RECOGNISING ACHIEVEMENT

INSET Training Materials

OCR GCSE Twenty First Century Science (J242 – J245):

Get started: controlled assessment (Practical Investigation) for GCSE Additional Science A, Biology A, Chemistry A and Physics A (Units A154, A164, A174 and A184)

Name:		Date Attended:	

Course overview

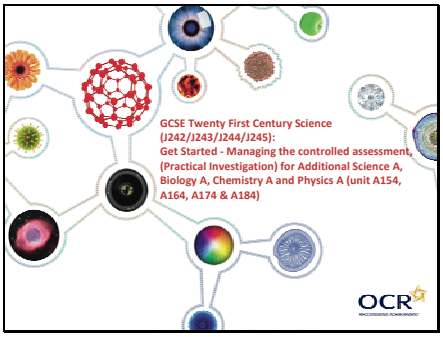
This half day course will:

- include a brief introduction to GCSE Twenty First Century Sciences for delegates new to the suite
- explain the administration procedures for Units A154, A164, A174 and A184
- provide guidance on how to prepare for your first Controlled Assessment (Practical Investigation)
- review Sample Assessment Materials
- review the support and resources on offer
- enable delegates to network and share ideas for best practice.

Programme

Afternoon course

13.00	Registration and lunch
13.30	Introduction to Twenty First Century Science and Controlled Assessment
13.45	The Practical Investigation: levels of control
14.15	Hypotheses and secondary data
14.45	Tea/coffee break
15.00	The new assessment aspects
15.30	Marking the Practical Investigation
15.45	Marking exercise
16.00	Close



GCSE assessment rules have changed

- Learners must take at least 40% of the assessment of each specification in the final examination series when they certificate.
- Learners may only re-sit a unit assessment once. The better result for the two attempts at a unit counts. If a re-sit is part of the 40% terminal requirement, that mark must count, even if the mark is lower than that achieved at a previous sitting.
- Each specification will have a maximum of four units, and each unit must carry a minimum weighting of 20%.
- Controlled assessment replaces coursework.

New assessment model – Biology A, Chemistry A, Physics A and Additional Science A

New model – Separate Sciences and Additional Science		
Unit	Content	Weighting
1	Exam paper on 3 modules 60 marks	25%
2	Exam paper on 3 modules 60 marks	25%
3	Exam paper on final module 60 marks (Additional Science Exam on 3 modules)	25%
4	Controlled Assessment Practical Investigation Task	25%

Changes to controlled assessment

- Changes here mostly result from the new regulations for controlled assessment.
- OCR must specify the task (*centres no longer choose which activities to use*)
- It will no longer be possible to 'double count' the same strand I and strand E marks for both Science and Additional/Separate Sciences.
- All separate sciences must use investigations (*case studies not allowed for B/C/P*)

How much have we changed the controlled assessment?

- We are only making changes where needed.
- We have taken this opportunity to greatly simplify the marking of controlled assessment in order to minimise the burden on staff in centres.
- We have reduced the number of rows of mark descriptors to be assessed in the investigation from 15 to 8.

Controlled Assessment

The rationale

- provides candidates with an opportunity to demonstrate skills that are more difficult to assess in an examination environment

while at the same time, it

- provides a degree of control to ensure that the process is fair for all candidates.

See also: http://www.ocr.org.uk/download/sm/ocr_53021_sm_gcse_ca.pdf

Controlled Assessment

One task for Biology A, Chemistry A, Physics A or Additional Science A:

A Practical Investigation

- Assesses skills central to the nature of science as an evidence based activity.

Practical Investigation

The Assessment Objectives

Assessment Objective (AO)	Total marks
AO1: Recall, select and communicate their knowledge and understanding of science	6
AO2: Apply skills, knowledge and understanding of science in practical and other contexts	12
AO3: Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence	46
TOTAL	64

Tasks provided each year

Separate Sciences	Additional
Investigation	
B(4 – 6) + B(1 – 7)	Either
C(4 – 6) + C(1 – 7)	Either
P(4 – 6) + P(1 – 7)	Either

Biology: either one chosen from 2
Chemistry: either one chosen from 2
Physics: either one chosen from 2
Additional science: any one chosen from 6

ONLY available for entry in one year

Controlled Assessment

Planning and managing

- is based on the science in any topic in the specification.
- each task is valid for submission in one specified examination series only.
- each year, two new tasks for each subject will be made available, two years ahead of the examination series in which they are to be submitted.
- it is not necessary for all candidates from a centre to carry out the same task.
- A candidate who submits a task at the end of yr 10, and will not aggregate until the end of yr 11 may then also submit another task at the end of yr 11 and count the better mark.

Practical Investigation

The format

- the Practical Investigation (64 marks):
  - Information for Candidates (1) – background information that sets the scene and identifies the topic to be investigated.
  - Information for Candidates (2) – Some secondary data that may be used by the candidates.
  - Information for Teachers – guidance on administration of the task and practical work, including apparatus requirements, and assessment guidance specific to the Practical Data Analysis in question.

The Practical Investigation

- is based on the science in any topic in the specification.
- requires candidates to:
  - develop hypotheses and plan practical ways to test them, including risk assessment and manage risks when carrying out practical work
  - collect, process, analyse and interpret primary and secondary data, including the use of appropriate technology to draw evidence-based conclusions
  - review methodology to assess fitness for purpose
  - review hypotheses in the light of outcomes

Levels of control – we are not the first!

Other subjects have been using controlled assessment for 2 – 3 years.

Colleagues in English, Geography, History etc, have already devised procedures.

Attempt to build on established practice in your school.

Levels of Control

The practical investigation can be thought of in three parts –

- Research and planning (limited control)
- Collecting Data (carrying out the experiments) (limited control)
- Analysis, evaluating and review (high control)

Levels of Control

Research and Planning stage 1.5 - 2 hours

Conditions of limited control

- candidates can undertake this part of the task without direct teacher supervision and away from the centre, and can work in collaboration.
- during the research phase, candidates can be given support and guidance: teachers can explain the task, discuss how the task can be approached, along with advising on resources.
- but candidates must develop an **individual** response.

Levels of Control

Collecting Data stage 1.5 - 2 hours

Conditions of limited control

- candidates will carry out **practical** work under direct supervision to collect primary data.
- collaboration is permissible, but all candidates must be actively involved.
- candidates must develop own response in deciding how best to collect both primary and secondary data and record data.

Levels of Control

Analysis, evaluation and review stage: 1.5 - 2 hours

Conditions of high control

- candidates work individually to write their analysis, evaluation and review section of the report under direct teacher supervision.
- resources and notes from the planning stage, tables and graphs from the collecting data stage and research notes may be used.
- if write-ups extend over several sessions, work, including electronic data storage devices, must be collected in.

Levels of Control

The report – a summary

Written in three sections:

- Planning – limited control
- Procedures and results presentation – limited control
- Analysis, Evaluation and Review – high control

- Teachers must be able to authenticate ALL work. You will sign to say so.

The Practical Investigation

The Hypothesis

* A scientific hypothesis is a tentative explanation of science-related observations, or some phenomenon or event.

  A useful hypothesis allows a prediction to be made from it that can be tested experimentally.

The Practical Investigation

Secondary Data

- Secondary data can be:
  - researched from the internet, library, text books
  - provided by OCR
  - another group's results
- Researching secondary data is limited control.
- Some search for secondary data should be done at the planning stage.

Task: Plan for a class to do an investigation

- Select a Practical Investigation (the specimen Investigations are included in your pack)
- How many lessons will you need?
- How much time outside lessons will your candidates need?
- How will you introduce the investigation?
- How will you manage the practical?

Practical Investigation: Assessment

Strand S: Strategy
- (a) Formulating a hypothesis or prediction
- (b) Design of techniques and choice of equipment

Strand C: Collecting data – range and quality of primary data

Strand A: Analysis - revealing patterns in data

Strand E: Evaluation
- (a) Evaluation of apparatus and procedures
- (b) Evaluation of primary data

Strand R: Review
- (a) Collection and use of secondary data.
- (b) Reviewing confidence in the hypothesis.

The Assessment Aspects (1)

S Strategy	S(a) - formulating a hypothesis or prediction	Candidates review factors that might affect their results (this may include preliminary tests of these effects) and use their scientific knowledge to choose an effect to study, based on a prediction or testable hypothesis. Responses in this aspect will be in extended writing and should be assessed for quality of written communication of the content.
	S(b) - design of techniques and choice of equipment	Candidates test different experimental methods or apparatus, and justify the choices they make. They show awareness of safe working practices and the hazards associated with materials. At the highest level, a full risk assessment is included.
C Collecting data	C - range and quality of primary data	Candidates make decisions about the amount of data to be collected, the range of values covered, and effective checking for reproducibility.
A Analysis	A - revealing patterns in data	To allow access to a wider range of activities, this strand has two alternative sets of criteria. One is for the quality of graphical display. The alternative row can be used to award credit for statistical or numerical analysis of data, eg species distribution surveys.

The Assessment Aspects (2)

E Evaluation	E(a) - evaluation of apparatus and procedures	Candidates show awareness of any limitations imposed by the apparatus or techniques used and suggest improvements to the method. .
	E(b) - evaluation of primary data	Candidates consider carefully the reproducibility of their data, recognise outliers and treat them appropriately.
R Review	R(a) - collection and use of secondary data	Candidates collect secondary data, which can be considered together with their own primary data, to give a broader basis for confirmation, adaptation or extension of the initial hypothesis or prediction.
	R(b)- reviewing confidence in the hypothesis	Candidates make an overall review of the evidence in relation to the underlying scientific theory and consider how well it supports the hypothesis, and what extra work might help to improve confidence in the hypothesis. Quality of written communication should be taken into account in assessing this aspect of the work.

new strands	old strands
Sa	-
Sb	S(b) + Safety
C	C(b)+C(c)
A	I(a)
Ea	E(a)
Eb	E(b)
Ra	-
Rb	-

Marking the Practical Investigation (1):

Strand S(a): range and quality of primary data

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
S a	Make a prediction to test, but without any justification. The response may be simplistic, with frequent errors of spelling, punctuation or grammar and have little or no use of scientific vocabulary.	Suggest a testable prediction and justify it by reference to common sense or previous experience. Some relevant scientific terms are used, but spelling, punctuation and grammar are of variable quality	Consider major factors and refer to scientific knowledge to make a testable hypothesis about how one factor will affect the outcome. Information is effectively organised with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	After consideration of all relevant factors, select one and propose a testable hypothesis and quantitative prediction about how it will affect the outcomes. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.

Marking the Practical Investigation (2):

Strand S(b): design of techniques and choice of equipment

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
S b	Follow a given technique, but with very limited precision or accuracy. Make an appropriate comment about safe working.	Select and use basic equipment to collect a limited amount of data. Correctly identify hazards associated with the procedures used.	Select and use techniques and equipment appropriate for the range of data required, and explain the ranges chosen. Identify any significant risks and suggest some precautions.	Justify the choice of equipment and technique to achieve data which is precise and valid. Complete a full and appropriate risk assessment, identifying ways of minimising risks associated with the work.

Marking the Practical Investigation (3):

Strand C: range and quality of primary data

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
C	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality	Choose an appropriate range of values to test across the range, with regular repeats and appropriate handling of any outliers. Checks or preliminary work are included to confirm or adapt the range and number of measurements to ensure data of high quality.

Marking the Practical Investigation (4):

Strand A: revealing patterns in data

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
A	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line of best fit, or construct complex charts or diagrams e.g. species distribution maps.	Indicate the spread of data (e.g. through scatter graphs or range bars) or give clear keys for displays involving multiple datasets.
	Select individual results as a basis for conclusions.	Carry out simple calculations e.g. correct calculation of averages from repeated readings	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data e.g. statistical methods, use of Inverse relationships, or calculation of gradient of graphs.

Marking the Practical Investigation (5):

Strand E(a): evaluation of apparatus and procedures

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
E a	Make relevant comments about problems encountered whilst collecting the data.	Describe the limitations imposed by the techniques and equipment used.	Suggest (in outline) improvements to apparatus or techniques, or alternative ways to collect the data; or explain why the method used gives data of sufficient quality to allow a conclusion.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement; or explain fully why no further improvement could reasonably be achieved.

Marking the Practical Investigation (6):

Strand E(b): evaluation of primary data

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
E b	Make a claim for accuracy or repeatability, but without appropriate reference to the data.	Correctly identify individual results which are beyond the range of experimental error (are outliers), or justify a claim that there are no outliers.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and repeatability and explain how this assessment is made.	Consider critically the repeatability of the evidence, accounting for any outliers.

Marking the Practical Investigation (7):

Strand R(a): collection and use of secondary data

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
R a	Compare own experimental results with at least one piece of secondary data and make basic comments on similarities and/or differences. Secondary data collected is limited in amount and not always relevant to the investigation.	Identify in detail similarities and differences between the secondary data and primary data. Secondary data collected is relevant to the investigation and sources are referenced, though these may be incomplete.	Describe and explain the extent to which the secondary data supports, extends and/or undermines the primary data, and identify any areas of incompleteness. A range of relevant secondary data is collected from several fully referenced sources.	Assess the levels of confidence that can be placed on the available data, and explain the reasons for making these assessments. Comment on the importance of any similarities or differences.

Marking the Practical Investigation (8):

Strand R(b): reviewing confidence in the hypothesis

	1 – 2 marks	3 – 4 marks	5 – 6 marks	7 – 8 marks
R b	Correctly state whether or not the original prediction or hypothesis is supported, with reference only to common sense or previous experience. The response is simplistic, with frequent errors in spelling, punctuation or grammar and has little or no use of scientific vocabulary.	Comment on whether trends or correlations in the data support the prediction or hypothesis and suggest why by reference to appropriate science. Some relevant scientific terms are used correctly, but spelling, punctuation and grammar are of variable quality.	Explain the extent to which the hypothesis can account for the pattern(s) shown in the data. Use relevant science knowledge to conclude whether the hypothesis has been supported or to suggest how it should be modified to account for the data more completely. Information is organised effectively with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Give a detailed account of what extra data could be collected to increase confidence in the hypothesis. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.

