GCSE

Additional Science A

Twenty First Century Science Suite

Teacher Support

OCR GCSE in Additional Science A J631

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Managing Skills Development and Assessment in Twenty First Century Science

An education in science means different things for different people. The report *Beyond 2000 – science education for the future* [Robin Millar and Jonathan Osborne, eds; King's College, London 1998, ISBN 1 871984 78 5] identified two main purposes for science education at secondary level:

- the first stage in training for future scientists;
- a preparation for life in a modern society for all pupils.

The new assessment structure for GCSE Science in the National Curriculum recognises that these two purposes require courses with different content and different approaches. Thus, the former "Double Award" science, which tried to combine the different purposes into a single course, has been replaced by "Dual Science" – two separate specifications, taught with different aims in view, and leading to two independent qualifications.

The Twenty First Century Science suite of specifications has been designed from the beginning to address both purposes in a way which allows the maximum curriculum flexibility. It provides valid, meaningful and motivating learning experiences for the widest possible variety of students, regardless of interest, ability or career intentions.

The key to this flexibility is provision of a full suite of single subject specifications, which can be combined in many different ways.

The National Curriculum core requirement for science is a minimum of single award science. This must provide a basis of scientific literacy: science for citizenship, for all young people, based on sufficient knowledge of science content to comprehend major issues in modern society.

This coverage is provided through the specification

- Science (J630), which provides an education for all students, based on scientific contexts and issues in contemporary society.

It is anticipated that the majority of students will wish to learn more about science. In this suite, two alternative varieties of Additional Science are offered:

- Additional Science (J631), which extends knowledge and understanding of science to provide a sound basis for more advanced study
- Additional Applied Science (J632), which provides a work-oriented experience of how science is applied in chosen manufacturing or service areas

These three specifications are designed to suit different populations with different needs. Thus, the assessment of skills is different in each specification and designed to match the different objectives of each specification. Because many students will take one of the additional sciences as well as Science, the assessments for the Additional Science specifications are designed to be complementary to those for Science, not merely to repeat similar activities.

The three schemes of assessment are different, but each is based on activities which should occur as a normal part of teaching and learning in the course. The general procedures followed in awarding, recording and submitting assessment marks follow the same pattern for all of the specifications.

An Introduction to Skills Assessment for the Three Schemes

Where a centre is introducing all three schemes at the same time, it may be helpful to ask different staff to 'lead' on different schemes, thus sharing out the load of developing new techniques and learning new marking criteria.

The key features of the three schemes are summarised in table 1.

Table 1: *Key features of each skills assessment scheme*

specification	Science A J630	Additional Science A J631	Additional Applied Science J632
Abilities to be developed	Responding to science in the media and in society	Practical investigative skills	Workplace skills and activities
Assessment activities	Analysis of first-hand experimental data + A case study of science in the media	A complete practical investigation	Standard procedures + Suitability test + Work-related report

For each separate science subject (J633:Biology, J634:Chemistry or J635:Physics), each candidate may offer:

either: a case study and data exercise, as for Science

or: a practical investigation, as for Additional Science

Staff at a centre may decide to allow candidates to carry out both types of activity, thus developing the full range of skills, and then submit whichever gives the higher mark; or to concentrate on just the one type of assessment.

Marking Internally Assessed Work

Strands and aspects of performance

The method of marking the skills assessment is the same across all specifications in this Science suite. The award of marks is based on the professional judgement of the science teacher, working within a framework of descriptions of performance which are divided into **strands** and **aspects**. Within each strand there are different aspects of performance, which in turn have four descriptions of performance illustrating what might be expected from candidates working at different levels.

For example, in the assessment of Data Analysis, Strand I: Interpreting Data

Aspect of Performance	Strand I Mark 2	4	6	8
a graphical or numerical processing of data	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 (normally a line of best fit) or construct complex charts or diagrams (e.g. stacked histograms, species distribution maps).	Additionally, indicate the spread of data (e.g. through scatter-graphs or error bars) and give clear keys for displays involving multiple data-sets.
	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.

Each aspect in turn should be considered, comparing the work first against the two mark performance descriptor, then the four mark, then six etc until the best match is found.

Where performance significantly exceeds that required by one descriptor, but does not sufficiently match the next, the intermediate mark (1, 3, 5 or 7) should be awarded.

Note the implication that performance descriptors indicate the quality of performance required, as distinct from mark criteria which look for mechanical matching and too easily lead to 'hoop jumping' for its own sake.

Thus, the level of performance in each aspect is decided. The single, overall, mark for the whole strand is then taken as the best fit to the level of performance shown. This would normally be the average of the levels judged for the individual aspects.

In a few instances, dotted lines on the assessment scheme are used to indicate alternative ways of accessing credit. For example, some work may be best described by graphical display of results, and other work by numerical processing – either can be used as the basis for the mark, allowing a wider variety of different types of investigation to match the criteria. Where it is possible to award some credit under both of the alternatives, the better of the two should be taken as the mark to count.

With these few exceptions, all the aspects must be taken into account in reaching the final mark for the strand. If there is no evidence of achievement for an aspect, a mark of zero should be recorded and included in calculation of the overall strand mark.

Candidates may not always report their work in a particular order, so evidence of achievement in a strand may be located almost anywhere in the work. Thus, it is necessary to look at the whole piece of work for evidence of each strand.

Where a decision is based partly on teacher observation of the candidate at work, the work should be suitably annotated at the appropriate point in the report.

Marking Grids

Marking decisions should be recorded on marking grids. A master copy for Additional Science is provided in Appendix D. The completed grid serves as a cover-sheet for the work if it is required for moderation.

Within any one strand, each aspect should be considered in turn. A tick on the grid should be used to indicate the performance statement that best matches the work.

When each aspect of performance within a strand has been assessed in this way the pattern of achievement is interpreted by a ‘best-fit' judgement to give a mark for that strand. For example,

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
I	(a) graphical or numerical processing of data					✓					5
	(b) summary of evidence					✓					
	(c) explanations suggested							✓			

This method of marking can be applied even where there is a wide variation between performance in different aspects. Thus, weak performance in one aspect need not depress marks too far if other aspects show better performance.

In some cases, in order to allow credit for the widest possible variety of activities, an aspect of performance is represented by two (or more) rows of performance descriptions (for example, graphical or numerical processing in the Strand I example above). In such cases, where a row is not relevant or appropriate for a particular activity, it should be left blank and not included in making any marking decision. If both rows are appropriate then the best mark for that aspect can be used.

Managing the activity in action

During the practical sessions ask what might be called enabling or checking questions to ensure progress for all students, independent of ability.

For example, questions such as

- Can you explain to me your basic method?
- How do you know that the experiment is a fair test?
- How accurate are your measurements?
- How reliable are your measurements?

The aim is to encourage students to reflect on their work and refine their procedure if necessary.

Writing up the activity and marking

During the time period of the activity it is suggested that students write up as they go along and show you the various stages. If the coursework is word processed changes, alterations, and additions can easily be done. If hand written then writing on one side of A4 allows the opportunity to include extra pieces of paper as and when needed.

The teacher should make **general** comments about aspects that are missing or need further development e.g. ‘is your results table complete?’ ‘is the range of measurements sufficient?’, ‘have you drawn a best fit line on your graph?’

At the end of the activity a suitable short deadline is set and the work handed in for marking.

The work should not be returned for further re-drafting.

Appendix B includes suggestions of suitable topics for Investigations. Appendix E provides some guidance notes that can be used with students. Appendix F provides specific guidance for supporting very weak students doing Investigations.

A Rationale for Skills Assessment in Additional Science A

This Additional Science specification is designed so that, when taught along with Science A, it will provide a suitable foundation for further studies of science. It is most suitable for candidates with an interest in becoming professional scientists, or for those who want to learn more about scientific facts and principles and the experimental work that they are based on.

In scientific research, investigations play an important part, especially those based on experimental work under carefully controlled conditions. Over the past 20 years, investigative work has increasingly formed the basis for coursework assessment in school science courses, as well as being a powerful teaching and learning process.

The use of practical investigations to assess skills in school science was based on work done by the APU, and research in a number of centres, particularly the University of Durham. For more than 10 years, it has formed the basis of coursework assessment for GCSE science.

Investigations require the drawing together of skills in planning, collecting data, interpreting data and evaluation. They provide an effective and valid assessment instrument for a course which is seen as a basis for further studies and possible future careers in science. However, the assessment of investigations in the National Curriculum has led to an ever narrower range of activities being used, and to rather mechanical ‘criterion matching’ rather than genuine open-ended work.

For this specification, the basic structure of investigations is retained, but the emphasis on prediction is removed, allowing a much wider range of activities and approaches. A different marking style, drawing more on professional judgment of teachers has also been developed. Rather than “mark criteria” which imply a formal, standard matching, we prefer the term “performance descriptors” which indicate the type and quality of performance expected at each level.

The investigation aims to motivate candidates and help them to appreciate the importance of having a clear and manageable question, to learn how to choose equipment and use it appropriately, and to design suitable apparatus for making observations and measurements. First-hand experience of the problems of collecting valid and reliable data can give candidates a better sense of what the difficulties really are, and a 'feel' for how great they are in specific cases, and provide a context for beginning to understand how to tackle and perhaps overcome these.

