • 'Consider margins of error, accuracy and precision of data'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • The scenario used in this question is not standard practice for this type of practical but this does not cloud the focus of the question. In fact, it is good to show that there are different approaches available. • Part (b) (i) would be more accessible to students who have had the chance to have practical experience of this technique (using digital or Vernier scales is a practical requirement). • Questions (b) (ii) and (iii) solely assess mathematical skills in a practical context, meeting the requirements for both the indirect assessment of practical skills and the assessment of mathematical skills.

Example P5

4 (a)* You are given an unmarked sealed square box which has four identical terminals at each corner.

Fig 4.1 shows the circuit diagram for the contents of the box with the four terminals labelled **A**, **B**, **C** and **D**.

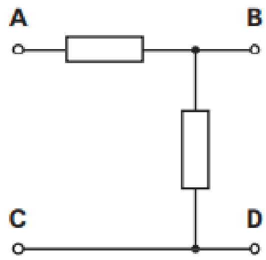


Fig. 4.1

One of the resistors in the box has resistance 220 Ω. The other resistor has resistance 470 Ω. Two of the terminals are connected by a wire.

The four terminals on your unmarked sealed box are **not** labelled.

You are given a 6.0 V d.c. supply, a 100 Ω resistor (labelled R) and a digital ammeter.

Plan an experiment to determine the arrangement of the components and identify which terminal of your unmarked sealed box is **A**, **B**, **C** and **D**.

A space has been left for you to draw circuit diagrams to illustrate your answer.

....

....

....

....

....

....

.... **[6]**

Example P5 mark scheme

Question			Answer	Marks	Guidance
4	(a)		**Level 3 (5 - 6 marks)** Clear planning and correct identification of terminals and position of components *There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.* **Level 2 (3 – 4 marks)** Clear planning and correct identification of some components / terminals *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** Some planning and/or an attempt at identifying component / terminals *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1 x 6**	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** **Indicative scientific points may include:** **Planning** • suitable circuit arrangements/diagrams drawn between two points which could be connected to the box terminals • use of R to limit current, e.g. to find CD terminals • logical plan of connection across terminals e.g. connect circuit to each pair of terminals in turn • identify terminals C and D as the circuit with the largest current/smallest resistance • A and B identified because CD known **or** the circuit including terminals AC/D has the smallest current/largest resistance **Identifying** • $V = IR$ quoted or used in calculations • $R_T = \Sigma R$ used to determine the 220 Ω or the 470 Ω resistors • For 220 Ω resistor (between AB or BC/D) current is 27 (mA) A **or** 19 (mA) with R • For 470 Ω resistor (between AB or BC/D) current is 13 (mA) **or** 11 (mA) with R • For both resistors (between AC/D) current is 8.7 (mA) **or** 7.6 (mA) with R • For wire (between CD) current is 0.060 A

Example P5 Commentary

Description	Part (a) of this question assesses the quality of an extended response and requires students to plan an experiment relating to an electrical circuit.
Appendix 5a skills assessed	• 'Comment on experimental design and evaluate scientific methods'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students will be better prepared to answer this type of question as a result of undertaking a range of practical work and considering why methods are carried out in the way that they are (design and construct circuits are practical requirements). • Practical work should include students discussing and exploring steps in procedures so that they have the opportunity to gain full understanding of the experimental design. This question assesses that application of practical skills.

Example P6

39 A class observes the absorption of α, β and γ radiation.
A Geiger tube is placed 1.0 cm from radioactive sources **X**, **Y** and **Z** as shown in **Fig. 39.1**.