Marking Exercise

- Try applying the criteria to the samples in the pack
- Check your marks against the Commentary
- How could the examples be improved to gain higher marks?

Marks for Exemplars

strand	Fermentation	Waves in Water
Sa	7	6
Sb	8	5
C	7	7
A	8	7
Ea	6	6
Eb	7	6
Ra	7	6
Rb	7	7

Practical Investigation - Overview of the Level of Control for Assessment Aspects

Strand	Aspect	Level of Control	Notes
S Strategy	S(a) - formulating a hypothesis or prediction	**Limited**	
	S(b) - design of techniques and choice of equipment	**Limited**	
C Collecting data	C - range and quality of primary data	**Limited**	
A Analysis	A-revealing patterns in data	**Limited** if done during data collection phase **High** if done during evaluation/review phase	
E Evaluation	E(a) - evaluation of apparatus and procedures	**High**	
	E(b) - evaluation of primary data	**High**	
R Review	R(a) - collection and use of secondary data	collection - **Limited** Use - **High**	
	R(b)- reviewing confidence in the hypothesis	**High**	

Practical Investigation - Overview of the Assessment Aspects

Strand	Aspect	Notes
S Strategy	S(a) - formulating a hypothesis or prediction	Candidates review factors that might affect their results (this may include preliminary tests of these effects) and use their scientific knowledge to choose an effect to study, based on a prediction or testable hypothesis. Responses in this aspect will be in extended writing and should be assessed for quality of written communication of the content.
	S(b) - design of techniques and choice of equipment	Candidates test different experimental methods or apparatus, and justify the choices they make. They show awareness of safe working practices and the hazards associated with materials. At the highest level, a full risk assessment is included.
C Collecting data	C - range and quality of primary data	Candidates make decisions about the amount of data to be collected, the range of values covered, and effective checking for reproducibility.
A Analysis	A-revealing patterns in data	To allow access to a wider range of activities, this strand has two alternative sets of criteria. One is for the quality of graphical display. The alternative row can be used to award credit for statistical or numerical analysis of data, eg species distribution surveys.
E Evaluation	E(a) - evaluation of apparatus and procedures	Candidates show awareness of any limitations imposed by the apparatus or techniques used and suggest improvements to the method.
	E(b) - evaluation of primary data	Candidates consider carefully the reproducibility of their data, recognise outliers and treat them appropriately.
R Review	R(a) - collection and use of secondary data	Candidates collect secondary data, which can be considered together with their own primary data, to give a broader basis for confirmation, adaptation or extension of the initial hypothesis or prediction.
	R(b)- reviewing confidence in the hypothesis	Candidates make an overall review of the evidence in relation to the underlying scientific theory and consider how well it supports the hypothesis, and what extra work might help to improve confidence in the hypothesis. Quality of written communication should be taken into account in assessing this aspect of the work.

Practical Investigation - Assessment Criteria

0 marks if No response or response not sufficient for award of 1 mark

Strand/ Aspect	1-2 marks	3-4 marks	5-6 marks	7-8 marks
S a	Make a prediction to test, but without any justification. The response may be simplistic, with frequent errors of spelling, punctuation or grammar and have little or no use of scientific vocabulary.	Suggest a testable prediction and justify it by reference to common sense or previous experience. Some relevant scientific terms are used, but spelling, punctuation and grammar are of variable quality.	Consider major factors and refer to scientific knowledge to make a testable hypothesis about how one factor will affect the outcome. Information is effectively organised with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	After consideration of all relevant factors, select one and propose a testable hypothesis and quantitative prediction about how it will affect the outcomes. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.
S b	Follow a given technique, but with very limited precision or accuracy. Make an appropriate comment about safe working.	Select and use basic equipment to collect a limited amount of data. Correctly identify hazards associated with the procedures used.	Select and use techniques and equipment appropriate for the range of data required, and explain the ranges chosen. Identify any significant risks and suggest some precautions.	Justify the choice of equipment and technique to achieve data which is precise and valid. Complete a full and appropriate risk assessment, identifying ways of minimising risks associated with the work.
C	Record a very limited amount of data (eg isolated individual data points with no clear pattern), covering only part of the range of relevant cases/situations, with no checking for repeatability. Data is generally of low quality.	Record an adequate amount or range of data, allowing some errors in units or labelling, and with little checking for repeatability. Data is of variable quality, with some operator error apparent.	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality.	Choose an appropriate range of values to test across the range, with regular repeats and appropriate handling of any outliers. Checks or preliminary work are included to confirm or adapt the range and number of measurements to ensure data of high quality.
A	Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line of best fit or construct complex charts or diagrams eg species distribution maps.	Indicate the spread of data (eg through scatter graphs or range bars) or give clear keys for displays involving multiple data-sets.
	Select individual results as a basis for conclusions.	Carry out simple calculations eg correct calculation of averages from repeated readings.	Use mathematical comparisons between results to support a conclusion.	Use complex processing to reveal patterns in the data eg statistical methods, use of inverse relationships, or calculation of gradient of graphs.
E a	Make relevant comments about problems encountered whilst collecting the data.	Describe the limitations imposed by the techniques and equipment used.	Suggest (in outline) improvements to apparatus or techniques, or alternative ways to collect the data; or explain why the method used gives data of sufficient quality to allow a conclusion.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement; or explain fully why no further improvement could reasonably be achieved.
E b	Make a claim for accuracy or repeatability, but without appropriate reference to the data.	Correctly identify individual results which are beyond the range of experimental error (are outliers), or justify a claim that there are no outliers.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and repeatability and explain how this assessment is made.	Consider critically the repeatability of the evidence, accounting for any outliers.
R a	Compare own experimental results with at least one piece of secondary data and make basic comments on similarities and/or differences. Secondary data collected is limited in amount and not always relevant to the investigation.	Identify in detail similarities and differences between the secondary data and primary data. Secondary data collected is relevant to the investigation and sources are referenced, though these may be incomplete.	Describe and explain the extent to which the secondary data supports, extends and/or undermines the primary data, and identify any areas of incompleteness. A range of relevant secondary data is collected from several fully referenced sources.	Assess the levels of confidence that can be placed on the available data, and explain the reasons for making these assessments. Comment on the importance of any similarities or differences.
R b	Correctly state whether or not the original prediction or hypothesis is supported, with reference only to common sense or previous experience. The response is simplistic, with frequent errors in spelling, punctuation or grammar and has little or no use of scientific vocabulary.	Comment on whether trends or correlations in the data support the prediction or hypothesis and suggest why by reference to appropriate science. Some relevant scientific terms are used correctly, but spelling, punctuation and grammar are of variable quality.	Explain the extent to which the hypothesis can account for the pattern(s) shown in the data. Use relevant science knowledge to conclude whether the hypothesis has been supported or to suggest how it should be modified to account for the data more completely. Information is organised effectively with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Give a detailed account of what extra data could be collected to increase confidence in the hypothesis. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.

Practical Investigation - Assessment Criteria - Sorting task

Cut out criteria and arrange into Strands and levels:

Indicate the spread of data (eg through scatter graphs or range bars) or give clear keys for displays involving multiple data- sets	Correctly state whether or not the original prediction or hypothesis is supported, with reference only to common sense or previous experience. The response is simplistic, with frequent errors in spelling, punctuation or grammar and has little or no use of scientific vocabulary.	Make a prediction to test, but without any justification. The response may be simplistic, with frequent errors of spelling, punctuation or grammar and have little or no use of scientific vocabulary.	Select and use techniques and equipment appropriate for the range of data required, and explain the ranges chosen. Identify any significant risks and suggest some precautions.
Record a very limited amount of data (eg isolated individual data points with no clear pattern), covering only part of the range of relevant cases/situations, with no checking for repeatability. Data is generally of low quality.	. Suggest a testable prediction and justify it by reference to common sense or previous experience. Some relevant scientific terms are used, but spelling, punctuation and grammar are of variable quality.	After consideration of all relevant factors, select one and propose a testable hypothesis and quantitative prediction about how it will affect the outcomes. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	Justify the choice of equipment and technique to achieve data which is precise and valid. Complete a full and appropriate risk assessment, identifying ways of minimising risks associated with the work.
Consider major factors and refer to scientific knowledge to make a testable hypothesis about how one factor will affect the outcome. Information is effectively organised with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Record an adequate amount or range of data, allowing some errors in units or labelling, and with little checking for repeatability. Data is of variable quality, with some operator error apparent.	Collect and correctly record data to cover the range of relevant cases/situations, with regular repeats or checks for repeatability. Data is of generally good quality.	Choose an appropriate range of values to test across the range, with regular repeats and appropriate handling of any outliers. Checks or preliminary work are included to confirm or adapt the range and number of measurements to ensure data of high quality.

Display limited numbers of results in tables, charts or graphs, using given axes and scales.	Construct simple charts or graphs to display data in an appropriate way, allowing some errors in scaling or plotting.	Correctly select scales and axes and plot data for a graph, including an appropriate line of best fit or construct complex charts or diagrams eg species distribution maps.	Follow a given technique, but with very limited precision or accuracy. Make an appropriate comment about safe working..
Describe the limitations imposed by the techniques and equipment used.	Carry out simple calculations eg correct calculation of averages from repeated readings.	Use mathematical comparisons between results to support a conclusion.	Compare own experimental results with at least one piece of secondary data and make basic comments on similarities and/or differences. Secondary data collected is limited in amount and not always relevant to the investigation.
Give a detailed account of what extra data could be collected to increase confidence in the hypothesis. The report is comprehensive, relevant and logically sequenced, with full and effective use of relevant scientific terminology. There are few, if any, grammatical errors.	Select individual results as a basis for conclusions.	Consider critically the repeatability of the evidence, accounting for any outliers..	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement; or explain fully why no further improvement could reasonably be achieved.
Make a claim for accuracy or repeatability, but without appropriate reference to the data.	Correctly identify individual results which are beyond the range of experimental error (are outliers), or justify a claim that there are no outliers.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and repeatability and explain how this assessment is made.	Identify in detail similarities and differences between the secondary data and primary data. Secondary data collected is relevant to the investigation and sources are referenced, though these may be incomplete.

Use complex processing to reveal patterns in the data eg statistical methods, use of inverse relationships, or calculation of gradient of graphs.	Suggest (in outline) improvements to apparatus or techniques, or alternative ways to collect the data; or explain why the method used gives data of sufficient quality to allow a conclusion	Describe and explain the extent to which the secondary data supports, extends and/or undermines the primary data, and identify any areas of incompleteness. A range of relevant secondary data is collected from several fully referenced sources.	Assess the levels of confidence that can be placed on the available data, and explain the reasons for making these assessments. Comment on the importance of any similarities or differences.
Explain the extent to which the hypothesis can account for the pattern(s) shown in the data. Use relevant science knowledge to conclude whether the hypothesis has been supported or to suggest how it should be modified to account for the data more completely. Information is organised effectively with generally sound spelling, punctuation and grammar. Specialist terms are used appropriately.	Comment on whether trends or correlations in the data support the prediction or hypothesis and suggest why by reference to appropriate science. Some relevant scientific terms are used correctly, but spelling, punctuation and grammar are of variable quality.	Select and use basic equipment to collect a limited amount of data. Correctly identify hazards associated with the procedures used	Make relevant comments about problems encountered whilst collecting the data.

Candidate exemplar 1

Fermentation

Investigation: Factors that affect the rate of fermentation

Introduction
In this activity I am going to monitor the growth of brewer's yeast, *Saccharomyces cerevisiae*. Yeast is a microorganism which under the correct conditions produces alcohol and carbon dioxide by the fermentation of sugars. Fermentation is a type of anaerobic respiration.

Yeast is a Fungus that lives on the surface of fruit. It feeds on sugars to obtain its energy, producing carbon dioxide and water. In a brewery fermenter, however, the oxygen runs out, and its respiration switches from aerobic to anaerobic respiration. Alcohol and carbon dioxide are produced:

$C_6H_{12}O_6 \rightarrow$ ENERGY + $2C_2H_5OH$ + $2CO_2$

Alcoholic fermentations are extremely important economically to many people, ranging from the manufacturer of alcoholic drinks, the baker, to the industrial chemist. In 2009, 73 billion litres of alcohol were produced worldwide [1]. All but 5% of which was from fermentation [2].

It is important that the producer of alcohol provides the optimum conditions for yeast to grow in order to obtain maximum alcohol production. This investigation sets out to investigate how one factor affects the rate of fermentation of yeast.

Factors that might affect yeast growth
Factors that might affect yeast growth are:

- Temperature
- Concentration of yeast
- Concentration of sugar
- Concentration of oxygen
- Concentration of ethanol
- Time for fermentation
- pH
- Light

Factor chosen: temperature

In this investigation, the effect of temperature on yeast growth will be monitored.

Temperature is one of the most important factors affecting the activity of all organisms.
The production of alcohol and carbon dioxide and alcohol by yeast is a series of chemical reactions called anaerobic respiration or fermentation. So I would expect that as the temperature increases, the rate of reaction will also increase.

My hypothesis is therefore:
Changing the temperature will affect the rate of fermentation of yeast

I predict that as the temperature increases, the rate of fermentation will also increase. For many biological reactions, I have found out that there is a doubling of the rate or reaction for every 10°C [3], so I would expect the rate of fermentation at 20°C to be double that at 10°C, and the rate at 30°C to be double that at 20°C, etc. I predict that the fermentation rate will increase up to a certain temperature, however. Above 40-50°C, I would expect the enzymes in the yeast (which

control the rate of fermentation) to be denatured by the high temperatures, so the rate of fermentation will decrease.