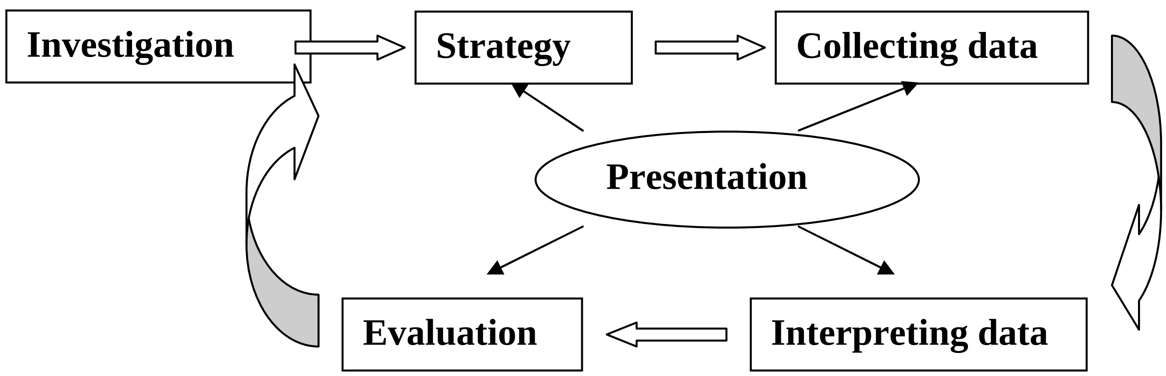
The changed approach to planning investigations is designed to avoid over-direction of students using given standard procedures. Hence, there is an increased emphasis on the autonomy shown by the student in considering factors to be controlled, and in preliminary testing to establish suitable conditions for the investigation.

Summary of differences between assessment of investigations in established GCSE courses (Sc1.2) and in 21st Century Science courses	
Former GCSE Courses (Sc1.2)	Additional Science A
Planning must be based on use of prior knowledge of relevant theory. This restricts access except to a small number of topics.	Students devise a strategy to ensure adequate, good quality evidence. Activities may be based on theory provided for them or may be exploratory.
Only studies across a range of values of a test variable can easily match the criteria.	Comparisons, distribution surveys or tests of reliability can also match the mark descriptors.
Investigations may be based on first hand or secondary evidence (e.g. simulations or web-searches).	Investigations must include collection of some first-hand practical evidence.
Individual marks for different skill areas may be collected from different activities and aggregated.	The final mark is the total for the best single piece of work.
Mark criteria must be matched in particular order, leading to mechanical 'hoop-jumping'	Performance descriptors allow 'best-fit' marking using professional judgement over a range of aspects of the work.

Presenting and Marking Investigations

The type of investigation used for this assessment is developed from those used in GCSE assessment for the past 10 years. This model in turn, was developed from work of the Assessment of Performance Unit in schools. The advancement of science knowledge and understanding through investigations is seen as a cyclic process – as each investigation progresses it becomes possible to review the progress made so far, and the results of each investigation inform the planning of the next.

In this model, the whole process of an investigation is made up of four stages – formulating the idea and deciding what to do, carrying out the work to collect the evidence, making sense of the evidence, and finally evaluating the whole process, either as a summation of the work, or in preparation for the next investigation.



We have retained this basic structure. However, assessment over the past few years has attached particular meanings to the labels used in Sc1, and now the emphasis is changed, so we have chosen new labels to allow a fresh approach. We have also added a fifth strand to the assessment, which provides credit for effective communication through the investigation report.

The five strands which make up the assessment are:

Strand S: Devising the strategy

Strand C: Collecting the evidence

Strand I: Interpreting and explaining the evidence

Strand E: Evaluating the evidence and the procedures used

Strand P: Presenting a report of the investigation

The full criteria are given in Appendix A.

Strand S: Devising the strategy

It is expected that normal teaching will have established the context for any investigation and have developed understanding of the underlying science. The task for the student is to decide how much evidence, and what quality of evidence will be needed to solve the problem or answer the question, and to select the most suitable equipment and procedures.

Students are no longer expected to predict the answer before they begin, so high marks are not restricted only to studies where suitable explanatory theory is available. This is intended to allow work on e.g. species distribution, behaviour patterns, or quality control to match the criteria.

In recent years, too much work in Sc1 has become simply using carefully-drilled standard procedures. Here, successful students will show some independence or autonomy in selecting the best ways to proceed and in deciding how much evidence to collect. Those who are less able to work in this way may be given guidance, or even provided with standard procedures to follow, but this will reduce the maximum mark they can access in this strand.

It is advised that more time should be made available for the planning stage than has been usual in the past. This should allow students to explore the background to the task, establishing what factors may be important and how to control or allow for them. It should also allow them to consider different approaches, and to carry out preliminary tests to establish suitable ranges to cover.

For example, in an investigation of ‘Craters’, students could explore whether sand or flour made a more suitable surface to land on, or how to ensure standard release of the projectiles. They could also discover that round marbles gave more easily measured craters than irregular stones, or that very heavy objects caused so much ‘splashing’ of material that results were difficult to interpret. Help in devising suitable strategies should be given where students need it, but this reduces the mark which can be given for “autonomy”. The level of help given to each student should be recorded.

The necessary skills can be encouraged whenever practical work is undertaken by allowing time for class discussion step-by-step as the work is planned, and linking this to the amount and quality of evidence which will be obtained as a result.

Strand C: Collecting evidence

In this strand, the assessment is not simply based on the data which is reported. Valuable indications can also be obtained from the detail given in the strategy, where students show their awareness of factors which might affect the results. Indications of the quality of the work can also be found by looking at graphical displays to see the quality and consistency of the final data.

Both students and markers should be encouraged to look at the quality of individual raw data, and the level of agreement between repeat readings, as well as looking at the overall pattern of results.

Strand I: Interpreting results

Three aspects of performance are considered:

- revealing patterns of behaviour in the data

- summarising or describing these in words
- explaining the patterns found

The first aspect allows alternative approaches. Much work e.g. the ‘craters’ study, is best displayed graphically. Some e.g. species distribution patterns, heats of combustion, may be better described by suitable numerical processing. The scheme allows either approach to score.

Simple charts or histograms can be credited in the lower mark ranges. Line graphs with lines of best fit can score up to 6 marks (as previously in Sc1). To access 7 or 8 marks, something extra is required. Both Additional Science A and the linked course Science A place great emphasis on the quality of data. Progression to 7 or 8 marks may come from an indication of the underlying quality and reliability of the raw data (e.g. plotting all raw data in a ‘scatter-graph’ with a single line of best fit, or use of error bars) or display of multiple data-sets on common axes, or use of more complex data display formats.

The remaining two aspects spread the marks more widely than the former Sc1 criteria. In Sc1, a general statement of a trend scores 4 marks, and this can rise to 6 if supported by some scientific explanation. In these new regulations, the quality of the conclusion must improve for 6 marks, being more detailed and/or mathematical. In Sc1, no explanation was required until the 6 mark stage. Here, some attempt at explanation is required at all levels.

In Sc1, marks below 4 for this strand were very rare. In the pilot scheme, marks below 4 were more common. This provides a better spread of marks to allow more reliable grading, but teachers should be aware of the need to encourage clear conclusions and explanations to improve scores in this strand.

Strand E: Evaluation

There is a high level of continuity here from skill area E of Sc1. Students tend to consider their data separately from the procedures they used to obtain it. The final aspect encourages them to bring these two together as a basis for some overall judgement of reliability, and to think about what extra work might help to further improve the reliability. As with Sc1, the intention is NOT to simply suggest other, related investigations that might be done instead!

Strand P: Presentation

Scientific investigation reports should contain sufficient detail to allow later workers to repeat the experiments if necessary. Thus the method used should be described in detail, including explanations of why particular methods, equipment or test ranges were chosen. Reports should also provide full detail of all data obtained, and of any fixed parameters (e.g. concentrations of stock solutions, etc). Finally, reports should be clear and grammatically correct.

Managing the Assessment of Investigations

Sufficient work must take place under direct supervision to allow the teacher to authenticate each student's work with confidence.

There is a potential conflict between the normal role of teacher and that of someone who has to make an assessment of their students' work for an external public exam. Naturally different teachers vary in their procedures and the amount of help and guidance they give but a significant variation can cause uncertainty and it is essential that our students see that each teaching group is being treated uniformly.

The following guidelines represent a broad approach to the subject of managing internal assessment that should help to alleviate significant differences without affecting the autonomy of teachers.

Helping students to develop investigative skills

Every occasion when class practical work or a practical demonstration takes place provides an opportunity to demonstrate and discuss aspects of relevant investigative skills. Time should be taken to build up the design of any experiment or demonstration through class discussion – "What's the best way to measure this?", "How many times should I measure it?".

Students should also be involved in discussing what can be deduced from results obtained, and in looking for weaknesses in the evidence collected, or ways of improving procedures.

Essential preparation for the assessed task

- Choose a task appropriate to the ability of the set or to the development stage they are at.
- Ensure that the necessary scientific knowledge, practical/research skills have been covered.
- Ensure that the students are familiar with and understand the assessment criteria from first hand experience in a non-assessed situation.
- Circulate and discuss the departmental prompt/guidance sheets.

Introducing the activity

The essential aim is to encourage students to ask questions and put forward tentative ideas and suggestions. The teacher should aim to promote discussion without giving specific answers to direct questions, which may block potential avenues of investigation. The teacher can give ideas about resources, reminders about relevant theory etc. and can steer the lesson to a particular title of task if appropriate. This might be done, for example:

- by a teacher demonstration/video/computer simulation
- from questions arising from a class discussion
- from a brainstorming session with the class
- by referring to the knowledge and skills gained from a previous lesson

Managing the activity in action

During the practical sessions ask what might be called enabling or checking questions to ensure progress for all students, independent of ability.

For example, questions such as:

- Can you explain to me your basic method?
- How do you know that the experiment is a fair test?
- How accurate are your measurements?
- How reliable are your measurements?

The aim is to encourage students to reflect on their work and refine their procedure if necessary.

Writing up the activity and marking

During the time period of the activity it is suggested that students write up as they go along and show you the various stages. If the coursework is word processed changes, alterations, and additions can easily be done. If hand written then writing on one side of A4 allows the opportunity to include extra pieces of paper as and when needed.

The teacher should make **general** comments about aspects that are missing or need further development e.g. ‘is your results table complete?’ ‘is the range of measurements sufficient?’, ‘have you drawn a best fit line on your graph?’.

At the end of the activity a suitable short deadline is set and the work handed in for marking.

The work should **not** be returned for further re-drafting.