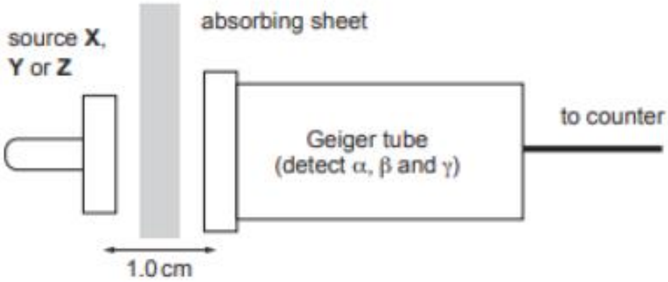


Fig. 39.1

The time to reach 10^4 counts is recorded and the count rate *C* per second is calculated with an uncertainty of ± 1%. The data has been corrected for background radiation.

	count rate C / s^{-1}			
Absorbing material	**1.0 cm air**	**0.1 mm paper**	**2 mm aluminium**	**5 mm lead**
Source X	395	397	22	background
Source Y	950	420	138	35
Source Z	550	547	238	27

(a) One of the sources emits α, β and γ radiation,
one source emits β and γ
and one source emits pure β.

For each source below state which radiations are emitted. Justify your choices using data from the table.

X emits .... justification ....

....

Y emits .... justification ....

....

Z emits .... justification ....

....

....

[3]

Example P6 mark scheme

Question		Answer				Marks	Guidance
39	(a)	X	pure β	no γ at background with 5 mm lead	✓	1	all identifications correct for **first mark even if no** explanations **total** zero if three sources incorrect
		Y	α, β, γ	large drop with paper ∴ must have α	✓	1	**two** correct explanations for **second mark**
		Z	β, γ	(no drop with paper ∴ no α) counts with lead so some γ	✓	1	**three** correct explanations for **third mark** **ignore** comments on β as present in all three sources **not** credit for descriptions of data expect logical analysis

Example P6 Commentary

Description	This question requires students to take a problem solving approach when applying their practical understanding of the radiation emitted from a variety of sources.
Appendix 5a skills assessed	• 'Solve problems set in practical contexts'. • 'Apply scientific knowledge to practical contexts'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • The problem solving approach in this question is an example of applying knowledge to a practical situation (use ionising radiation, including detectors, is a practical requirement).

Example P7

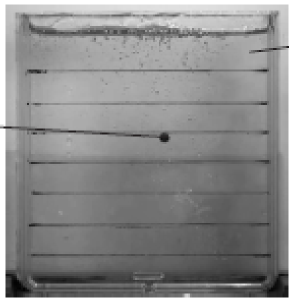
SECTION B

Answer ALL questions.

15 A student carried out an experiment to identify a fluid from its viscosity at room temperature.

A ball bearing of diameter d was released at the top of a container containing the fluid. The motion of the ball bearing was recorded using a video camera and hence the terminal velocity v of the ball bearing was determined.

This was repeated for ball bearings of increasing diameter with the fluid at a constant temperature.



(a) To determine the viscosity η, the student used the equation $v = \dfrac{d^2 g(\rho_b - \rho_f)}{18\eta}$

where ρ_b = density of the material of the ball bearing
ρ_f = density of the fluid.

Explain why a graph of v on the y-axis and d^2 on the x-axis should be a straight line through the origin.

(3)

(b) The student obtained the following data.

d / 10^{-3} m	d^2 / 10^{-6} m^2	v / 10^{-3} m s^{-1}
1.0	1.0	2.3
2.0	4.0	11
3.0	9.0	23
4.0	16.0	39
5.0	25.0	64

Plot the graph of v against d^2.

(4)

(c) The table shows the viscosity of some different fluids.

Fluid	**Viscosity at room temperature / Pa s**
castor oil	1.0
glycerol	1.2
corn syrup	1.4
honey	1.9

Use the graph to deduce which fluid the student used.

density of ball bearing = 8000 kg m^{-3}
density of fluid = 1260 kg m^{-3}

(4)

(Total for Question 15 = 11 marks)