Strategy
I found several methods of measuring the rate of fermentation:

- Measuring carbon dioxide production [4]
- Measuring ethanol production [4]
- Counting the yeast cells [5]. The energy produced by anaerobic respiration (fermentation) is used for growth of yeast cells and cell division so the number of yeast cells is an indirect way of measuring the rate of fermentation.
- Another way is to filter off the yeast cells, wash them, then weigh the yeast cells.

I have decided to measure the rate of fermentation by the yeast cell counting method. The methods I have seen for measuring carbon dioxide production do not look reliable. It would also be difficult to set these pieces of equipment up at different temperatures and keep them at these temperatures for several days.

Measuring the rate of alcohol production may be the best method, but it is too difficult to do in the school lab.

Measuring the mass of the yeast cells would be difficult. This would yield inaccurate results because of the small masses involved (one yeast cell weighs only approximately 0.02 μg), so yeast cells from a sample of only 5-10 cm^3 would be difficult to weigh.

I will set up yeast fermentations at a range of different temperatures, keeping other factors, i.e. light, concentration of yeast, concentration of sugar and pH constant. The range of temperatures we have chosen is 0 - 50°C. This is a range of temperatures over which most organisms live. Investigating a higher range would not be appropriate as commericial organisations that produce alcohol would not use high temperatures because of the energy inputs required to maintain the fermentations.

A suitable time over which to do the investigation is 10 days – most fermentations are complete inside this time.

The counting technique we will use uses a device called a haemacytometer, used in hospitals to count red blood cells.

Risk assessment

Hazard	Risk	Reducing risk	Comments
Bunsen Burner	Of burning you.	Make sure that its used carefully, and close the air hole so that the flame can be seen when you're not heating things. Wear eye protection when using.	
Glassware (beakers, boiling tubes, pipettes, haemacytometer)	When it gets hot you could burn your hand or you could drop it break it and cut yourself.	Wait for glassware to cool, or use tongs to remove hot glassware from the incubator. Be careful when using the haemacytometer not to break it or the coverslip	Make sure the broken glass kit is available. Record accidents and seek medical help.

		(focus away from the slide).	
Yeast	A microorganism (fungus) but low risk.	Wipe up any spills. Wash hands after use.	
Glucose	Low risk.	Wipe up any skills. Wash hands after use. Wear goggles and a lab coat. Wash hands after use. Always check with HAZCARD and CLEAPSS before carrying out an investigation.	Make sure Hazcards are available.
Microscope	Chance of being blinded or getting eye damage from light.	Check that the microscope is on low illumination before looking down it.	
Incubator	Chance of electrocution.	Check for label on incubator to show that its been tested this year.	

Materials and Methods

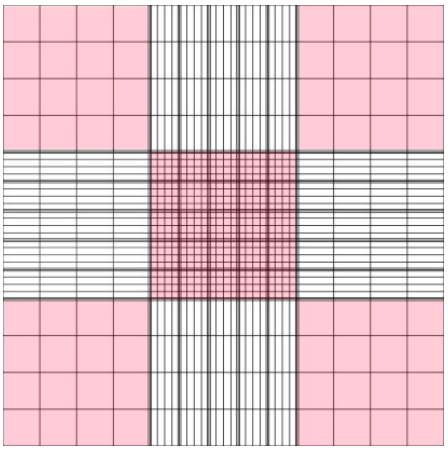
We set a number of boiling tubes. In each, we added a solution of glucose containing 200 g/ glucose per dm^3 of water. The mixture was heated for 30 minutes to kill any microorganisms present. When the liquid was cool, I added 1 g of yeast to the mixture, and mixed it thoroughly. I then pipetted 20 cm^3 of the mixture into each boiling tube (a pipette will measure the volume more accurately than a measuring cylinder). I think that this is a better method than adding yeast to individual boiling tubes. I am more likely to put an identical amount of yeast in each tube doing it this way.

The boiling tubes were placed at six different temperatures – 4, 13, 25, 30, 40 and 50°C. The samples at 4°C were placed in the fridge. The samples at 13°C were placed in store room. The others were placed in incubators at set temperatures. We set up repeats at each temperature to make sure that we got reliable results.

After ten days, we did the cell counts. First we gently shook the boiling tubes to mix up the contents. We then pipetted a little of each liquid onto a haemacytometer, and counted the yeast cells in ten 1 x 1 mm squares, then took an average.

My results

This table shows the cell counts in the 10 large cells counted over the two grids on the haemacytometer. From my results, I calculated the mean number of yeast cells per haemacytometer square. One or two of the results were very different – I think they were outliers, so I didn't include them in my calculations when working out the averages.



I counted cells in these squares on each of the two haemacytometer grids.

Image [6] from: http://en.wikipedia.org/wiki/File:Haemocytometer_Grid.png

Temperature, °C	Yeast cell counts, per 1.0 x 1.0 x 0.1 mm^3 'cell' of haemacytometer										Mean count per cell
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
4	37	28	38	43	45	43	38	39	47	44	**40**
13	123	122	100	130	120	124	105	127	103	111	**117**
25	634	627	612	640	638	606	523	590	537	520	**593**
30	701	683	743	707	900	850	770	695	587	756	**721**
40	810	747	927	673	776	712	827	696	721	698	**740**
50	8	9	12	8	12	2	12	12	8	10	**10**

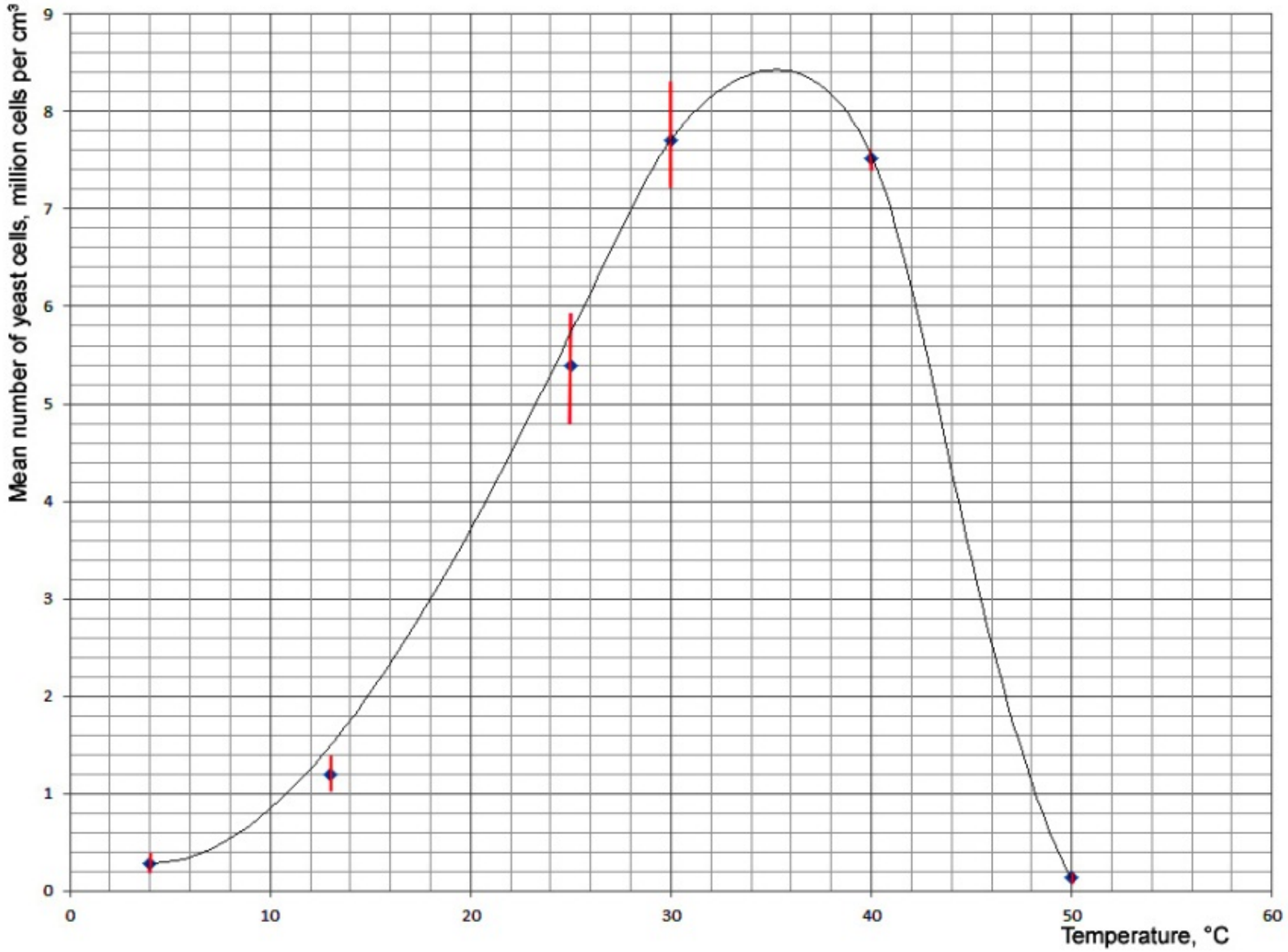
The volume of the small haemacytometer cells is 1.0 x 1.0 x 0.1 mm^3 = 0.1 mm^3

So I then calculated cell counts per cm^3 by multiplying each figure by 10 000.

Temperature, °C	Mean yeast cell count per 0.1 mm^3	Mean yeast cell count per cm^3
4	40	**400 000**
13	117	**1 170 000**
25	593	**5 930 000**
30	721	**7 210 000**
40	740	**7 400 000**
50	10	**100 000**

We repeated the investigation at each temperature. The results are below (I have not written out all the results – just the mean number of yeast cells per cm^3).

Temperature, °C	Results 1 Yeast cell count, millions of cells per cm^3	Results 2 Yeast cell count, millions of cells per cm^3	Results 3 Yeast cell count, millions of cells per cm^3	Mean yeast cell count, millions of cells per cm^3
4	0.40	0.25	0.22	**0.29**
13	1.17	1.40	1.02	**1.20**
25	5.93	4.81	5.46	**5.40**
30	7.21	8.33	7.54	**7.70**
40	7.40	7.60	7.55	**7.52**
50	0.10	0.15	0.18	**0.14**


Mean number of yeast cells, million cells per cm³
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
Temperature, °C

Evaluation
The results we obtained were repeatable. The readings for 4, 13, 40 and 50°C were very close together, as shown by the error bars on my graph. The results for 25 and 30°C were not quite as consistent, and the error bars were longer. Also, we left some readings out at these temperatures. When doing cell counts with a haemacytometer, the World Health Organisation [7] says that for a valid test, the results of the two counts should be within 20% of the mean value.

In any scientific investigation in the laboratory, the results will always vary slightly from one group of researchers to another. This is called random error. Other kinds of error are down to the scientist and can be eliminated. These are often due to the equipment or technique used.

When we placed the boilng tubes in the incubators at different temperatures, the contents of the boiling tubes would not reach the temperature immediately. This problem should have been eliminated, though, as we left the yeast to grow for 10 days. But it could have meant that at 50°C, when I expected no growth, the yeast could have fermented before the contents of the tube got up to the temperature.

I think a major problem though was the thorough mixing of the contents of the boiling tubes before pipetting some of the liquid onto the haemacytometer. We were careful that we did this, but other groups, who got different results, might not have been as careful.

The counting of the cells was also difficult. It is important to be consistent when counting cells on the boundary of a square. The way to do this is to include cells touching the top and left of the grid, but don't include the cells touching the bottom and right side.

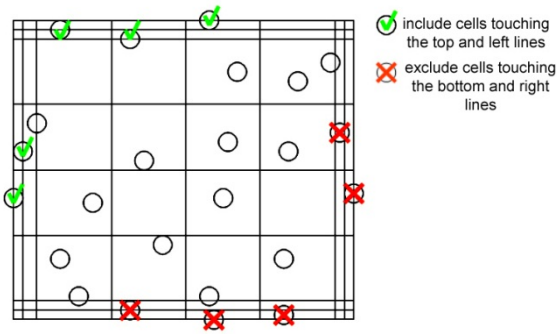


Diagram from [8]
http://www.hpacultures.org.uk/technical/ccp/cellcounting.jsp

When samples were placed on the haemacytometer, air bubbles would have made the volume of liquid trapped under the coverslip less than 1 x 1 x 0.1 mm^3 and the multiplication factor (10 000) would have magnified the error.

Some groups of students may also have made errors when counting the cells, or for cells on the edge of squares, been inconsistent as to whether to include these or not.

When looking at other groups' results, it was the 50°C results that varied most. When we made our count, there appeared to be a lot of what looked like dead cells or bits of cells. We did not include these, but I think that other groups might have included these in their counts. We could have added methylene blue to our haemacytometer. This will show up yeast cells that are dead (blue) and those that are living (colourless) to improve the validity of our results.

Also, the temperatures in the incubators and storeroom could have fluctuated. We could have set up a datalogger to see if these varied.

Review
My results, along with the results of other groups in the class and some of the OCR secondary data, increase my confidence in my hypothesis and prediction.

My hypothesis:
Changing the temperature will affect the rate of fermentation of yeast

I predict that as the temperature increases, the rate of fermentation will also increase.