Appendix B includes suggestions of suitable topics for Investigations. Appendix E provides some guidance notes that can be used with students. Appendix F provides specific guidance for supporting very weak students doing Investigations.

Management and Administration of the Skills Assessment

The scheme of skills assessment is designed to award credit for capabilities which are developed as part of the normal teaching and learning process through the course. In order to achieve this, schemes of work should:

- make pupils familiar with the assessment requirements and the marking criteria
- present activities in ways which emphasise aspects of the assessable skills
- identify activities which will be suitable for formal assessment

Record-keeping

Many practical activities throughout the course could provide evidence for assessment. Teachers may wish to award marks and record these, either as evidence of pupil progress or as a 'fall-back' source of marks if a more formal assessment later in the course is missed or not well done. The final mark submitted for additional science must come from one investigation and evidence for this must be kept safely.

Appendix D is a master copy for the cover-sheet which should be kept with the marked script following assessment. It has spaces in which all marking decisions can be recorded as the work is marked. The sheet is then attached to the pupil work. If the work is later required for moderation, the pupil scripts and cover sheet are simply taken from the store and posted to the moderator. The cover sheet will be used by the moderator when checking the marks for the work. It will be retained by OCR as a complete record of all marking decisions made by both the centre and the moderator.

Internal Standardisation of Marks

It is the responsibility of the centre to make sure that the rank-order of pupils is secure. This requires that all work is consistently marked to the same standard.

Appendix C provides examples of Investigations with commentaries to explain the mark decisions. These can be used as a focus for discussion between all staff involved in the marking, to exemplify standards.

Internal standardisation should also be carried out. Some or all of the following procedures may be found to be effective:

- one member of staff moderates samples from all markers, thus providing a single reference standard for all
- copies of scripts are passed round for marking agreement trials at department meetings (it is essential that this is accompanied by discussion of reasons for any disagreements)
- a common approach to marking, or customised mark-scheme can be devised and agreed by all markers
- scripts from one cohort, which have been part of external moderation samples, can be kept and referred to, to help in carrying forward consistent standards from year to year.

OCR provide a free consultancy service. As part of this, centres can send in up to three marked scripts and receive feedback on their marking standards.

External Moderation of Marks

After work has been marked in the centre, a sample of the work will be checked by an external moderator. The purpose of this is to ensure that the activities used are appropriate and match the specification requirements, and that the marking standards used in the centre are consistent and in line with national standards.

Shortly after entries are submitted for the skills assessment, OCR will provide form MS1 (mark-sheet) and instructions for what must be submitted from the centre (Appendix G). The mark sheet is in three layers and is self-carboning. The top copy is sent to OCR and will be used to enter raw marks on the computer. The second copy is sent to the moderator. The third copy is kept by the centre as a record.

The moderator will ask for the work of a sample of candidates. The work which counts towards the final total must be sent, together with information which shows what activities were used and how they were presented to pupils. In a few cases, the moderator may ask for further work or information to be sent.

The work will be returned, and a moderator's report will be sent to the centre when results are published. This will provide a commentary on the work seen. In the past, marks from the majority of centres have been in line with standards and have been accepted without change. Where any change has been required, this will be clearly stated and an explanation of the reasons for any changes will be given.

Authentication of Students' Assessed Work

Overall authentication

Samples of work sent for moderation must be accompanied by a signed copy of the centre authentication form. Staff involved in the assessment sign this form to certify that the work presented is the authentic work of the individual candidates.

Investigations

The Investigation is an individual activity where the candidate has carried out a whole investigation.

Candidate authentication

Candidates should complete an authentication statement as a cover sheet for their work, a master copy of this can be found in Appendix H.

Appendix A: Marking Criteria for Investigation

Within each strand, different aspects of performance are identified. Achievement related to each of these is assessed, and the professional judgement of the teacher is then used to award an overall mark out of 8 for the strand.

Strand S: Strategy

Practical investigations are likely to arise out of work on most or all of the course modules. Suitable tasks might be suggested to candidates, but they should also have opportunities to modify or extend these, or to suggest questions or tasks to investigate in topic areas they are studying. Candidates can (and should) obtain more credit for tackling somewhat more demanding tasks, and for being involved in devising the question/task, rather than 'playing safe' with a given, or routine task, or one involving little skill in the use of equipment.

Whilst candidates should be encouraged to plan an investigation before starting, there is limited value in requiring them to produce a detailed written plan – as their actions should be open to modification as they proceed. Indeed, it is good practice to try taking a few measurements or making a few observations to get a 'feel' for the equipment and the system being investigated, before planning a detailed data collection strategy. For that reason, the candidate's understanding of issues concerning data is better assessed from the final data set they present (see strand C below), rather than from an initial plan.

Assessment of the quality of strand S focuses on:

- the complexity and demand of the task and approach chosen;
- the choice of equipment, materials and techniques;
- the degree of independence shown in formulating the task and the approach to it.

Aspect of performance	Strand S Mark			
	2	4	6	8
a complexity and demand of task	Simple measurement or comparison task, based on straight-forward use of simple equipment.	Routine task requiring only limited precision or range of data to be collected.	Straightforward task of limited complexity, but requiring good precision or a wide range of data.	Complex task requiring high levels of precision/reliability in the data collected.
b techniques used	Follow a given technique, but with very limited precision or reliability.	Select and use basic equipment to collect a limited amount of data.	Select and use techniques and equipment which are appropriate for the range of data required.	Justify the choice of equipment and technique to achieve data which is precise and reliable.
c autonomy and independence	The task has been set by the teacher and/or is based on specific, task-related structured worksheets.	The task is closely defined by the teacher, but is carried out with little further guidance.	The task is defined by the candidate from a more general brief, then carried out independently.	The topic is reviewed by the candidate to justify a choice of task. The work is completed independently.

Strand C: Collecting Data

Candidates are expected to be able to collect a set of data in a manner which shows understanding of how to ensure (and assess) quality.

The quality of a data set depends on:

- the quality of individual data points, which in turn depends on:
    - how carefully the measurements have been taken, and how accurate the available instruments are (IaS 1.1-2);
    - how much variation or scatter there is in repeated measurements and the steps that have been taken to assess and deal with this (IaS 1.1-4);
    - whether the instruments used, or the way they are used, results in measurements that differ from the 'true' value of the quantity (IaS 1.1-2).
- the extent and design of the set of data points collected, that is:
    - whether enough data points have been collected (IaS 2.1, 2.3, 2.7);
    - whether these cover an adequate range (of cases, or situations, or values of an independent variable) (IaS 2.3);
    - (if a relationship is being explored) whether the design of the data set enables the effect of other variables to be excluded (e.g. (IaS 2.2-3, 2.6-7).

Candidates should use preliminary experiments or other information to confirm that their choices of techniques and range of values to be tested will lead to results of good quality.

The statements are written to refer to primary data that the candidate has collected. Where this is supported by data from secondary sources, the statements should be read as referring to the data 'selected' (as opposed to 'collected'). The mark awarded should be based on all of the data considered as a whole.

Aspect of performance	Strand C Mark			
	2	4	6	8
a identification and control of interfering factors	Little or no care has been taken to identify or control outside influences.	Identifies some factors which may affect the outcomes and need to be controlled or accounted for.	Identifies the majority of factors which may affect the outcomes and need to be controlled or accounted for.	Reviews factors which might affect the outcomes and describes how they have been controlled or accounted for.
b extent and design of data set	The data is very limited in amount (e.g. isolated individual data points, with no clear pattern), covering only part of the range of relevant cases/ situations, with no checking for reliability.	An adequate amount or range of data is collected, but with little or no checking for reliability.	Data is collected to cover the range of relevant cases/ situations, with regular repeats or checks for reliability.	Values tested are well-chosen across the range, with regular repeats and appropriate handling of any anomalous results. Preliminary tests are used to establish the range.
c quality/ precision of manipulation	Little care evident in use of apparatus. Data generally of low quality.	Use of techniques and apparatus generally satisfactory. Data of variable quality, with some operator error apparent.	Sound techniques in use of apparatus/ equipment. Data of generally good quality.	Consistent precision and skill shown in use of apparatus/ equipment. Where appropriate, checks or preliminary work are included to confirm or adapt the apparatus or techniques to ensure data of high quality.

Strand I: Interpreting Data

Candidates are expected to be able to:

- present or process a set of data in such a manner as to bring out any 'patterns'[1] that are present;
- state conclusions based on these patterns;
- relate their conclusions to scientific theories or understanding;

In the following table, each row represents increasing achievement in a different aspect of performance.

Aspect of Performance	Strand I Mark 2	4	6	8
a graphical or numerical processing of data	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 (normally a line of best fit) or construct complex charts or diagrams (e.g. stacked histograms, species distribution maps).	Additionally, indicate the spread of data (e.g. through scatter-graphs or error bars) and give clear keys for displays involving multiple data-sets.
	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.
b summary of evidence	Note differences between situations/cases, or compare individual results.	Identify trends or general correlations in the data.	Describe formal or statistical relationships within the cases/situations studied.	Review the extent of, or limitations to, formal conclusions in relation to the scatter evident in the data.
c explanations suggested	Link the outcomes to previous experience or 'common sense'.	Relate the conclusion to scientific ideas/explanations.	Justify the conclusion by reference to relevant scientific knowledge and understanding.	Use detailed scientific knowledge to explain all aspects of the given conclusion.

[1] 'Patterns' here means similarities, or differences, or the presence or absence of a relationship (e.g. a correlation between a factor and an outcome, or a trend linking two variables)

Strand E: Evaluation

Candidates are expected to be able to look back at the investigation they have carried out, showing what they have learned from doing it and explaining how they would modify it in the light of this, were they to carry it out again. These suggestions may demonstrate understanding of:

- difficulties in collecting valid and reliable data;
- weaknesses in the design of the data set collected, such as imperfect control of other variables, or the size and matching of samples compared;
- assessing the level of confidence that can be placed in these conclusions.