Example P7 mark scheme

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>15(a)</td><td>Comparison to $y = mx + c$
Identify that η, ρ_s, ρ_f and g are constants
$c = 0$ so the graph passes through the origin
Or when $d^2 = 0$, $v = 0$ so would pass through the origin</td><td>(1)
(1)
(1)</td><td>MP1 e.g. $y = mx + c$ so
$v = \left(\frac{g(\rho_b - \rho_f)}{18\eta}\right) \times d^2\ (+ 0)$</td><td>3</td></tr>
<tr><td>15(b)</td><td>Axes labelled with quantities and units
Suitable scale
Correct plotting
Line of best fit (judged by eye)</td><td>(1)
(1)
(1)
(1)</td><td>MP1: v / 10^{-3} m s^{-1} on y-axis and d^2 / 10^{-6} m^2 on x-axis
<table><tr><th>d^2 / 10^{-6} m^2</th><th>v / 10^{-3} m s^{-1}</th></tr><tr><td>1.0</td><td>2.3</td></tr><tr><td>4.0</td><td>11</td></tr><tr><td>9.0</td><td>23</td></tr><tr><td>16.0</td><td>39</td></tr><tr><td>25.0</td><td>64</td></tr></table></td><td>4</td></tr>
<tr><td>15(c)</td><td>Attempt to find gradient, at least half drawn line used
Use of $\eta = \frac{g(\rho_s - \rho_f)}{18} \times \frac{1}{\text{gradient}}$
$\eta = 1.4 - 1.5$ (Pa s)
Corn syrup identified as the fluid</td><td>(1)
(1)
(1)
(1)</td><td>MP4 to be consistent with calculated value for η

<u>Example of calculation</u>
$\eta = \frac{9.81\ \text{N kg}^{-1} \times (8000\ \text{kg m}^{-3} - 1260\ \text{kg m}^{-3})}{18 \times 2.52 \times 10^3\ \text{m}^{-1}\ \text{s}^{-1}}$
$\eta = 1.46$ Pa s</td><td>4</td></tr>
</table>

(Total for Question 15 = 11 marks)

Example P7 Commentary

Description	This question is about the identification of a fluid from its viscosity at room temperature. Part (a) requires the student to explain why the equation used to determine the viscosity from the experimental data should result in a straight line on a graph. Part (b) asks the student to plot experimental data on a graph. Part (c) requires analysis of the graph to determine the fluid used in the experiment.
Appendix 5a skills assessed	• 'Process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science'. • 'Plot and interpret graphs'. • 'Solve problems set in practical contexts'.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • This question shows the importance of students developing good skills in graphically presenting data over their 2 year A level course (use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings is a practical requirement). • The blank grid for the plotting of the graph requires greater understanding from students and will allow them to demonstrate their skills in this area. Some students are likely to be familiar with the context of the question, but even if they are, it is not direct recall but the interpretation of the results that is the focus of the assessment. • Part (c) is an example of a problem-solving approach and the student is directed to use the graph and the experimental data.

Example P8

5 In an experiment a student is taking a measurement of a time interval in seconds.

He repeats the measurement and collects the following three readings:

3.2 s   3.2 s   3.3 s

Which one of the following is a correct statement?

☐ **A** The reading of 3.3 s is an error.

☐ **B** The average should be recorded as 3.23 s.

☐ **C** The uncertainty is 0.1 s.

☐ **D** The error is 0.1 s.

(Total for Question 5 = 1 mark)

Example P8 mark scheme

5	C The uncertainty is 0.1 s.		1

Example P8 Commentary

Description	This is a multiple-choice question that asks students to choose an answer to a question about repeated measurements.
Appendix 5a skills assessed	• ‘Consider margins of error, accuracy and precision of data’.
Rationale for identifying the indirect assessment of practical skills	Subject experts are of the opinion that: • Students will have developed the skills needed for this question in a wide range of practical contexts (use methods to increase accuracy of measurements is a practical requirement) so should be able to tackle this question with confidence.

© Crown Copyright 2019

This publication is licensed under the terms of the Open Government Licence v3.0 except where otherwise stated.

To view this license, visit

www.nationalarchives.gov.uk/doc/open-government-licence/

or write to

Information Policy Team, The National Archives, Kew, London TW9 4DU

Published by:

ofqual

Earlsdon Park
53-55 Butts Road
Coventry
CV1 3BH

0300 303 3344
public.enquiries@ofqual.gov.uk
www.gov.uk/ofqual

April 2019 Ofqual/19/6489