As the temperature increases up to around 35°C, the numbers of yeast cells produced over a 10 day period increases, indicating that the rate of fermentation increases. The rate of fermentation was greatest between 30°C and 40°C. This agrees with the results from the other groups, showing that ours are reproducible, and also with the OCR secondary data [9]:

Here, the rate of fermentation is greatest at 40°C, as shown by the rate of carbon dioxide production. The secondary data also suggest that there is a doubling of fermentation rate every ten degrees between 10 and 30°C. I did not find this in my results, but when I did my research, I discovered that "a 10° temperature rise doubles reaction rates" is just a rule of thumb, not a law of nature [10]."

temperature in °C	mean rate of carbon dioxide production in cm^3/min
0	0.002
10	0.062
20	0.120
30	0.235
40	0.237
50	0.202

The secondary data also suggest that some fermentation takes place at 50°C. We found evidence of very little. Yeasts, as do most living things, grow more quickly as cell or body temperature increases, and have an optimum temperature of around 37°C, because this is the temperature at which their enzymes work best. I would expect that at temperatures higher than 50°C in yeast, the enzymes in yeast cells are denatured and the yeast dies. I think that all we could see was cell debris – this is dead yeast cells, but I think other groups counted these as living cells. The methylene blue test would help us to find out if they were dead or alive. At low temperature, molecular collisions are slower, so the enzymes used for respiration will not be working as quickly and the yeast will not grow and reproduce as quickly.

Theoretically, 37°C should be the best temperature for producing alcohol. Brewers do not use such a high temperature. Economically, it would also be too expensive, and at high temperatures, some of the alcohol would be converted into fruity chemicals called esters [10].

I could improve my investigation by monitoring yeast cell numbers over several days, and not just taking a count at the end. It is possible that the rate of fermentation is not constant over the ten day period. This is supported by some of the OCR secondary data [8].

time in hours	ethanol concentration in g/dm^3
0	0
6	5
12	22
24	44
48	42
72	41
96	41
120	40

Also, I used glucose in my investigation, and the OCR secondary data show that the rate of fermentation in yeast is different when the yeast is using different sugars. The data show that glucose produces the fastest rate of fermentation (0.100 cm^3 carbon dioxide per minute in the study), followed by fructose (0.091 cm^3 carbon dioxide per minute in the study), maltose (0.085 cm^3 carbon dioxide per minute in the study), then sucrose (0.080 cm^3 carbon dioxide per minute in the study). No fermentation is obtained with the sugar lactose or with starch. I could extend my investigation to see if my hypothesis is also true when yeast is using these other sugars for respiration.

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[4] Spilatro S.R. Yeast on the Rise: Investigative Study of Fermentation in the Introductory Biology Curriculum. http://www.cur.org/rl2000/pdf/ystferm.pdf

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[9] OCR. Factors that affect the rate of fermentation. Information for candidates [2]. 2011

[10] Senese F. Does a 10°C temperature rise double reaction rates? General Chemistry Online. http://antoine.frostburg.edu/chem/senese/101/kinetics/faq/temperature-and-reaction-rate.shtml. 2010.

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Commentary

Investigation Title - Fermentation

Strand/Aspect	Mark	Comments
S(a) - formulate a hypothesis or prediction	7	The candidate has used scientific knowledge to list relevant factors and to propose a testable hypothesis an quantitative prediction. However the factors are not fully considered and some are irrelevant. This section of the report is comprehensive and clear, with no significant errors in spelling, punctuation or grammar. Scientific terminology is used correctly; Criteria for 6 are fully met, but criteria for 8 only partially. 7 marks awarded
S(b) - design of techniques and choice of equipment	8	The equipment, procedure and range of data selected are all appropriate and choices justified. The data recorded is valid and precise. The risk assessment is complete with ways of reducing risk identified. 8 marks awarded
C - range and quality of primary data	7	The range of data collected is suitable to the task of testing the hypothesis. Repeats are carried out. The data is of high quality. Some checking is apparent in the repeats, but the outliers do not appear to have been checked and they are not dealt with appropriately (In this case they should be included in the averages). Not all raw data is recorded in the report. Criteria for 6 are fully met, but criteria for 8 only partially. 7 marks awarded
A - revealing patterns in data	8	The graph is correctly drawn with sensible axes and scales. the line of best fit is appropriate and the spread of data is clearly shown. 8 marks awarded
E(a) - evaluation of apparatus and procedures	6	Limitations to the procedure used are clearly identified and some suggestions are made. However there is little detail in the suggested improvements. No criteria for 7-8 met 6 marks awarded
E(b) - evaluation of primary data	7	Outliers are identified (although it is questionable whether these are truly outliers, acceptable at GCSE level) A correct attempt is made to explain the outliers in terms of random variation. The degree of scatter and general pattern are used to critically consider the evidence 8 marks awarded
R(a) - collection and use of secondary data	7	The extent to which secondary data supports the hypothesis is explained well, a possible problem with the secondary data from other groups is identified but there is no other consideration of the reliability of secondary sources. A full range of secondary sources is used, other groups, provided by OCR and Internet/textbook sources. Most of which are fully referenced. The criteria for 6 marks are fully met; however the criteria for 8 marks are not fully met. 7 marks awarded
R(b) - reviewing confidence in the hypothesis	7	The candidate has used relevant science to explain how the patterns shown in the data support the hypothesis. The suggestion concerning collecting extra data is limited and lacks detail. The report is comprehensive, logically sequenced with effective use of scientific terminology. The spelling punctuation and grammar are good. The criteria for 6 marks are fully met; however the criteria for 8 marks are not fully met. 7 marks awarded.
Total:	**57/64**	

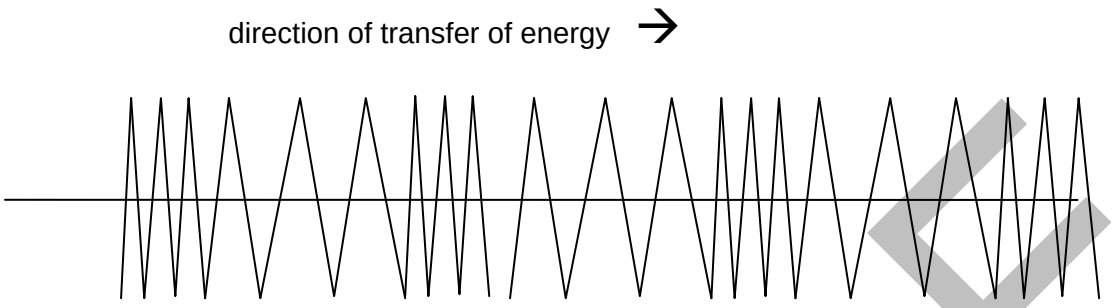
Candidate exemplar 2

Waves in water

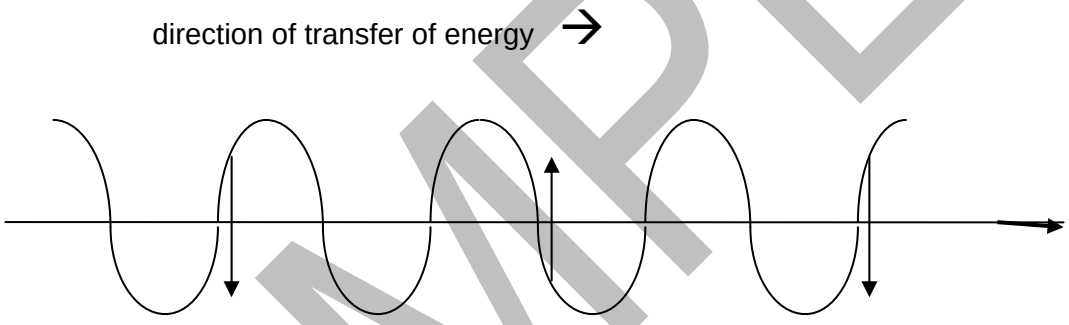
Waves in water

Waves are regular patterns of disturbances which transfer energy in the direction of travel without transferring matter. There are two types of waves, 'longitudinal' and 'transverse'.

In longitudinal waves, the movement is backwards and forwards along the direction of travel of the wave.



In transverse waves, the vibrations (displacements) are at right angles to the direction of travel of the wave –

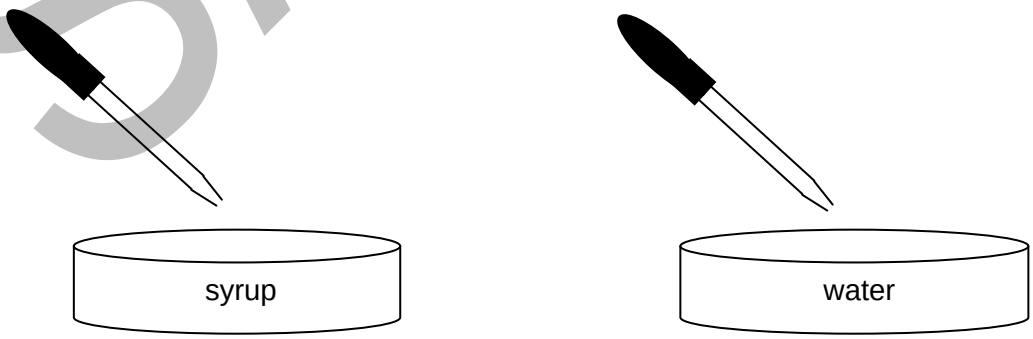


Waves in water are basically transverse waves, but not quite – the water particles move with a circular motion, and are also carried along very slightly in the direction of the wave.

I have been asked to study how fast the waves travel. First, I will consider what factors might affect this.

<u>The type of liquid</u>

Some liquids are thicker than others and this may have an effect. We tested this with some golden syrup.



We put syrup in one dish and water in another, then allowed one drop to fall into each dish. We watched very carefully to see which set of ripples spread across the dish fastest. We found that the waves in the syrup were much slower and died out almost at once. We also tried with mixtures of syrup and water and found that the runnier the liquid, the faster and further the ripples spread.

In most practical situations, it is waves in water that people want to know about, and syrup is messy to work with. We decided that we would work only with water. However, the viscosity of water is affected by changes in temperature, so we always used distilled water and we checked the temperature each day.

We had been told that waves moved more slowly in shallow water. This is why waves pile up and get bigger as they near the shore. We decided that we would test the effect of how deep the water is. The hypothesis I will test is: "Waves move more slowly in shallow water, because the 'drag' against the bottom slows them down."

The number of waves.

In a ripple tank, the waves are made by a rod which is bounced up and down by an electric motor. This makes a series of waves and it was too difficult to keep track of which one was which. We needed a single wave, but we found it was difficult to move a stick in a consistent way. However, we found that if we put the container on a firm flat surface, lifted one end slightly then let it drop, we got one single wave which ran across the surface.

Timing the waves

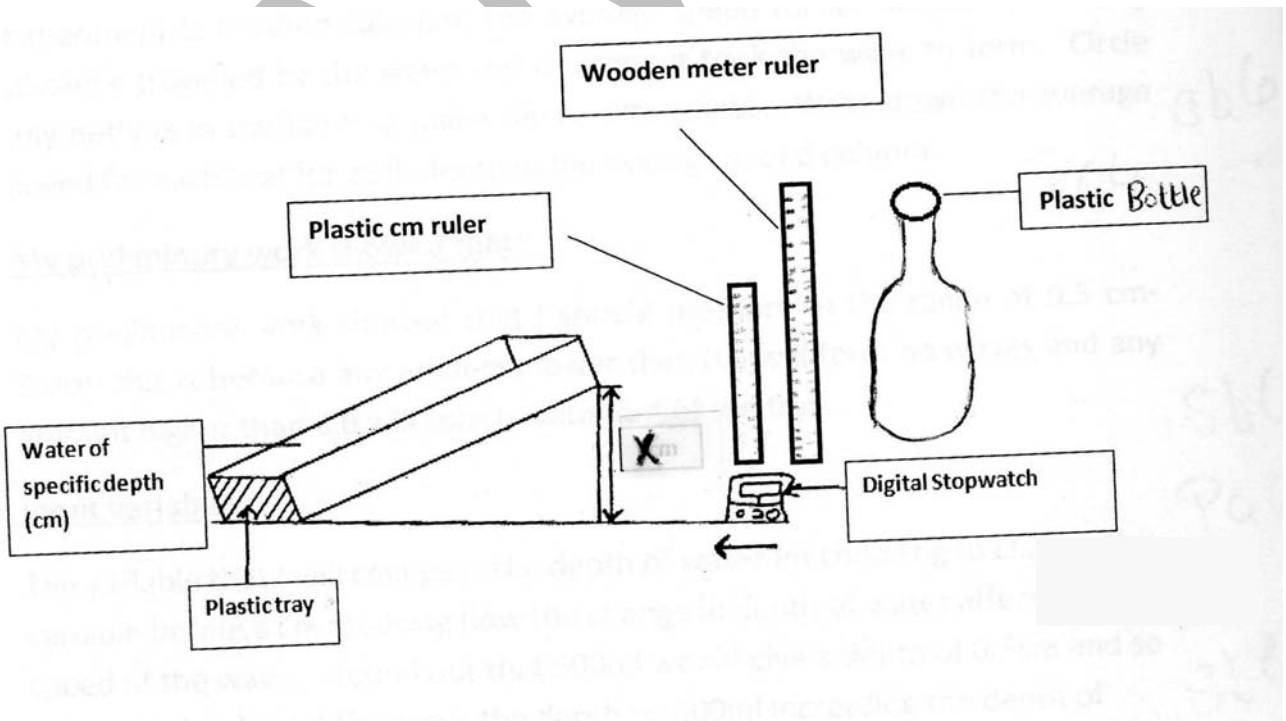
The biggest trough in our laboratory had diameter 50 cm. When we made a wave across it, the wave only took about 1 second to travel across. This was too quick to measure accurately.

We noticed that the wave bounced back from the other side of the trough, so we thought we could time it for several times across (like timing lots of swings with a pendulum). Because the wall of the trough was curved, the bounce-back wave got all jumbled up.