Aspect of Performance	Strand E Mark			
	2	4	6	8
a evaluation of procedures	Make a relevant comment about how the data was collected and about safety procedures.	Comment on the limitations to accuracy or range of data imposed by the techniques and equipment, used.	Suggest improvements to apparatus or techniques, or alternative ways to collect the data, but without sufficient practical detail.	Describe in detail improvements to the apparatus or techniques, or alternative ways to collect the data, and explain why they would be an improvement.
b reliability of evidence	Make a claim for accuracy or reliability, but without appropriate reference to the data.	Note the presence or absence of results that are beyond the range of experimental error.	Use the general pattern of results or degree of scatter between repeats as a basis for assessing accuracy and reliability.	Consider critically the reliability of the evidence, accounting for any anomalies.
c reliability of conclusion	Relate judgement of the reliability (or otherwise) of the conclusions only to techniques used, not to data collected.	Link confidence in the conclusion to the apparent reliability of the data collected.	Discuss the precision of apparatus and techniques, the range covered and reliability of data to establish a level of confidence in the conclusions	Identify weaknesses in the data and give a detailed explanation of what further data would help to make the conclusions more secure.

Strand P: Presentation

The ability to report clearly and effectively on one's work is essential in order to demonstrate understanding of the Ideas about Science that relate to practical investigations.

Credit is awarded for three aspects of reporting and communicating a practical investigation:

- completeness of the report, with all practical procedures clearly described, all parameters and evidence reported, a full analysis of the evidence, and an evaluation of both procedures and evidence;
- presentation of the report, including layout and effective sequencing, use of illustrations as appropriate and use of graphs and charts to present information;
- correct use of English, including accurate grammar, punctuation and appropriate use of scientific terms.

Aspect of Performance	Strand P Mark			
	2	4	6	8
a description of work planned and carried out	The purpose/ context of the investigation is not made clear. Key features of experimental procedures are omitted or unclear.	The purpose of the work is stated. Main features of the work are described, but there is a lack of detail.	There is a clear statement of the question/task and its scope. Practical procedures are clearly described.	All aspects of the task are reviewed. Practical procedures are discussed critically and in detail.
b recording of data	Major experimental parameters are not recorded. Some data may be missing.	Most relevant data is recorded, but where repeats have been used, average values rather than raw data may be recorded.	All raw data, including repeat values, are recorded.	All relevant parameters and raw data including repeat values are recorded to an appropriate degree of accuracy.
	Labelling of tables is inadequate. Most units are absent or incorrect.	Labelling is unclear or incomplete. Some units may be absent or incorrect.	All quantities are identified, but some units may be omitted.	A substantial body of information is correctly recorded to an appropriate level of accuracy in well-organised ways.
	Observations are incomplete or sketchily recorded.	Recording of observations is adequate but lacks detail.	Observations are adequate and clearly recorded.	Observations are thorough and recorded in full detail.
c general quality of communication	Spelling, punctuation and grammar are of generally poor quality. Little or no relevant technical or scientific vocabulary is used.	Use of appropriate vocabulary is limited. Spelling, punctuation and grammar are of very variable quality.	Appropriate scientific vocabulary is used. Spelling, punctuation and grammar are generally sound.	There is full and effective use of relevant scientific terminology. Spelling, punctuation and grammar are almost faultless.

Appendix B: Activities Which Might be Used for Teaching or Assessment of Investigations

The additional science specification provides opportunities for investigative work in every module of the course. Some of these activities can be used to introduce and develop procedural understanding of how to carry out investigations.

The suggestions given here indicate some activities related to the specification content which could be used either for developing understanding or for assessment. In a few cases some brief notes have been added in italics. These offer suggestions as to how the activity might be used and/or particular aspects of investigative work which could be brought out.

A useful early stage in planning investigative skills development and assessment would be to work up similar notes to a good range of the activities as a preliminary screening stage in selecting which ones may be of most value with particular teaching groups.

Candidates who have taken, or are taking, Science A will carry out a data analysis exercise as part of their skills assessment for that course. The data analysis activity uses the performance descriptors for strands I (interpretation of data) and E (evaluation of procedures and data) of an investigation. Many of the activities which are used for this exercise in Science could be extended to complete investigations, providing additional opportunities for assessment in Additional Science. However, in strand C of the Additional Science assessment, only work done and data collected by the individual candidate can be credited. Many of the Science activities are ones which require pooling of group results to provide enough data for effective interpretation and so they are not easily adapted for use in assessment of Additional Science.

B4 Homeostasis
Investigate respiration rate of yeast/germinating peas/maggots
Investigate osmosis in potato chips in varying concentration of salt solution
Investigate the effect of temperature on protease digestion of photographic film gelatin
Investigate the effect of temperature on rennin milk coagulation
Effect of temperature on the decomposition of hydrogen peroxide using an enzyme
Investigate the cooling effect of ethanol
Comparison of body temperature at extremities and core under different conditions
Effect of body size on heat loss *e.g. this is a readily accessible task for lower achieving students but tends to attract low level responses, with inadequate ranges of data and little control of conditions.*

B5 Growth and Development
Germination *e.g. broad bean seeds measuring length of root and shoot. Cress seeds grown on an inert support, irrigated with ethanoic acid/sodium ethanoate buffer solutions of different pH. Germination rates counted and data pooled for statistical analysis to link germination with pH. Better for teaching about quality of evidence than for assessment as individuals rarely have time to collect sufficient data.*
Investigating auxin distribution and phototropism in shoots

B6 Brain and Mind

Estimating the speed of a nerve impulse from reaction time experiments

Testing areas of the tongue with bitter, sour, sweet and salt

Photo-taxis in brine and shrimps

Choice chambers for wood-lice

C4 Chemical patterns

Investigation by observation of the changes at the electrodes during electrolysis of aqueous solutions

C5 Chemicals of the natural environment

Effect of temperature on the solubility of salts

Electrolysis of aqueous solutions.

e.g. in the electrolysis of aqueous copper salts is the amount of copper deposited always in proportion to the quantity of electricity transferred?

Investigate the relationship between conductivity and concentration of aqueous salts.

Is magnesium oxide always the same?

e.g. measuring the mass of magnesium oxide formed by burning different masses of magnesium requires readings to 1/100th of a gram.

Measuring small concentrations of transition metal compounds.

e.g. copper/iron/cobalt ions catalyse the iodide/persulphate reaction and using suitable calibration curves students can determine ionic concentrations by a clock reaction.

C6 Chemical Synthesis

Measuring pH/temperature changes during neutralisation reactions

Which brand of vinegar/bleach is the best value?

e.g. using suitable dilution and titration techniques and cost analysis.

Rates of reaction

e.g. any of the popular investigations acid/limestone, magnesium/acid, thiosulphate/acid

P4 Explaining motion

Investigation of distance/ speed travelled by an object.

e.g. stopping distances of objects down a ramp, bicycles

Investigating the effects of friction between different surfaces

e.g. ‘margarine tub or coins or metal masses being propelled by elastic bands across surfaces

Practical investigation of air resistance forces on shapes, using a fan or when immersed in a flowing liquid.

Investigating an object falling through a viscous medium

Investigation of the effect on terminal velocity of the mass, volume and shape of an object

Investigation of the factors affecting the design of a model parachute

e.g. What factors affect the rate of descent of a paper parachute.

Investigating the factors which affect the sag of a bridge

P5 Electric circuits

Investigating the factors which affect the resistance of a wire

Investigation of current-voltage characteristics of different components (filament lamp)

Investigating the factors which affect the efficiency of electrical appliances

Investigations into the factors affecting the size and the direction of induced potential differences

Investigating the heating effect on water as a result of electrical heating

Investigating the factors that affect the strength of an electromagnet

P6 The wave model of radiation
Investigation into the effect of frequency on the wavespeed of water waves and/or of waves travelling along springs or elastic strings
Investigation into the effect of water depth and/or the tension of a spring on wavespeed and wavelength; the direction of travel of water waves when their speed changes
Investigation of the materials that absorb, transmit or reflect infrared radiation
Investigating optical fibres/total internal reflection and/or measuring critical angles
Investigating the absorption of light through different thicknesses of a translucent material
Investigating the refraction of light through materials of different types and shape

Appendix C: Example of Investigations with Commentaries

Investigation 1

To see how stopping distance is related to energy of movement

A moving vehicle is stopped by brakes. The brakes grip the wheels of the vehicle. The friction of the brakes rubbing against the wheels turns the movement energy into heat. The brakes get hot, and the vehicle slows down, because the total amount of energy must remain constant. When all the movement (kinetic) energy has been turned into heat, the vehicle will stop.

We will test the theory that if the vehicle is moving faster (has more kinetic energy) it will take further to stop. We will also find out whether the stopping distance is proportional to the speed of movement, or to the kinetic energy.

Kinetic energy of a moving object $KE = \frac{1}{2} mv^2$

where m – mass of vehicle and v = velocity.

The moving object will be a steel ball-bearing. We have three different sizes to choose from.

We will roll the ball-bearing down a v-shaped length of metal (aluminium). By rolling it from different heights, we will give it different speeds.

We can choose between three surfaces of different types of carpet. The friction between the ball-bearing and the carpet is what will slow it down. We need to find a way to make sure the ball goes smoothly from the ramp onto the carpet without bouncing or losing any of its energy.

Preliminary tests

When the ramp was very shallow, the ball didn't run very far. If the ramp was too steep, the ball bounced when it reached the bottom. It lost energy and sometimes swerved off sideways. We decided that 30º was the steepest we could use.

We cut out a piece of plastic from a lemonade bottle and fixed it to the bottom of the ramp. It was fixed with sellotape and sand under it so that it didn't move. It made a smooth curve for the ball to run off onto the carpet without losing energy.

The woolly carpet was too rough and stopped the ball very quickly. The smooth carpet let it roll right off the end. We chose a carpet with a sort of ridge pattern because the ridges kept the ball going straight, and it was rough enough to stop it quite quickly.