We decided to use the largest rectangular container we could find. This was a plastic toy tray, length 50 cm. width 35 cm, depth 20 cm.

Preliminary experiments.

We put about 5 cm depth of water in the toy-box and then tried dropping it from different heights.



The results that we got are on the next page.

Dropping from different heights

Height of end of box / cm	What happened
1	Wave faded after one length of box – too small
2	Wave too small
3	Wave lasted about 3 x up or down the box
4	Wave still going after 4 lengths
5	Wave OK
6	Other ripples formed as well
7	second wave formed – interfered after reflection
8	second wave formed

We decided that the best height for dropping the box was 5 cm.

How many 'wave bounces'?

The time for the wave to travel once along the box was too short to measure accurately. We let the wave bounce backwards and forwards from one end of the box to the other and counted how many lengths it went and measured the time. The water in the box was 5 cm deep for each try.

Number of lengths	1st try / seconds	2nd try / seconds	average / seconds	range as % of time
1	0.77	0.73	0.75	5%
2	1.48	1.53	1.505	3.3%
3	2.30	2.25	2.275	2.2%
4	3.00	3.08	3.04	2.7%
5	3.75	3.80	3.775	1.3%
6	4.60	4.45	4.525	3.3%
7	too many ripples – wave breaks up			

If we used more reflections, we could measure the time more accurately. However, the wave gets very weak. Each time it bounces it loses some energy. Also, each time some little ripples are formed and these begin to interfere with the wave and make it uneven or unstraight.

What my preliminary work showed

My preliminary work showed that I should use pure water and keep the temperature the same. I must use a box with straight sides and square corners, so that there would not be waves reflected at angles which break up the main wave. I then fill the toy box with water to the correct depth, then prop up one end to 5 cm. Then I carefully remove the blocks. I will measure for 5 lengths of the box.

Method for main experiment

Apparatus:

Plastic toy box (50 cm x 35 cm x 20 cm)
Large plastic bottle
metre ruler
2 x wood blocks, 5 cm thick
thermometer
digital stop clock.

- First set up all the apparatus on the classroom experiment bench.
- Collect enough water in the large bottle and measure the temperature.
- Pour water into the toy box until it is 1.0 cm deep.
- Lift one end of the box onto the two wooden blocks.
- Leave to settle until the water is still.
- Grip the rim of the box at the high end. Someone carefully pull away the blocks.
- Let the box drop. As it hits the table, start the clock.
- Count the wave up and down the box for 5 lengths, then stop the clock.
- Repeat until three readings agree.
- Add more water until the total depth is 2.0 cm.
- Repeat the measurements.
- Continue to add water 1.0 cm at a time and repeat.

If the box wasn't dropped absolutely level, we got a wobbly wave that bounced around and broke up. We had to wait for the water to settle then repeat. We only recorded the times when we got a good, straight wave.

Once the experiments are over, calculate the average speed for each depth of water.

Results

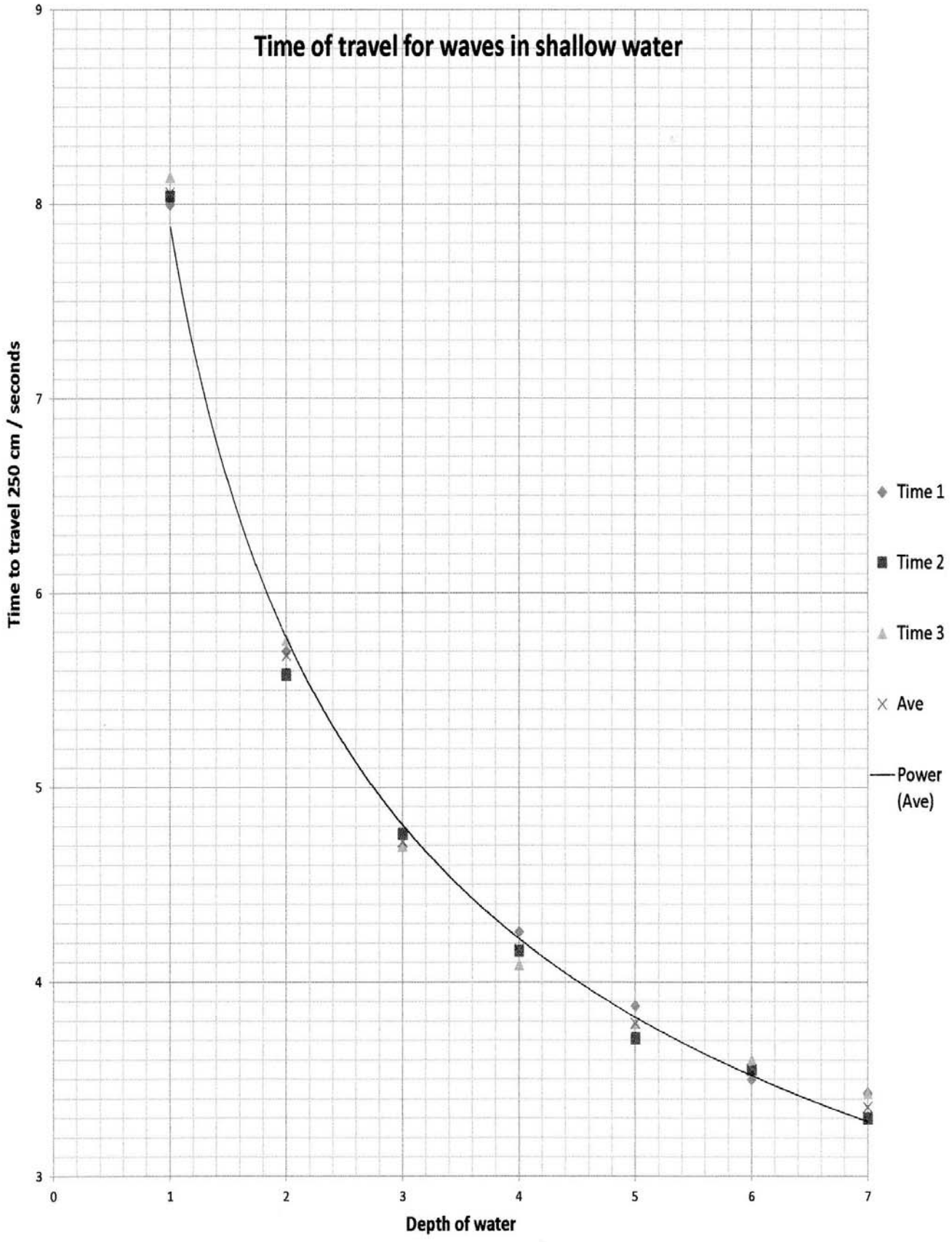
Temperature of the water 17^{o}C

Length of tray = 50 cm

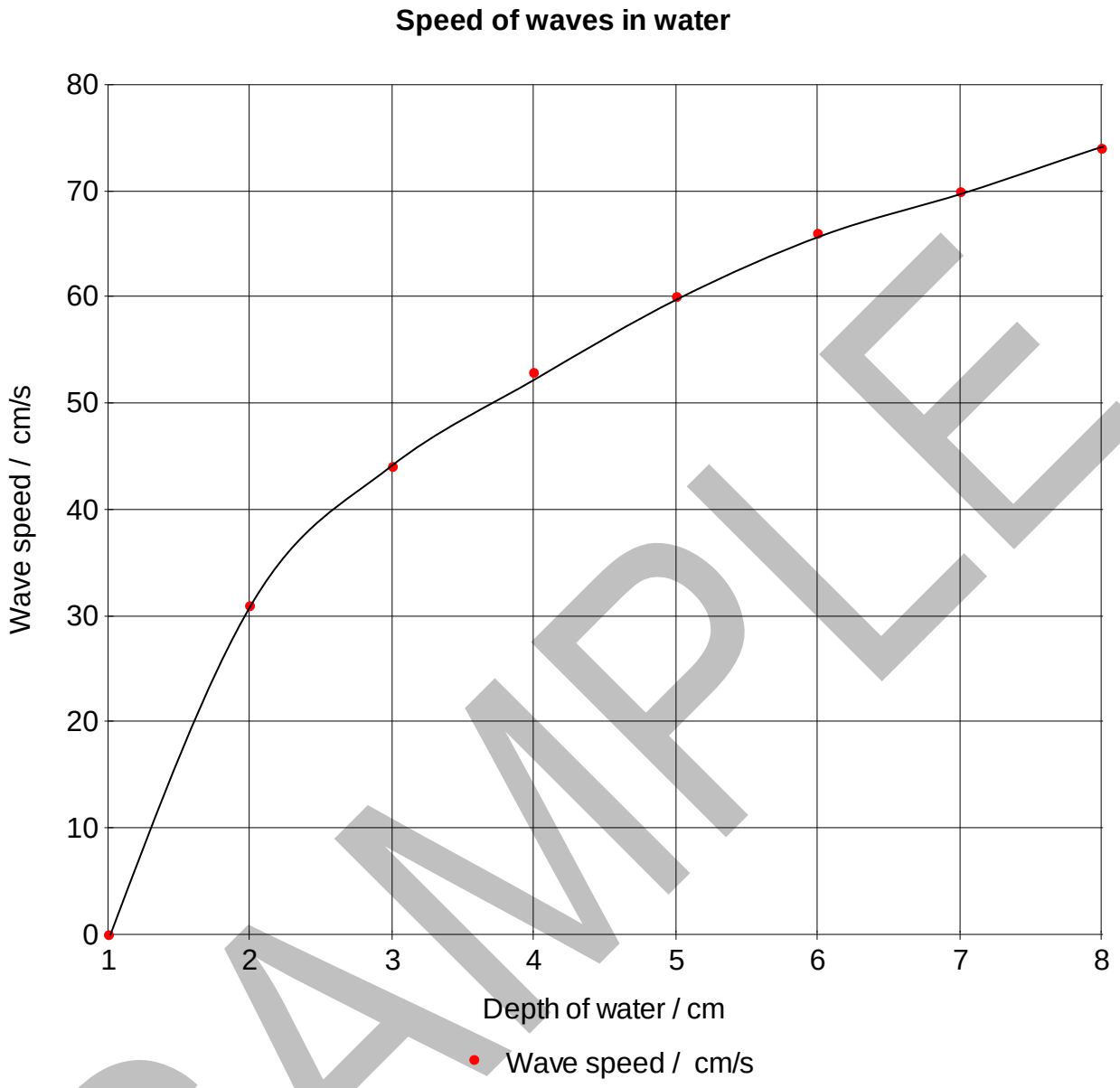
Total distance travelled by the wave = 5 x 50cm = 250 cm

Depth of water / cm	Time taken to travel 250 cm / seconds				Average speed cm/s
	1st attempt	2nd attempt	3rd attempt	Average	
1	8.00	8.04	8.14	8.06	31.0
2	5.70	5.58	5.76	5.68	44.0
3	4.70	4.76	4.70	4.72	53.0
4	4.26	4.16	4.09	4.17	59.9
5	3.88	3.71	3.79	3.79	66.0
6	3.50	3.55	3.60	3.55	70.4
7	3.43	3.30	3.43	3.36	74.4

See graph 1


Time of travel for waves in shallow water
Time to travel 250 cm / seconds
Depth of water
9
8
7
6
5
4
3
0
1
2
3
4
5
6
7
Time 1
Time 2
Time 3
Ave
Power (Ave)

Graph 2



Conclusion:

Graph 2 shows clearly that as the water gets less deep, the wave moves more slowly. Waves approaching the shore slow down as the water becomes shallower. Because of this, the water piles up and the waves become bigger. If they are big enough, they may tip over ("break") because the top of the water is moving fastest.

This is not a straight line relationship. At first the slope is steep. As the water begins to get deeper, the wave rapidly gets faster. However, the line becomes less steep and it looks as if there would finally be a limit where the wave has reached its maximum speed.

A graph of $y = c\sqrt{x}$ has a shape that looks rather like this one in graph 2,
where
y = wavespeed

c = a constant

x = depth of water so $\sqrt{x}$ is the square root of the depth

I tried out some of the numbers and this seems to nearly fit, with c = 30

for c = 30

Depth of water / cm	Square root of depth	calculation		observed speed
1	1.00	1 x 30 =	30	31
2	1.41	1.41 x 30 =	42.3	44
3	1.73	1.73 x 30 =	51.9	53
4	2.00	2.00 x 30 =	60	59.9
5	2.24	2.24 x30 =	67.2	66
6	2.45	2.45 x 30 =	73.5	70.4
7	2.65	2.65 x 30 =	79.5	74.4

This is not quite perfect, but it is quite a good fit. I can therefore suggest that the relationship between water depth and wavespeed depends on the square root of the water depth.

The slowing down may be because the shallow depth restricts the movement of the water molecules as the wave passes over, but I can't explain the exact shape of the graph.

Evaluation

Safety

There are no dangerous chemicals in this experiment. The box full of water is heavy. It should be gripped by the top rim and carefully released to avoid any risk of fingers underneath. It must also be dropped level, or the wave does not go straight and more waves may also be made. Be careful that water does not spill out and mop up any spills.

Method

It was difficult to drop the box cleanly and level. There were a lot of times when we didn't get a good clear wave, so we did not record any result for these. So for each height, we kept on doing it until we had three results that worked.

The depth of water was only measured with the end of a metre ruler and this is not very accurate. Afterwards we thought that we knew the area of the box (50 x 35 = 1750 cm^2) so we could have used measuring cylinders to put 1750 cm^3 of water into the box for each depth and this would have been a much better method.

We had to start and stop the stop clock by eye and this involves a reaction time error. I practiced starting and stopping it and found that I could do this in 0.2 seconds, so there may be this much error in the times. It was also difficult to decide exactly when the wave was formed and began to move. We tried to start as the box hit the table top. On the other hand, I did all the timing so that errors should be consistent and I could prepare for each start or stop because I knew when the box would drop and I could watch the wave approaching the end. I think we did the best we could for hand timing, and this is shown by the fact that the biggest range in any set of 3 results is only 0.18 seconds.

I am not sure that bouncing the wave off the ends of the box gives the same answer you would have for a single straight journey. It would be better to use a much longer trough and do a single straight run. However, we didn't have one. It would also have meant finding a different way to make a single wave, since we couldn't have dropped a very long trough.

Data

Graph 1 shows all of the results. All the repeat values are very close together (range 0.18 seconds or less) because we didn't record the results when we didn't get a single, straight-running wave. The points form a smooth curve and all lie on the curve. We have a range of 7 different depths which is enough to show the shape of the curve and that it isn't a straight line. I am confident that they are correct and consistent for the method we used.

To improve the investigation, we could work in a much larger pool, or continue up to greater depths to see whether the slope does actually flatten out to a steady final speed.

As I repeated the experiment three times for each depth it suggests a high level of accuracy and reliability in my results because it is very important for measurements to be repeated as if you look at only one value you cannot tell if it is reliable, however if you look at lots of measurements any errors will stand out.

Research for secondary data

Because I couldn't really explain my results properly, I searched on the internet to find information about "the speed of water waves". I took information from three different sites, and full references are at the end of this report.

Ref [1]:

The velocity of idealized traveling waves on the ocean is wavelength dependent and for shallow enough depths, it also depends upon the depth of the water. The wave speed is

$$v = \sqrt{\frac{g\lambda}{2\pi}\tanh\left(2\pi\frac{d}{\lambda}\right)}$$

λ = wavelength
d = depth
g = acceleration of gravity

In deep water, the hyperbolic tangent in the expression approaches 1, so the first term in the square root determines the deep water speed. The limits on the tanh function are

$\tanh x \approx 1$ for large x
$\tanh x \approx x$ for small x

so the limiting cases for the velocity expression are

$$v \approx \sqrt{\frac{g\lambda}{2\pi}} \quad \text{for deep water, } d > \frac{\lambda}{2}$$

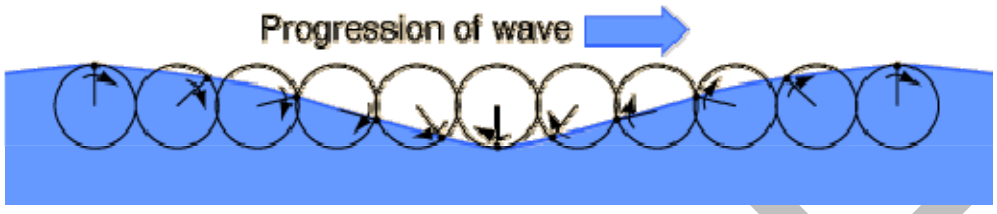
$$v \approx \sqrt{gd} \quad \text{for shallow water, } d < \frac{\lambda}{20}$$

This matches my results because it shows that in shallow water the speed of the wave is proportional to the square root of the depth of the water. This gives me greatly increased confidence that my results do show the right pattern.

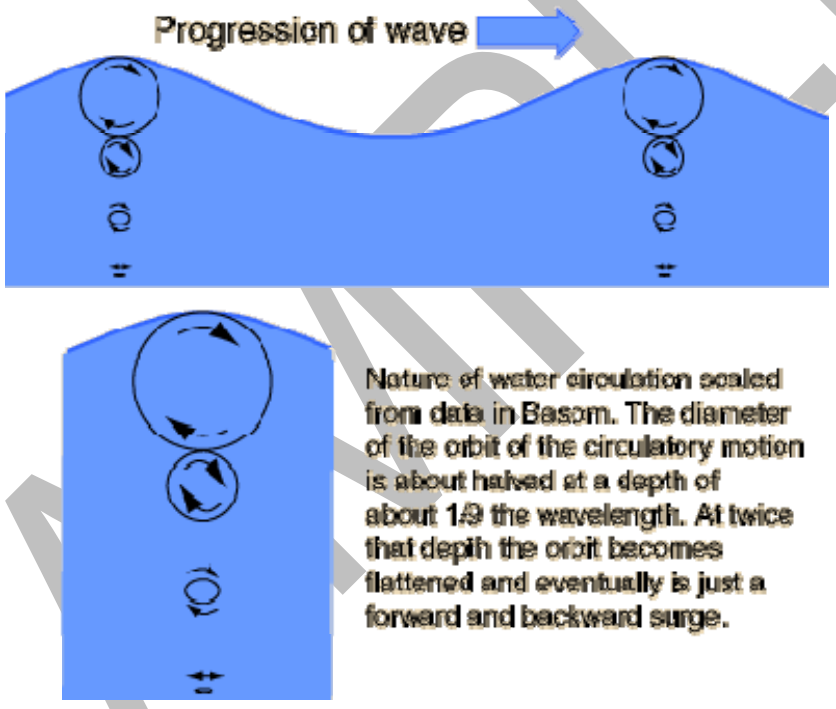
Except for very shallow water, the speed also depends on the wavelength of the waves.

Ref [1]

The motion of the water is forward as the peak of the wave passes, but backward as the trough of the wave passes, arriving again at the same position when the next peak arrives. (Actually, experiments show a slight advance of the water with the waves, but that advance is small compared to the overall circular motion.)



The illustration above, adapted from von Arx, shows the direction of the water motion at different points along the wave.



The circles summarize the total motion of the medium when a full wavelength passes. It was common practice to inject droplets of oil which were whitened with zinc oxide and adjusted to have the same density as the water. The orbits could then be traced out on the sides of the wavetank. It was found that there was a small progression of the orbits in the direction of the wave propagation.

This shows how the water moves as waves pass over the sea. The motion has an effect even down to quite a deep depth, which explains how it might be affected by the water getting shallower.

Ref [2]

Real waves do not travel as perfect sine waves, they travel as sets of waves, sometimes multiple sets of waves overlap and add together. Let me show you a drawing of one possible simple set of six waves.

A set of six waves.

If you watch such a set moving out from the wake of a boat for example you'll see something interesting. The set of waves moves. Imagine that the set of wave shown above is moving to the right. But the individual wave crests that make up the set move within the set. If you watch real waves closely you will see that a wave is born at the back side of the set, on the left, and then moves to the right twice as fast as the whole set is moving. It grows in amplitude until it reaches the middle of the above set, then it continues to the right shrinking in amplitude and disappearing at the front end of the set.

There are thus two velocities of travel associated with a deep water wave, the velocity of an individual peak, called the phase velocity, Cp, and the velocity of sets of waves called the group velocity, Cg. In theory, for deep water waves the phase velocity is exactly twice the group velocity.

All the stuff I found about waves was really about complete patterns of waves over the sea, but in our experiments we made just one single wave, so perhaps our results would not behave in exactly the same way.

Ref [3]

In words why this is the case -- for a shallow fluid, the motion of the fluid is mostly side-to-side, and in order to accumulate more fluid in one place (to make the crest of the wave), each little bit of fluid must travel a little farther than it would have to in deeper water. When a wave passes, the bits of fluid, if you could watch one at a time, travel in ellipses. For shallow water, the ellipses are stretched out horizontally, and in very deep water, they are very nearly circular. So for a wave of the same height (top to bottom of the ellipse), the bits of water must travel farther in the shallow tray than the deep tray. Because the waves of the same height in shallow and deep water exert the same pressure differences due to gravity to get the water moving (although the motion is different due to the fact that the bottom is there), similar forces push and pull on the water. To get the water moving farther and faster with the same force takes a longer time for each push, and hence a slower speed for the wave, in the shallow water.

Note: this speed formula assumes that the waves are small -- for waves whose heights are comparable to the depth of the tray, you will get even more complicated behaviour -- the most spectacular of these is the formation of "breakers" where the waves will curl over and crash as they do on beaches.

Final conclusion:

I can now conclude quite confidently that the speed of a water wave in shallow water is directly proportional to the square root of the water depth. This is the formula given on several academic web-sites and agrees with the pattern of my experiment results.

In my shallow box, where the water is at a constant depth, our waves lose energy by becoming smaller. We could see that this was happening because it got harder to be certain where the top of the wave was

as it moved backwards and forwards. But it kept going at the same speed, and I think this is the most interesting thing of all about the experiments.

The numbers that we got for the speed didn't exactly match the ones calculated from the formula. We did our measurements in a quite narrow box, so the sides may have an effect on the way the wave moves. We also used just a single wave, not a set of waves. Web site [1] also points out some other facts about 'real' waves –

> While this wave speed calculation may be a good approximation of the experimental wave speed, it cannot be depended upon as a precise description of the speed. It presumes an ideal fluid, level bottom, idealized waveshape, etc. It is also the speed of a progressive wave with respect to the liquid and therefore does not include any current speed of the water. In technical literature, this speed with respect to the liquid is called the "celerity" of the wave.

While I was looking for this information, I also found information about how tsunamis are formed and why they travel so fast and get so big as they reach the shore. I also found out how the shape of a beach fixes what sort of surf will be formed and why it can be very difficult to escape from surf because of the undertow of water back from the beach as the waves break.

References:

[1] http://hyperphysics.phy-astr.gsu.edu/hbase/watwav.html

HyperPhysics (©C.R. Nave, 2010) is a continually developing base of instructional material in physics. It is not freeware or shareware. It must not be copied or mirrored without authorization.

Carl R. (Rod) Nave, Department of Physics and Astronomy, Georgia State University

[2] **http://www.exo.net/~pauld/activities/waves/waterwavespeed.html**

[3] http://van.physics.illinois.edu/qa/listing.php?id=2223

Physics Questions? Ask the Van

Department of Physics, University of Illinois, Urbana-Champagne

Commentary

Investigation Title - **Waves in Water**

Strand/Aspect	Mark	Comments
S(a) - formulate a hypothesis or prediction	6	Some factors that may affect the speed of a wave are considered and one factor selected. Some knowledge of waves is used to develop a hypothesis although the hypothesis does not lead to a quantified prediction. There is correct use of some specialist terms and the work is well organised with no significant errors in spelling, punctuation or grammar. Clearly meets 5-6 criteria, but the lack of a quantitative prediction and any consideration of wavelength or frequency means the 7-8 criteria are not met. 6 marks awarded.
S(b) - design of techniques and choice of equipment	5	Basic equipment of plastic tray, meter ruler and stopwatch used and shape of tray and choice of water as the most appropriate liquid decided from preliminary work. But little explanation of the range of depths chosen. Some risks identified and vague precautions suggested. Just meets 5-6 marking criteria but 5 marks only.
C - range and quality of primary data	7	The selected range of depths of water in the tray appear appropriate to give suitable differences in times /speeds. Regular repeat measurements are taken for each depth. From inspection of the graph the date are of good quality and the preliminary work was used to inform the main experiment in the choice of liquid to use, the shape of the tray, the drop height and the number of 'wave bounces' Meets 7-8 criteria but The preliminary work was not used to establish the best range of depths so 7 marks.
A - revealing patterns in data	7	For graph 1 the points are correctly plotted, the axes suitably scaled and labelled (although missing units on x-axis), good line of best fit and all data plotted including repeats and averages. Graph 2 has a scaling error on the x-axis. Meets 7-8 criteria, but careless errors suggest 7 marks more appropriate
E(a) - evaluation of apparatus and procedures	6	Describes how the data was collected and identifies problems in measuring the depth of water accurately, timing errors in the use of the stopwatch and the limitations of the 'bouncing wave' technique in a small trough. The problem of dropping the box in a more consistent method is not referred to. Suggests improvements to measure volume rather than depth of water with measuring cylinders but suggestions to produce a more consistent single wave are not described. Fully meets the criteria at 5-6, 6 marks awarded.
E(b) - evaluation of primary data	6	The reproducibility of repeat measurements is very good but the candidate does acknowledge that 'we didn't record the results when we didn't get a single, straight-running wave' so potential anomalies are implicitly recognised, explained and eliminated at this stage. Suitable comments about reliability and accuracy of the data collected are made. On the border between 5-6 criteria and 7-8 criteria, but the lack of specific reference to outliers means 6 marks is more appropriate, as the outliers are only accounted for by implication.
R(a) - collection and use of secondary data	6	The candidate has provided three pieces of secondary data. all of which are relevant to the investigation. The sources are well referenced, but of limited variety. There is discussion of the extant to which the secondary data agrees with the primary data. However little comment on the importance of similarities and differences. Criteria for 5-6 are full met, Hence 6 marks awarded.
R(b) - reviewing confidence in the hypothesis	7	Considers the primary data fit to the original hypothesis. The hypothesis is revised to link wave speed to the square root of depth. Additional data to be collected related to the hypothesis is suggested, but little detail is given. The report is logically sequenced, uses scientific terminology with few grammatical errors. Just meets 7-8 criteria. 7 marks awarded
Total:	**50**	

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TWENTY FIRST CENTURY SCIENCE

ADDITIONAL SCIENCE A **A154**
Unit A154: (Controlled assessment)

BIOLOGY A **A164**
Unit A164: (Controlled assessment)

Factors that affect the rate of fermentation

Information for Candidates (1)

To be issued to candidates at the start of the task.

Information for candidates

You are going to carry out an investigation on a factor that affects the rate of fermentation in yeast.

Background

The world production of ethanol is around 70 billion litres per year. Alcohol is important as a fuel, in alcohol beverages and as a feedstock for the chemical industry. By far the biggest use of alcohol is as a fuel.

Only around 5% of the ethanol produced is produced synthetically. The rest is produced by a biological process – fermentation. The main organism used to produce ethanol is a species of yeast called *Saccharomyces cerevisiae*. In the absence of oxygen, yeast respires anaerobically. It ferments various sugars to produce ethanol and carbon dioxide.