We used the heaviest ball-bearing to get most kinetic energy.

Method:

Set up the apparatus as shown

Put the ball on the ramp. Hold it in place with a finger. Hold the metre rule vertical beside the ramp (use a spirit-level to test). Move the ball backwards or forwards until the bottom of the ball is exactly the height to be tested.

Let go of the ball. If it bounces or goes off course, do not count that test, but do it again. When it rolls straight, wait until it stops, then measure the distance it has gone.

Repeat twice more for each height.

Results

The angle of the ramp was 30º

The length of the ramp was 130cm. We measured distances from the bottom of the curved plastic.

The ball-bearing weighed exactly 10.00g

Expt	hight (cm)	Potential energy (mgh) (=kinetic energy) (J)	Distance taken to stop (cm) (to nearest cm)			
			1st time	2nd time	3rd time	Average
1	60	0.01 x 10 x 0.6 = 0.06	135	129	132	132
	50	0.01 x 10 x 0.5 = 0.05	105	111	114	110
	40	0.01 x 10 x 0.4 = 0.04	89	86	87	87
	30	0.01 x 10 x 0.3 = 0.03	65	67	~~53~~	66
	20	0.01 x 10 x 0.2 = 0.02	47	40	42	43
	10	0.01 x 10 x 0.1 = 0.01	20	23	21	21

Conclusion from the graph

The graph shows the average result for each height, with error bars to show the range of the data (except for the third reading at 30cm height. The ball-bearing bounced a bit and this result wasn't used.)

The graph is a straight line from the origin (no movement = no distance to stop). The distance needed to stop is directly proportional to the kinetic energy of the rolling ball.

This was what I predicted to start with. If the braking force is constant, the rate of transfer of energy will also be constant, so more energy needs more distance to stop. We had to assume that the carpet gave the same resistance all the way along its length, and it looks as if this is true.

In a real vehicle, this doesn't work so well, because the brakes get very hot and hot brakes are less efficient.

To test that stopping distance is not proportional to speed, I calculated the velocity of the ball each time. I assumed that there was no friction loss on the ramp, so all the potential energy of lifting the ball onto the ramp would turn into kinetic energy as it rolled down. Both the ball and the ramp are very smooth, so this is a fair approximation.

KE = ½ m v^2

Drop height (cm)	KE (J)	Speed (ms^{-1})	Stop distance
60	0.06	3.46	132
50	0.05	3.16	110
40	0.04	2.83	87
30	0.03	2.45	66
20	0.02	2.00	43
10	0.01	1.41	21

Evaluation:

The preliminary tests showed that the ball only rolled about the same distance to a few centimetres each time, so we only measured to the nearest centimetre. This was good enough for me to find a clear pattern in the results. We could measure to the nearest millimetre, but we would have to remember to always measure to the same place on the ball, exactly where it touches the carpet. We had to bend down to get level with the ruler when measuring the start height so that there would not be a parallex error. We measured to the bottom of the ball because this comes down to ground level at the end.

The ball almost always rolled straight because of the pattern on the carpet. All of the carpet was quite new and it seemed to give the same force all the way along.

Only one result went wrong and I did not include this in the average for that height.

The error bars on the graph are very short, which shows that the results are consistent and reliable. Because I have a lot of data and it all agrees, I am confident that the stopping distance is directly proportional to the kinetic energy of the ball, and not to its speed.

Investigation1 commentary

Title: To see how stopping distance is related to energy of movement

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
S	Complexity and demand of task							✓			6
	Techniques used							✓			
	Autonomy and independence								✓		
C	Identification and control of interfering factors								✓		7
	Extend and design of data								✓		
	Quality/precision of manipulation							✓			
I	Graphical processing of data							✓			6
	Numerical processing data										
	Summary of evidence							✓			
	Explanations suggested								✓		
E	Evaluation of procedures					✓					4
	Reliability of evidence					✓					
	Reliability of conclusion					✓					
P	Description of work planned and carried out								✓		7
	Recording data								✓		
	Labelling tables and units										
	Observations										
	General quality of communication									✓	
	Overall total mark for the investigation										30

Aspect	Mark	Comment
Strand S: Strategy		
(a)	6	A relatively straightforward task approached by the student but needing a wide range of data
(b)	6	Appropriate technique devised and used to collect sufficient data
(c)	7	Topic is reviewed to justify choice of task but more background and further detail could be provided.
Strand C: Collecting data		
(a)	7	Mass of ball-bearing, angle of slope, carpet surface, length of ramp and transition area between area and carpet controlled.
(b)	7	Preliminary tests performed to establish angle of slope but no results reported. Good range chosen to produce meaningful results. Anomalous results handled appropriately.
(c)	6	Sound technique, data of good quality produced but limited precision required
Strand I: Interpreting data		
(a)	6	Potential energy and speed calculated from results
(b)	6	Trend identified but quantitative relationship not developed.
(c)	7	Explanation in terms of friction, conservation of potential and kinetic energies used to explain results
Strand E: Evaluation		
(a)	4	Limitations in procedures recognised
(b)	4	Anomalous result identified and handled appropriately
(c)	4	Links reliability in data to level of confidence in conclusion
Strand P: Presentation		
(a)	7	Clear aim and purpose. Procedures discussed and adapted as necessary
(b)	7	All data recorded to appropriate degree of accuracy but improved body of information could have been collected.
(c)	8	Spg faultless and full and effective use of scientific vocabulary

The Formula of Magnesium Oxide

Magnesium is a soft, silvery metal. We were shown two reactions. If strongly heated it burns to form magnesium oxide

Magnesium + Oxygen = magnesium oxide.

Magnesium also reacts with acid to form hydrogen

Magnesium + Acid = Magnesium salt + Hydrogen (gas)

We could choose which one of these we would investigate. I chose to investigate burning of magnesium to form magnesium oxide.

Introduction:

We were shown that magnesium burns with a white light which is so strong it was done behind a sheet of dark glass. The magnesium oxide ash is a white powder. A lot of it was blown up in the flame, and most got spread on the bench. If we could collect it, we could weigh it to see how much magnesium and how much oxygen combined together.

Next we were shown that if the magnesium burned in a crucible with a lid, no smoke of ash escaped. But the magnesium didn't all burn, so you had to keep just lifting the lid a little bit to let in more oxygen. When the magnesium doesn't flare up any more it is done.

Theory

All magnesium atoms are the same as every other magnesium atom. All oxygen atoms are the same as every other oxygen atom – they all react in the same way and form the same number of bonds.

So, suppose that the formula of magnesium oxide is Mg_xO_y. Every molecule of magnesium oxide will have the same formula, so the percent of oxygen in the oxide will always be the same.

If we burn different weights of magnesium, the amount of oxide formed should always be directly proportional to the amount of magnesium burned.

Strategy:

I will burn different weights of magnesium and see how much oxide is formed.

Preliminary test:

The easy way to get different weights of magnesium is to measure out (roughly) different lengths. Then they can be weighed. We measured out one metre of magnesium ribbon and weighed it. It weighed 1.05g. This means each 10cm of ribbon weighs about 0.1g. If we take very small weights, there will be an error in the weighing (because we can only tell to the nearest 0.01g). So, the shortest length we will take will be 30cm. We will also test 40cm, 50cm, 60cm and 70cm.

We weighed an empty crucible, then cut off 30cm of magnesium ribbon and folded it into a tight knot and put it in the crucible then weighed again.

We put the crucible on a pipe-clay triangle and heated with a blue Bunsen flame. We could see a white light when the magnesium started to burn. When this faded out, we gently lifted the lid, but smoke came out so we put it down again. We did this four times until the magnesium didn't spark up when we lifted the lid. We let the crucible cool down, then weighed it again. Then we put it back onto the triangle and heated it again for 3 minutes. When it had cooled, we weighed it again. We kept on doing this until the weight didn't change any more.

What was weighed	Total weight (g)	Wt of magnesium (g)	Wt of oxide (g)
Empty crucible	11.12	-	-
Crucible + magnesium not heated	11.42	0.30	-
Crucible + magnesium heated once	11.57	-	0.45
Crucible + magnesium heated twice	11.61	-	0.49
Crucible + magnesium heated three times	11.62	-	0.50
Crucible + magnesium heated four times	11.62	-	0.50

11.61 is as near to 11.62 as you can get out balance, so it was really finished after two heatings.

We noticed in the first heating when you took the lid off, the magnesium sparkled a bit but didn't flare up or make smoke. We decided that we would heat once, lifting the lid, until no more smoke formed, then take off the lid and heat for three more minutes. This should be enough to get the magnesium all burned.

The lengths of magnesium we will use will be –

20cm, 30cm, 40cm, 50cm, 60cm, 70cm. We will do each length twice. Because there are two of us, we can take it in turns and heat the next crucible while the last one is cooling down.

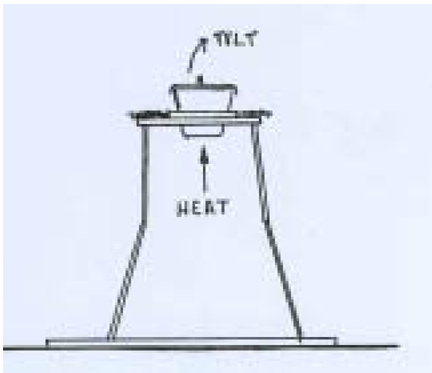
Method:

Put a heat-proof mat on the bench. Stand a tripod on it and put a pipe-clay triangle on the tripod.

Find a crucible with a lid that just fits over the top. Clean out any loose dust inside.

Weigh the crucible with its lid on and write down the weight.

Cut off the right length of magnesium ribbon. Wrap it up into a tight knot and push down in the bottom of the crucible so it will get really hot. Put on the lid. Weigh it.



Put the crucible on the triangle. Heat strongly with a blue Bunsen flame.

When the magnesium has finished flaring, use tongs to just lift one side of the lid a little bit. Don't let any smoke out. Put down the lid again and go on heating for 1 minute.