You will choose a factor and investigate this factor's effect on the rate of fermentation of yeast.

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TWENTY FIRST CENTURY SCIENCE

ADDITIONAL SCIENCE A **A154**

Unit A154: (Controlled Assessment)

BIOLOGY A **A164**

Unit A164: (Controlled Assessment)

Factors that affect the rate of fermentation

Information for Candidates (2)

- To be issued to candidates **only** on completeion of the data collection part of their Practical Investigation.
- Your quality of written communication will be assessed.
- The total number of marks for this Controlled Assessment task is **64**.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

Assessment evidence produced that does not reflect the relevant examination series will not be accepted.

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DC (AC/SW) 49106/3

This secondary data can be used as part of your practical investigation.

You can select the data that is useful for you.

Many breweries around the world are experimenting with the production of high ethanol beers.

Researchers in a Canadian brewery have been investigating fermentation in a strain of yeast, *Saccharomyces cerevisiae*, Strain 3001. When grown in a 10% glucose solution at 30°C, the researchers obtained the following results.

Time in hours	ethanol concentration in g/dm^3
0	0
6	5
12	22
24	44
48	42
72	41
96	41
120	40

In a follow-up study, they investigated the ethanol production using the same type of yeast, grown in different concentrations of glucose solution at 30°C.

Some of their results are shown below.

Time in hours	ethanol concentration in g/dm^3			
	10% glucose solution	20% glucose solution	30% glucose solution	40% glucose solution
0	0	0	0	0
6	5	4	2	0
12	22	17	7	5
24	44	48	34	22
48	42	52	67	37
72	41	54	83	42
96	41	53	84	42
120	40	51	85	41

Other researchers have been investigating the rate of yeast fermentation using different types of carbohydrate. Their results are shown below.

type of carbohydrate	mean rate of carbon dioxide production in cm^3 / min
fructose	0.091
glucose	0.100
lactose	0.000
maltose	0.085
starch	0.000
sucrose	0.080

In a follow-up investigation on the fermentation of glucose, the following results were obtained.

% glucose concentration	mean rate of carbon dioxide production in cm^3 / min
0	0.002
1	0.005
2	0.069
3	0.120
4	0.122
5	0.122

In a further investigation on the effect of temperature on the fermentation of glucose, the following results were obtained.

temperature in °C	mean rate of carbon dioxide production in cm^3 / min
0	0.002
10	0.062
20	0.120
30	0.235
40	0.237
50	0.202

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ADDITIONAL SCIENCE A **A154**

Unit A154: (Controlled assessment)

BIOLOGY A **A164**

Unit A164: (Controlled assessment)

Factors that affect the rate of fermentation

Information for teachers

This assessment will be changed every year. Please check on OCR Interchange that you have the Controlled Assessment material valid for the appropriate assessment session.

- This document is confidential to teachers and must not be released to candidates.
- For details of the level of control required for this assessment refer to Section 5 of the specifications.
- There are two documents provided for candidates for this Controlled Assessment task:
  Information for candidates (1) defines the topic of the investigation and places it into a relevant context. This should be issued to candidates at the start of the task.
  Information for candidates (2) provides some secondary data to supplement that which candidates collect for themselves. It should be issued to candidates only on completion of the data collection part of their investigation.
- The total number of marks for this Controlled Assessment task is **64**.
- Internally assessed marks **must** be submitted by 15 May.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

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DC (AC/SW) 49106/3

Turn over

Information for teachers

Specimen controlled assessment task:
Investigating a factor that affects the rate of fermentation of yeast

Each candidate for Controlled Assessment in the June 201# examination series must present marks for one of the Practical Investigation tasks that is appropriate to the applicable specification. All internally assessed marks must be submitted by 15 May.

The marked work of all candidates must be retained by the centre. Some of the work will be required for moderation.

General guidance for teachers

These notes provide background information for the preparation of candidates for this task and advice on the assessment of the practical investigation report.

Reference should also be made to Section 5 of the specification for Additional Science A or Biology A and the '*Guide for controlled assessment for GCSE Twenty First Century Science*'.

Task setting is under high control. Tasks are therefore set by OCR. Where appropriate, this task may be contextualised by individual centres to take account of local circumstances including availability of resources and the needs of candidates. However, assessments must be based on the published marking criteria (within Section 5 of the specifications). If there is any doubt about whether a contextualised task sufficiently matches the criteria, centres should seek confirmation from OCR that the task is still valid.

Preparation of candidates

It is expected that before candidates attempt this controlled assessment task they will have received general preparation in their lessons. Learning activities to develop the relevant skills should have been provided and the broad requirements of the assessment made clear to candidates.

More specific details of practical techniques, the development of skills associated with these techniques, and possible methods and choice of equipment for the task should be covered when teaching the relevant part(s) of the specification, and must be completed prior to setting the task.

From their work for 'Module B4: The processes of life', candidates should be familiar with the principles of enzyme action and a range of possible approaches for measuring the rate of fermentation, including the rate of production of ethanol or carbon dioxide. Measuring changes in yeast cell counts or yeast cell mass may also yield relevant data.

Assessment of the quality of written communication (QWC)

The quality of written communication is assessed in Strands S and R of this controlled assessment task. Candidates should be advised that the quality of written communication will be assessed. Further information about the assessment of QWC may be found in the specification.

Risk assessment

It is the centre's responsibility to ensure the safety of all candidates. Teachers are responsible for making their own risk assessment for the task prior to candidates attempting the practical work and for ensuring that appropriate health and safety procedures are carried out. However, teachers must not provide candidates with a risk assessment since this is included in the marking criteria for Strand Sb. If candidates require additional guidance on managing safety once the task has started then this will need to be reflected in the marks awarded.

Guidance on assessment

All assessment of the practical investigation is based on the final report submitted by the candidates.

The marking procedure and marking criteria are described in detail within Section 5 of the specifications. Marking decisions should be recorded on the respective cover sheets (available to download from www.ocr.org,uk and included in the '*Guide for controlled assessment for GCSE Twenty First Century Science*'). Candidates' reports should be annotated to show how marks have been awarded in relation to the marking criteria.

Additional guidance on marking criteria

Detailed guidance on applying the marking criteria will be found in the *Guide for Controlled Assessment for GCSE Twenty First Century Science.*

The following additional brief notes provide some clarification of what may be expected from candidates in some strands. However, all marking decisions must be consistent with the marking criteria.

Strand S

Reference should be made to the appropriate science in Module B4: The processes of life.

Quality of written communication is assessed in this strand.

Strand R

Reference should be made to the appropriate science in Module B4: The processes of life.

Quality of written communication is assessed in this strand.

Guidance for technicians and teachers

Specimen controlled assessment task:
Investigating a factor that affects the rate of fermentation of yeast

Candidates plan their own investigations and may therefore require access to other apparatus at the discretion of the centre.

Teachers are advised to check that the range of apparatus provided will enable candidates to plan and carry out appropriate experiments to collect valid data.

Suggested equipment

All investigations:

Yeast suspension, 5% in water

Solid sugars, or 5% solutions (e.g. glucose, fructose, lactose, maltose and sucrose)

Starch solution (1%)

Fermentation vessel or equivalent (e.g. conical flasks)

Water baths at appropriate temperatures

Buffer solutions across range of pH values

Bubble counts or volume of carbon dioxide:

Conical flasks or boiling tubes with side arm

Delivery tubes

Boiling tubes

Gas syringes

Measuring cylinders

Syringes (5 cm3)

Graduated pipettes (1 cm3)

Rubber tubing

Cell counts:

Haemocytometers

Microscopes

Pasteur pipettes

Dilutions:

Volumetric flasks (10 cm3 or 100 cm3)

Pipettes (1 cm3 or 10 cm^3)

Data-logging:

Pressure sensors and data-logging equipment

Fermentation vessel with airtight lid

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TWENTY FIRST CENTURY SCIENCE

CHEMISTRY A **A174**

Unit A174: (Controlled Assessment)

Factors that affect how calcium carbonate is dissolved by acid

Information for Candidates (1)

This assessment will be changed every year. Please check on OCR Interchange that you have the Controlled Assessment material valid for the appropriate assessment session.

- To be issued to candidates at the start of the task.
- Your quality of written communication will be assessed.
- The total number of marks for this Controlled Assessment task is **64**.
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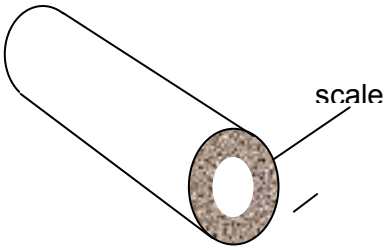
Released: June 201#
DC (AC/SW) 49106/3

Information for candidates

You are going to carry out an investigation on a factor that affect how calcium carbonate is dissolved by acid.

Background

In many parts of Britain, our water supply has small amounts of calcium hydrogencarbonate dissolved in it. When the water is heated, for example in kettles or boilers, the heat turns calcium hydrogencarbonate into calcium carbonate, which sticks to the insides of kettles, boilers and hot water pipes, forming 'hard water scale' that blocks up the spout or pipe.



Hot water pipes can become almost completely blocked by calcium carbonate.

The scale can be removed by using acid, which dissolves it.

For example:

calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water

(insoluble) (soluble)

This reaction with acid has been used for many years to remove calcium carbonate deposits, both in the home and on an industrial level.

You will choose a factor and investigate this factor's effect on how calcium carbonate is dissolved by acid.

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GENERAL CERTIFICATE OF SECONDARY EDUCATION

TWENTY FIRST CENTURY SCIENCE

CHEMISTRY A **A174**

Unit A174: (Controlled Assessment)

Factors that affect how calcium carbonate is dissolved by acid

Information for Candidates (2)

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Released: June 201#
DC (AC/SW) 49106/3

This secondary data can be used as part of your practical investigation.

You can select the data that is useful for you.

Hydrochloric acid does remove 'fur' from kettles very quickly, but it also corrodes metals and can be hazardous to use.

Researchers tested the effectiveness of some organic acids in limescale removal. Organic acids are safer to handle, and considered more 'friendly' to the environment.

In one investigation, they immersed a block of marble in different concentrations of each acid for 15 minutes. The mass of the marble was measured and the percentage decrease in mass calculated.

Some of their results are shown below.

% concentration of acid	% decrease in mass of marble after 15 minutes		
	citric acid solution	glycolic acid solution	lactic acid solution
1	0.21		
2	0.30	0.43	0.29
3	0.41	0.40	0.48
4	0.48	0.35	0.80
5	0.55	0.30	0.89
6	0.60	0.30	1.05
7	0.64	0.30	1.17
8	0.69	0.30	1.28
9	0.75	0.29	1.45
10	0.82	0.29	1.58

Research was also carried out at different temperatures, using 10% solutions of each acid.

Some of the results are shown below.

temperature in °C	% decrease in mass of marble after 15 minutes			
	citric acid solution	ethanoic acid solution	glycolic acid solution	lactic acid solution
20	0.8	2.0	0.4	1.8
25	1.2	2.1	0.6	3.0
30	1.5	2.0	0.8	4.3
35	1.7	2.4	1.1	5.5
40	2.0	2.7	1.6	6.6
45	2.1	3.3	2.1	7.3
50	2.4	3.7	2.6	7.9

The research team also investigated the corrosive action of different acids. Pieces of brass were immersed for 72 hours in 10% solutions of each acid.

Their results are shown below.

acid	corrosive action in arbitrary units
citric acid	1.2
ethanoic acid	4.3
lactic acid	1.0
phosphoric acid	2.8
sulfamic acid	2.9

The effectiveness of acids used to remove limescale is dependent on several factors.

Hydrogen ion concentration is very important. The greater the concentration of hydrogen ions in the acid solution, the faster the reaction will be between the acid and the limescale.

As an acid reacts with calcium carbonate, the formation of the calcium salt of the acid is also important. Calcium salts that are insoluble in water may coat the calcium carbonate particles that make up the limescale. The reaction between acid and limescale will then be slowed down.

The solubilities of different calcium salts are shown below.

	solubility in g per 100 g of water at 25°C
calcium citrate	0.10
calcium chloride	75
calcium ethanoate	40
calcium glycolate	1.8
calcium lactate	9
calcium dihydrogen phosphate	2
calcium hydrogen phosphate	0.02
calcium phosphate	0.02

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TWENTY FIRST CENTURY SCIENCE

CHEMISTRY A **A174**

Unit A174: (Controlled Assessment)

Factors that affect how calcium carbonate is dissolved by acid

Information for teachers

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- Your quality of written communication will be assessed.
- The total number of marks for this Controlled Assessment task is **64**.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

Assessment evidence produced that does not reflect the relevant examination series will not be accepted.

Released: June 201#
DC (AC/SW) 49106/3

Information for teachers

Specimen controlled assessment task:

An investigation on a factor that affect how calcium carbonate is dissolved by acid.

Each candidate for Controlled Assessment in the June 201# examination series must present marks for one of the Practical Investigation tasks that is appropriate to the applicable specification. All internally assessed marks must be submitted by 15 May.

The marked work of all candidates must be retained by the centre. Some of the work will be required for moderation.

General guidance for teachers

These notes provide background information for the preparation of candidates for this task and advice on the assessment of the practical investigation report.

Reference should also be made to Section 5 of the specification for Chemistry A and the '*Guide for controlled assessment for GCSE Twenty First Century Science*'.

Task setting is under high control. Tasks are therefore set by OCR. Where appropriate, this task may be contextualised by individual centres to take account of local circumstances including availability of resources and the needs of candidates. However, assessments must be based on the published marking criteria (within Section 5 of the specification). If there is any doubt about whether a contextualised task sufficiently matches the criteria, centres should seek confirmation from OCR that the task is valid.