After about three times, the magnesium does not glow or flare up. Take off the lid, but go on heating for three minutes.

Using tongs, carefully put the crucible down on the mat to cool. While it is cooling, the next one can be heated.

Test by holding your hand above the crucible (**not** touching). If it is still hot, you can feel hot air rising. When it is cool, weigh again.

Gently scrape out all of the loose ash, ready for the next test.

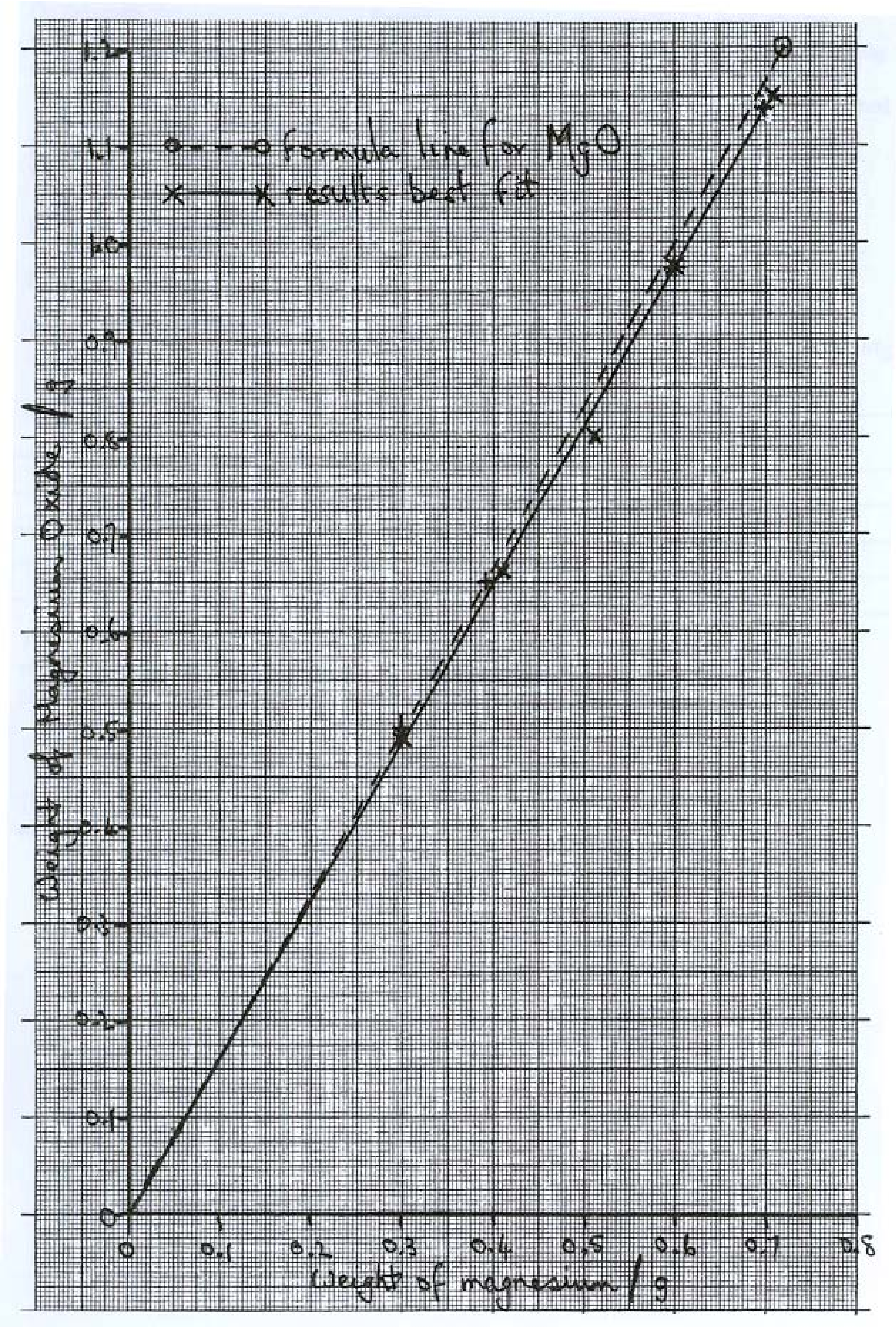
Safety:

Wear goggles. Keep loose clothes or hair away from the flames. Do not touch hot crucibles. Do not look directly at burning magnesium.

Results

Length of ribbon / cm	empty crucible / g	crucible = ribbon / g	crucible = ash / g	weight of Mg / g	weight of oxide / g
30	11.14	11.44	11.63	0.30	0.49
	use the results from preliminary test				
40	12.21	12.62	12.87	0.41	0.66
	11.17	11.56	11.82	0.39	0.65
50	12.25	12.76	13.05	0.51	0.80
	11.16	11.66	Crucible broke while heating		
60	12.24	12.84	12.21	0.60	0.97
	11.79	12.39	12.76	0.60	0.97
70	12.26	12.97	13.41	0.71	1.15
	11.82	12.52	12.96	0.70	1.14

Graph of amount of magnesium oxide made



Summary of the results:

On the graph showing weight of oxide formed against weight of magnesium burned, all of the points lie on or very close to a straight line through the origin (0.0g of magnesium would give 0.0g of oxide).

This shows that the mass of oxide formed is directly proportional to the mass of magnesium burned.

Interpreting the results:

The mathematical formula for a straight line is y = mx + c

If the line goes through the origin, then c = 0. So in this graph, y = mx

For the graph, y = (1.15 – 0) and x = (0.71 – 0) so m = 1.15/0.71 = 1.62

This can be compared to the result expected for different formulas. On the atomic weight scale, Mg = 24 and O = 16

Formula	Weight of magnesium	Weight of oxygen	weight of oxide	Ratio oxide/M
Mg_2O	24x2 = 48	16	64	1.33
MgO	24	16	40	1.67
Mg_2O_3	24x2 = 48	16x3 = 48	96	2.00
MgO_2	24	16x2 = 32	56	2.33

The line for MgO is drawn on the graph. It is very close for the best fit line for our results. This shows that magnesium oxide has always the same amount of oxygen to magnesium, and it is the right amount for the formula to be MgO – one atom of magnesium to one atom of oxygen.

$2Mg_{(s)} + O2_{(g)} = 2MgO_{(s)}$

This works because magnesium oxide is a pure compound. All of the molecules have the same numbers of each type of atom in them.

Evaluation:

We could tell the weights to 0.01g. Even for the shortest piece of magnesium, this was only about 3% of the real weight, so this would be the limit of how precise the results could be. This could only be improved by using a better balance to get weights to 0.001g.

The magnesium was not very clean and shiny, the surface was darker down the middle, so it may have had some of it turned to oxide already by reacting with air. This would make our results at the end a bit less than they should be.

The magnesium didn't burn up unless the lid was lifted a bit to let in more air. When we did this, bits of smoke sometimes came out. This would be dust of magnesium oxide, so it would also make the final result too low.

The bottom of the crucible got burned and it wasn't possible to get rid of all the ash after each test.

The graph shows that all of our final results were a little bit less than they should be, but only a very little bit, so it was a good result.

If we did more tests with really long bits of magnesium, the bigger weights could be weighed more accurately to confirm results.

Investigation 2 commentary

Title: Formula of magnesium oxide

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
S	Complexity and demand of task								✓		7
	Techniques used								✓		
	Autonomy and independence							✓			
C	Identification and control of interfering factors								✓		7
	Extend and design of data								✓		
	Quality/precision of manipulation								✓		
I	Graphical processing of data									✓	7
	Numerical processing data										
	Summary of evidence								✓		
	Explanations suggested							✓			
E	Evaluation of procedures						✓				4
	Reliability of evidence					✓					
	Reliability of conclusion				✓						
P	Description of work planned and carried out								✓		7
	Recording data								✓		
	Labelling tables and units										
	Observations										
	General quality of communication								✓		
	Overall total mark for the investigation										31

Aspect	Mark	Comment
Strand S: Strategy		
(a)	7	A task approached by the student involving some complexity and the need for reliable data.
(b)	7	Equipment and techniques justified although heating to constant mass could be developed more fully
(c)	6	Teacher demonstration used as a stimulus by the candidate to select and develop the investigation
Strand C: Collecting data		
(a)	7	Length of magnesium/heating to constant mass controlled
(b)	7	Measurements repeated to check for reliability but preliminary work did not establish range. Up to 70 cm length appears rather excessive?
(c)	7	Preliminary work used to adapt the method, data of good quality judged from inspection of the graph
Strand I: Interpreting data		
(a)	8	Graph drawn with suitably labelled axes, points plotted correctly, best fit line. All raw data plotted to show reliability. Theoretical line for MgO plotted with key.
(b)	7	Describes formal relationship in terms of the MgO formula using the data collected and compares with other ‘possible’ formulae
(c)	6	Justifies the MgO formula using relative atomic masses and ratios.
Strand E: Evaluation		
(a)	5	Identified limitations in the method but improvements involved only the use of longer lengths.
(b)	4	Although the match to the predicted values is noted, there are no specific references to close repeat values, or good fit of each data point to the line.
(c)	3	This aspect has been almost completely overlooked. There is plenty of evidence to support the reliability of the outcome, but little comment about it.
Strand P: Presentation		
(a)	7	Clear statement of task, practical procedures clearly described, not all aspects reviewed (e.g. use of air rather than oxygen etc.)
(b)	7	All raw data and repeats recorded to a suitable degree of accuracy although no units included in table 2
(c)	7	Spg very good, occasional inappropriate use of word ‘molecule’.

Investigation 3

How good are heart-burn tablets?

Our stomachs make hydrochloric acid to help digest food. Sometimes too much acid is made. One of the effects this can cause is heart-burn, a painful burning sensation in the chest.

Tablets for indigestion contain anti-acids to neutralise this acid and cure the pain.

One anti-acid that can be used is sodium bicarbonate (sodium hydrogencarbonate, bicarbonate of soda). I will find out how much sodium bicarbonate is needed to neutralise 20cm³ of 0.1M hydrochloric acid, then find out how much of the crushed-up anti-acid tablet will neutralise the same amount of acid. I will use the same amount of acid each time.

Method:

Apparatus:
- 25cm³ measuring cylinder
- 100cm³ beaker
- glass rod
- accurate balance
- filter papers
- wooden splint with the tip bent up
- sodium hydrogencarbonate
- hydrochloric acid (0.1M)
- methyl orange solution

Use the measuring cylinder to put 20cm³ of hydrochloric acid in the beaker. Add 2 drops of methyl orange. This goes pink in acid and will go orange or yellow when all the acid is used up. It is an indicator to tell when all the reaction is finished.

$NaHCO_3 + HCl = NaCl + H_2O + CO_2$

Put a heap of sodium hydrogencarbonate on a filter paper and weigh it. Use the splint to add a little bit of sodium hydrogencarbonate to the acid and stir with the glass rod.

Keep adding solid a little bit at a time until the acid in the beaker turns orange or yellow. Weigh the filter paper again to see how much has been used. Rinse out the beaker with water.

Repeat as many times as necessary to make sure of the right answer.

Now put 20cm³of the hydrochloric acid in the beaker and add 2 drops of methyl orange.

Crush up some indigestion tablets onto a filter paper and weigh it.

Add the powder a little at a time to the acid and stir until it goes orange or yellow.

Weigh the paper again to see how much has been used.

Results:

Using sodium hydrogencarbonate

Expt	Acid (cm3)	wt at first (g)	wt after (g)	wt used (g)
1	20	8.51	8.34	0.17
2	20	8.34	8.12	0.22
3	20	8.12	7.96	0.16
4	20	7.96	7.76	0.20
5	20	7.76	7.58	0.18

These are all quite close together and none of them are outliers. So all of the results can be used to calculate the best estimate.

Also there are enough results to show that the method is reliable.

Average = (0.17 + 0.22 + 0.16 + 0.20 + 0.18 / 5

= 0.93/5 = 0.186g

So if the table is made of pure sodium hydrogen carbonate, it will take 0.186g of it to make the acid go yellow.

Results with crushed up indigestion table

Expt	Acid	wt at first (g)	wt after (g)	wt used (g)
6	20	10.23	9.78	0.45
7	20	9.78	9.30	0.48
8	20	9.30	8.83	0.47
9	20	8.83	8.29	~~0.54~~
10	20	8.29	7.87	0.42

Four of these experiments gave close answers, but experiment 9 gave a different answer and was a lot more powder than the others. Experiment 9 was crossed out and not used for the best estimate.

Wt used = (0.45 + 0.48 +0.47 + 0.42) / 4

= 1.82 / 4 = 0.455g

Interpretation:

0.455g of the indigestion tablet uses up the same amount of acid as 0.186g of sodium hydrogencarbonate.

So, if the active chemical in the tablet is sodium hydrogen carbonate, the percentage of it is

(0.186 / 0.455) x 100% = 40.88%

This ingredient is put in to kill off acid in the stomach. The other ingredients may be to bind the powder together in the tablet, or to make it taste nice or look nice. Of course it might be a different anti-acid in the tablet, but whatever it is does the same as 40% of sodium hydrogencarbonate.

Evaluation:

The measuring cylinder was an easy way to measure out the acid, but you couldn't drain every drop of acid out. Perhaps we could have done the reaction in a measuring cylinder instead of using a beaker, then all the acid would have been used. Or we could use a syringe.

The results all except number 9 all agreed very well, which shows that they were reliable.

I am confident that this would be a good way to compare different types of indigestion tablet to see which gave best value for money. The experiment could be extended by testing more different types of tablets.

Investigation 3 commentary

Title: How good are heart-burn tablets?

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
S	Complexity and demand of task					✓					4
	Techniques used						✓				
	Autonomy and independence					✓					
C	Identification and control of interfering factors					✓					5
	Extend and design of data						✓				
	Quality/precision of manipulation						✓				
I	Graphical processing of data							✓			4
	Numerical processing data										
	Summary of evidence			✓							
	Explanations suggested						✓				
E	Evaluation of procedures				✓						4
	Reliability of evidence					✓					
	Reliability of conclusion					✓					
P	Description of work planned and carried out					✓					6
	Recording data						✓				
	Labelling tables and units										
	Observations										
	General quality of communication							✓			
	Overall total mark for the investigation										23

Aspect	Mark	Comment
Strand S: Strategy		
(a)	4	Limited precision involved adding a solid from a splint to an acid
(b)	5	Uses balance, measuring cylinder and indicator to collect a reasonable range of data
(c)	4	From evidence provided task closely defined by the teacher but carried out with little further guidance.
Strand C: Collecting data		
(a)	4	Uses constant volume of acid and same number of drops of indicator but not how much solid added each time
(b)	5	range of data collected is limited but repeat measurements taken
(c)	5	Simple technique lacking in precision
Strand I: Interpreting data		
(a)	6	Simple averages and percentage of active ingredient calculated
(b)	2	Notes difference between NaHCO3 and indigestion tablet
(c)	5	Writes equation of the reaction, recognises other ingredients in tablet causing different results
Strand E: Evaluation		
(a)	3	Comments on limitations in simple way e.g. draining of measuring cylinder
(b)	4	Identifies anomalous result
(c)	4	Links quality of data to confidence level in conclusion and also suggests extending investigation to other types of tablet
Strand P: Presentation		
(a)	5	Purpose of work identified, practical procedures described
(b)	6	Raw data and repeat measurement recorded with appropriate units
(c)	6	Spg sound and appropriate use of scientific vocabulary

Investigation 4

Energy from Fuel

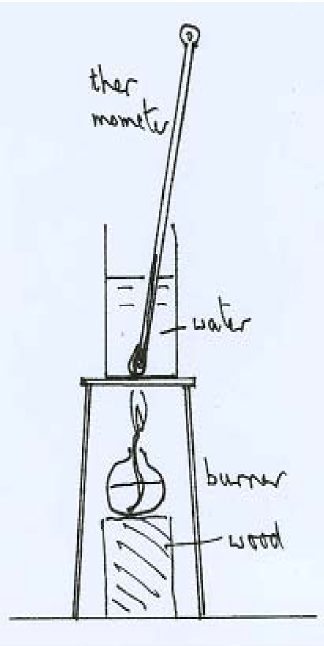
Fuels are usful for burning to heat things. We will burn alcol to make water hot.

To find out how much heat>

When alcol burns, chemical bonds are made, which makes energy to be a usful fuel. I will burn different amounts of alcol to find out how much it can heat water.

Method

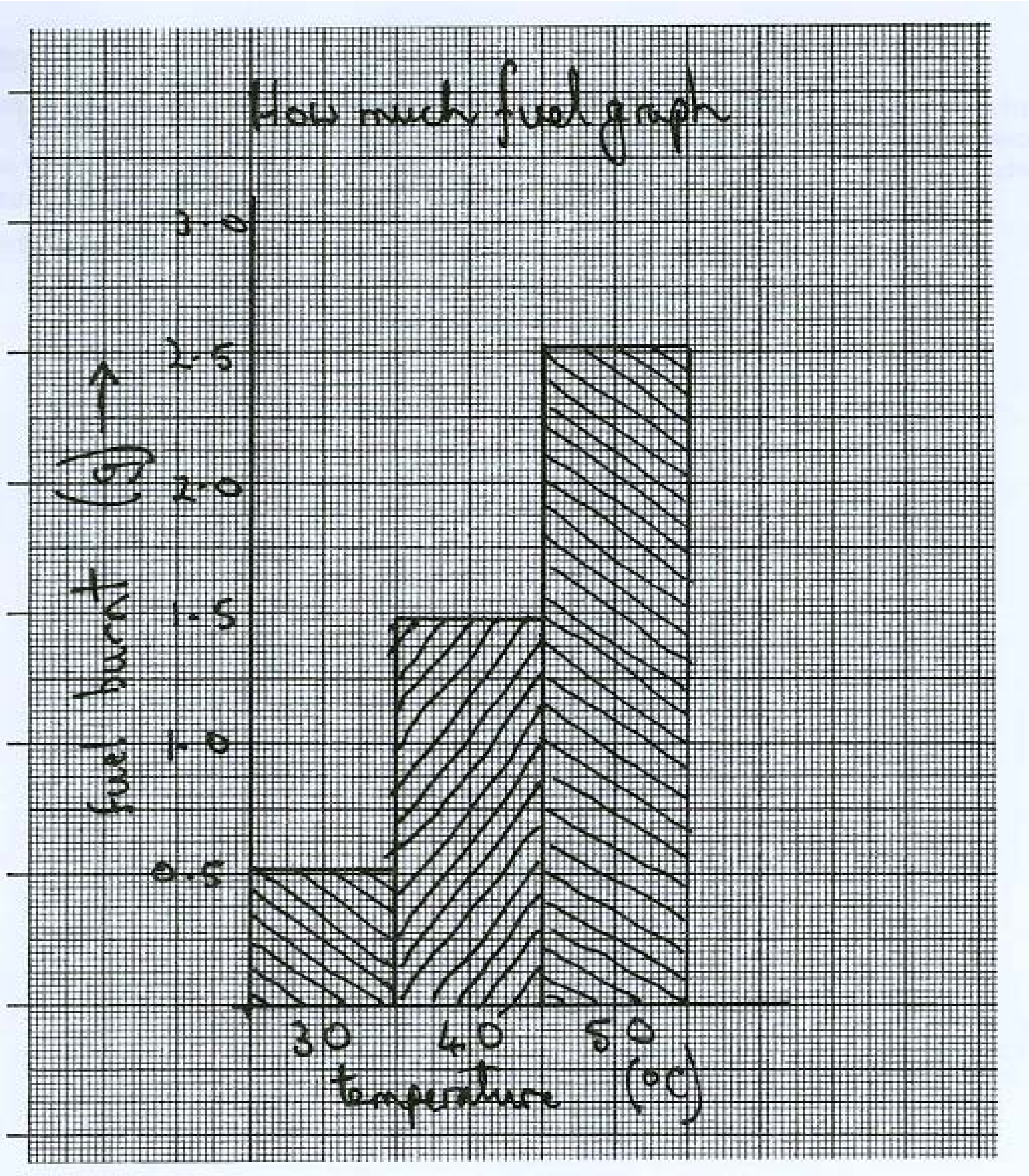
To make it fair, use the same amount of water each time in a tin. Put it over a burner with alcol and light the flame. When it gets hot to the right temperture, blow out the flame. Weigh the burner before then after each time to see how much alcol has gone.