Preparation of candidates

It is expected that before candidates attempt a Controlled Assessment task they will have received general preparation in their lessons. Learning activities to develop the relevant skills should have been provided and the broad requirements of the assessment made clear to candidates.

More specific details of practical techniques, the development of skills associated with these techniques, and possible methods and choice of equipment for the task should be covered when teaching the relevant part(s) of the specifications, and must be completed prior to setting the task.

From their work for Module C3: Chemicals in our lives – risks and benefits and Module C6: Chemical synthesis, candidates should be familiar with the reaction of acids with carbonates, properties of strong and weak acids, and the principles of reaction rates.

Assessment of the quality of written communication (QWC)

The quality of written communication is assessed in Strands S and R of this controlled assessment task. Candidates should be advised that the quality of written communication will be assessed. Further information about the assessment of QWC may be found in the specification.

Risk assessment

It is the centre's responsibility to ensure the safety of all candidates. Teachers are responsible for making their own risk assessment for the task prior to candidates attempting the practical work and for ensuring that appropriate health and safety procedures are carried out. However, teachers must not provide candidates with a risk assessment since this is included in the marking criteria for Strand Sb. If candidates require additional guidance on managing safety once the task has started then this will need to be reflected in the marks awarded.

Guidance on assessment

All assessment of the practical investigation is based on the final report submitted by the candidates.

The marking procedure and marking criteria are described in detail within Section 5 of the Chemistry specification. Marking decisions should be recorded on the respective cover sheets (available to download from www.ocr.org.uk and included in the '*Guide for controlled assessment for GCSE Twenty First Century Science*'). Candidates' reports should be annotated to show how marks have been awarded in relation to the marking criteria.

Additional guidance on marking criteria

Detailed guidance on applying the marking criteria will be found in the *Guide for Controlled Assessment for GCSE Twenty First Century Science.*

The following additional brief notes provide some clarification of what may be expected from candidates in some strands. However, all marking decisions must be consistent with the marking criteria.

Strand S

Reference should be made to the appropriate science in Module C3: Chemicals in our lives – risks and benefits and Module C6: Chemical synthesis.

Quality of written communication is assessed in this strand.

Strand R

Reference should be made to the appropriate science in Module C3: Chemicals in our lives – risks and benefits and Module C6: Chemical synthesis.

Quality of written communication is assessed in this strand.

Guidance for technicians and teachers

An investigation on a factor that affect how calcium carbonate is dissolved by acid

Candidates plan their own investigations and may therefore require access to other apparatus at the discretion of the centre.

Teachers are advised to check that the range of apparatus provided will enable candidates to plan and carry out appropriate experiments to collect valid data.

Apparatus Suggested

Dilute acids (See note 1)

Marble chippings (See note 2)

Top pan balances

Stop clocks or watches

Measuring cylinders (10 cm^3, 25 cm^3 and/or 50 cm^3)

Beakers or large test-tubes or conical flasks (various sizes)

Cotton wool (see note 1)

Filter papers (see note 2**)**

Bungs with delivery tubes (various shapes) to fit conical flasks

Small troughs or dishes to be filled with water

Test tubes, measuring cylinders or gas syringes (to collect gas)

Notes

1. 2-3 dm^3 per class; candidates could make up their own solutions of citric acid and produce other acid solutions by diluting the stock acid solution; when providing acids it is advisable to make up at least the total volume required in one batch so that the concentration will not vary between lessons

2. The marble chips should all be as nearly as possible the same size; it may be helpful to use a sieve when selecting from the main stock bottle, so that fine dust or small broken pieces are removed

3. to put in necks of flasks to prevent loss of acid spray

4. to cover beakers to prevent loss of spray

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GENERAL CERTIFICATE OF SECONDARY EDUCATION

TWENTY FIRST CENTURY SCIENCE

ADDITIONAL SCIENCE A **A154**
Unit A154: (Controlled Assessment)

PHYSICS A **A184**
Unit A184: (Controlled Assessment)

Factors that affect the motion of a vehicle along a surface

Information for Candidates (1)

This assessment will be changed every year. Please check on OCR Interchange that you have the Controlled Assessment material valid for the appropriate assessment session.

- To be issued to candidates at the start of the task.
- Your quality of written communication will be assessed.
- The total number of marks for this Controlled Assessment task is **64**.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

Assessment evidence produced that does not reflect the relevant examination series will not be accepted.

Released: June 201#
DC (AC/SW) 49106/3

Information for candidates

You are going to carry out an investigation on a factor that affect the motion of a vehicle along a surface.

Background

As an object moves along a surface, forces acting on the object will affect its ability to move. This is important in many situations, for instance, the movement of a ball in certain games and the movement of motor vehicles along road surfaces.

Organisations involved in road safety investigate and publish information on the stopping distances of vehicles travelling at different speeds. Car companies investigate the performance of their vehicles running at different speeds and on different road surfaces.

You will choose a factor and investigate the factor's effect on the motion of a vehicle along a surface.

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GENERAL CERTIFICATE OF SECONDARY EDUCATION

TWENTY FIRST CENTURY SCIENCE

ADDITIONAL SCIENCE A **A154**
Unit A154: (Controlled Assessment)

PHYSICS A **A184**
Unit A184: (Controlled Assessment)

Factors that affect the motion of a vehicle along a surface

Information for candidates (2)

This assessment will be changed every year. Please check on OCR Interchange that you have the Controlled Assessment material valid for the appropriate assessment session.

- To be issued to candidates **only** on completeion of the data collection part of their Practical Investigation.
- Your quality of written communication will be assessed.
- The total number of marks for this Controlled Assessment task is **64**.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

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Released: June 201#
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This secondary data can be used as part of your practical investigation.

You can select the data that is useful for you.

The effect of road texture on fuel consumption

Fuel consumption of cars is affected by many factors, including the resistance offered by the road surface. The following investigation was carried out by scientists at the Swedish Road and Traffic Research Institute.

A Volvo car with special instrumentation was run on four types of road surface at 20 test sites in Sweden. Its average fuel consumption was measured when run at three different speeds.

Some of the results are shown below.

road type	average fuel consumption in cm^3 / km		
	speed = 50 km/h	speed = 60 km/h	speed = 70 km/h
asphalt, with 0 - 8 mm chippings	69.5	67.6	73.6
asphalt, with 0 -16 mm chippings	71.4	69.2	73.2
asphalt, with 12 -16 mm chippings	70.8	72.5	78.8
concrete, with 0 - 25 mm chippings	72.0	71.0	75.6

The scientists also measured the texture of the four road types the car was driven on. Road texture is dependent on several factors, including the roughness of the road surface caused by the chippings of rock or aggregate that are used to make it.

Road texture is difficult to measure. As an indication of road texture, the scientists recorded data about the surface by scanning a laser over the road from a moving vehicle.

road type	road texture in arbitrary units
asphalt, with 0-8 mm chippings	48.0
asphalt, with 0-16 mm chippings	50.2
asphalt, with 12-16 mm chippings	63.9
concrete, with 0-25 mm chippings	52.0

From: Sandberg, Ulf S. I. *Road Macro- and Megatexture Influence on Fuel Consumption.* ASTM STP 1031 page 460-479, USA 1990, published in JOINT EAPA/EUROBITUME TASK GROUP FUEL EFFICIENCY (2004). *Environmental Impacts and Fuel Efficiency of Road Pavements.* EAPA/EUROBITUME

The effect of 20 mph speed limits on road injuries

In order to reduce deaths and injuries on the roads, many towns have introduced 20 mph speed limits in residential areas. In London, the effect of these new 20 mph zones was monitored by measuring the reduction in the number of injuries to pedestrians.

	% reduction in injuries after introduction of 20 mph zones	
pedestrians	**in the 20 mph zones**	**in nearby 30 mph zones**
All pedestrians	32.4	4.3
0-5 years old	47.0	9.9
6-11 years old	50.8	3.7
12-15 years old	26.3	6.3

Effect of 20 mph traffic speed zones on road injuries in London, 1986-2006: controlled interrupted time series analysis; Chris Grundy et al; http://www.bmj.com/content/339/bmj.b4469.full

Braking distance

The theoretical braking distance can be calculated from this equation:

$$s = \frac{v^2}{2a}$$

where:

v = initial velocity
a = rate of deceleration
s = distance travelled during deceleration (the breaking distance)

If we assume that the deceleration due to braking is 10 m/s^2, we can estimate braking distances for cars travelling at different speeds. For example:

speed in km/h	**braking distance in metres**
65.0	16.3
60.0	13.9

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TWENTY FIRST CENTURY SCIENCE

ADDITIONAL SCIENCE A **A154**

Unit A154: (Controlled Assessment)

PHYSYCS A **A184**

Unit A184 (Controlled Assessment)

Factors that affect the motion of a vehicle along a surface

Information for teachers

This assessment will be changed every year. Please check on OCR Interchange that you have the Controlled Assessment material valid for the appropriate assessment session.

- This document is confidential to teachers and must not be released to candidates.
- For details of the level of control required for this assessment refer to Section 5 of the specifications.
- There are two documents provided for candidates for this Controlled Assessment task:
  Information for candidates (1) defines the topic of the investigation and places it into a relevant context. This should be issued to candidates at the start of the task.
  Information for candidates (2) provides some secondary data to supplement that which candidates collect for themselves. It should be issued to candidates only on completion of the data collection part of their investigation.
- The total number of marks for this Controlled Assessment task is **64**.
- Internally assessed marks **must** be submitted by 15 May.
- This Controlled Assessment task is valid for submission in the June 201# examination series only.
- This document consists of # pages. Any blank pages are indicated.

Teachers are responsible for ensuring that assessment is carried out against the Controlled Assessment set for the relevant examination series (detailed above).

Assessment evidence produced that does not reflect the relevant examination series will not be accepted.

Released: June 201#
DC (AC/SW) 49106/3

Information for teachers

Specimen controlled assessment task:
Investigating a factor that affects the motion of a vehicle along a surface

Each candidate for Controlled Assessment in the June 201# examination series must present marks for one of the Practical Investigation tasks that is appropriate to the applicable specification. All internally assessed marks must be submitted by 15 May.

The marked work of all candidates must be retained by the centre. Some of the work will be required for moderation.

General guidance for teachers

These notes provide background information for the preparation of candidates for this task and advice on the assessment of the practical investigation report.

Reference should also be made to Section 5 of the specification for Additional Science A or Physics A and the '*Guide for controlled assessment for GCSE Twenty First Century Science*'.

Task setting is under high control. Tasks are therefore set by OCR. Where appropriate, this task may be contextualised by individual centres to take account of local circumstances including availability of resources and the needs of candidates. However, assessments must be based on the published marking criteria (within Section 5 of the specifications). If there is any doubt about whether a contextualised task sufficiently matches the criteria, centres should seek confirmation from OCR that the task is valid.

Preparation of candidates

It is expected that before candidates attempt a Controlled Assessment task they will have received general preparation in their lessons. Learning activities to develop the relevant skills should have been provided and the broad requirements of the assessment made clear to candidates.

More specific details of practical techniques, the development of skills associated with these techniques, and possible methods and choice of equipment for the task should be covered when teaching the relevant part(s) of the specifications, and must be completed prior to setting the task.

From their work for 'Module P4: Explaining motion', candidates should be familiar with the principals of inter-conversion of gravitational potential energy and kinetic energy as a vehicle moves down a slope, and the dissipation of energy as the vehicle slows down.

Assessment of the quality of written communication (QWC)

The quality of written communication is assessed in Strands S and R of this controlled assessment task. Candidates should be advised that the quality of written communication will be assessed. Further information about the assessment of QWC may be found in the specification.

Risk assessment

It is the centre's responsibility to ensure the safety of all candidates. Teachers are responsible for making their own risk assessment for the task prior to candidates attempting the practical work and for ensuring that appropriate health and safety procedures are carried out. However, teachers must not provide candidates with a risk assessment since this is included in the marking criteria for Strand Sb. If candidates require additional guidance on managing safety once the task has started then this will need to be reflected in the marks awarded.

Guidance on assessment

All assessment of the practical investigation is based on the final report submitted by the candidates.

The marking procedure and marking criteria are described in detail within Section 5 of the specifications. Marking decisions should be recorded on the respective cover sheets (available to download from www.ocr.org.uk and included in the '*Guide for controlled assessment for GCSE Twenty First Century Science*'). Candidates' reports should be annotated to show how marks have been awarded in relation to the marking criteria.

Additional guidance on marking criteria

Detailed guidance on applying the marking criteria will be found in the *Guide for Controlled Assessment for GCSE Twenty First Century Science.*

The following additional brief notes provide some clarification of what may be expected from candidates in some strands. However, all marking decisions must be consistent with the marking criteria.

Strand S

Reference should be made to the appropriate science in Module P4: Explaining motion.

Quality of written communication is assessed in this strand.

Strand R

Reference should be made to the appropriate science in Module P4: Explaining motion.

Quality of written communication is assessed in this strand.

Guidance for technicians

Guidance for technicians and teachers

Investigating a factor that affects the motion of a vehicle along a surface

Candidates plan their own investigations and may therefore require access to other apparatus at the discretion of the centre.

Teachers are advised to check that the range of apparatus provided will enable candidates to plan and carry out appropriate experiments to collect valid data.

The factors under investigation may include the effect of speed, mass or surface on the stopping distance of a vehicle.

Suggested equipment

All investigations:

Choice of different materials for the slope, e.g., planks of wood or dynamics ramps to give minimum directional guidance and/or or plastic piping or wooden beading to give more positive guidance.

Vehicles - trolley, model car or toy railway wagon

Masses

Range of different surfaces

Rules or tape measures

Balance

Stop watches or stop clocks

Light gate