Use 200cm3 of water each time. Start at same temperture each time. Use new water each time.

Results

Experiment number	Hot water degrees C	start weight	end weight	alcol used up	average (g)
1	30	29.55	29.01	0.54	0.55
2	30	29.01	28.44	0.57	
3	40	28.44	26.64	1.8	1.49
4	40	26.64	24.82	1.18	
5	50	31.55	29.04	2.51	2.54
6	50	29.04	26.47	2.57	



Conclusion:

When more alcol was used up, the water got hotter. The amount of heat is more if more fuel is burnt.

To go up 10 deg from 30 to 40 needed 0.94g of alcol which is nearly one gram.

To go up 10 deg from 40 to 50 needed 1.05g of alcol which is nearly one gram.

The amount of extra heat is proportional to the amount of extra fuel.

This worked because if more alcol is used, more chemical bonds are made which means more energy.

Evaluation:

These experiments worked well because we used an acurat balance and the results came out right. The heat would have been better if we could stop people walking past because it made the flame wobble and so some of the heat got blown away. This might be why the results for 50 deg were different, but I made an average so it came out right. You could do this again with a bigger tin to see if it needed more fuel.

Investigation 4 commentary

Centre Number : Candidate Number: Student:

Title: Energy from fuel

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
S	Complexity and demand of task					✓					
	Techniques used					✓					4
	Autonomy and independence					✓					
C	Identification and control of interfering factors						✓				
	Extend and design of data					✓					4
	Quality/precision of manipulation					✓					
I	Graphical processing of data					✓					
	Numerical processing data										
	Summary of evidence					✓					4
	Explanations suggested					✓					
E	Evaluation of procedures					✓					
	Reliability of evidence			✓							2
	Reliability of conclusion	✓									
P	Description of work planned and carried out					✓					
	Recording data						✓				4
	Labelling tables and units										
	Observations										
	General quality of communication					✓					
	Overall total mark for the investigation										18

Aspect	Mark	Comment
Strand S: Strategy		
(a)	4	Approached in a simple /routine way with a limited range of data collected
(b)	4	Basic equipment selected and only one alcohol burnt to produce a limited range of data to find out if more alcohol burnt the more energy produced.
(c)	4	From evidence available task defined by teacher but carried out by student with little further guidance.
Strand C: Collecting data		
(a)	5	Uses standard amount of water, same initial temperature but distance of water above tin and also draughts not controlled.
(b)	4	Range rather limited but repeats measurements taken
(c)	4	Data of variable quality with an obvious error in one of the results
Strand I: Interpreting data		
(a)	4	Simple bar chart constructed
(b)	4	Simple trend identified
(c)	4	Relates conclusion to scientific ideas with little detail
Strand E: Evaluation		
(a)	4	Recognises limitations in method but no improvements suggested
(b)	2	Claims for accuracy - 'made an average so it came out right'
(c)	0	No confidence level in the conclusion based on results/technique
Strand P: Presentation		
(a)	4	Main purpose of the investigation is clear but limited detail
(b)	5	Raw data included but units missing from table
(c)	4	Spg is variable and limited use of scientific vocabulary

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Water pressure and water flow

If a container of water has a hole or small exit at the bottom, the weight of water causes a pressure which makes the water flow out. In this investigation I find out how rate of flow of water us affected by the pressure of water.

The apparatus is made from a cleaned out 400g soup tin. The lid pulls off completely so that water can be poured in easily. A neat round hole was made in the bottom by putting it upside down over a wooden cylinder, then punching a nail through the bottom of the can as near the middle as possible.

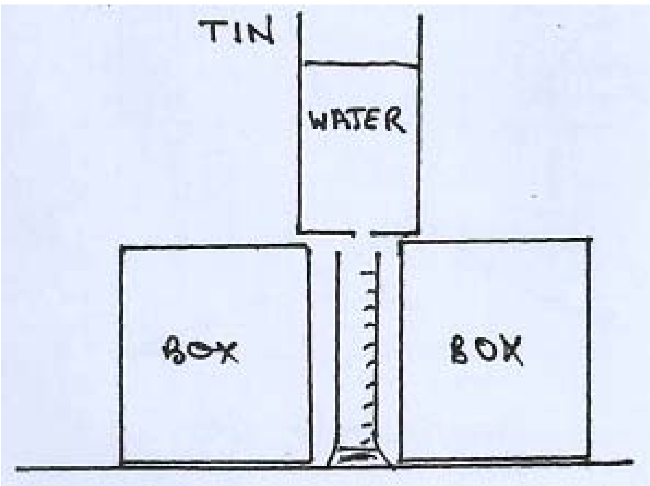
I tried a few times seeing how long it took for the water to run out. At first it was too slow, so I made the hole bigger with a bigger nail.

The method was to fill the tin with 250 cm3 of water while I had my finder under the hole. Then the tin was put over a measuring cylinder and timed while the water ran out. The tin wouldn't balance on the cylinder and if I held it, I couldn't hold the watch and write down the answers, I worked with a partner. Also, we got two cardboard boxes and stood the tin on them so we didn't need so many hands. The measuring cylinder just fitted in between the boxes.

Method

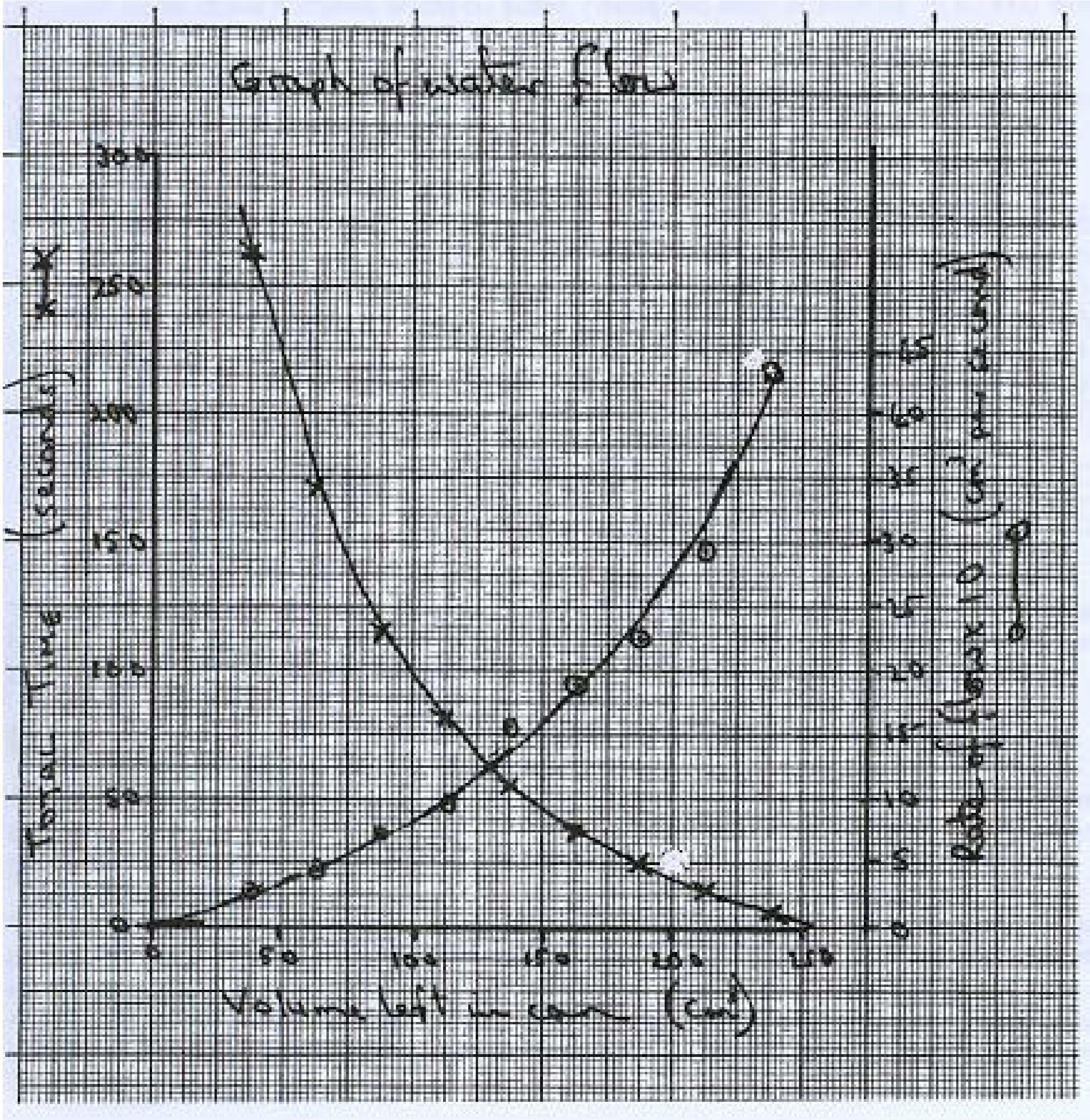
I put two boxes on the bench and balanced the empty tin on top. I held the tin with one finger pressing against the outside of the hole in the bottom. With a 250 cm3 measuring cylinder I put 250 cm3 of water in the tin. Then I put the empty measuring cylinder underneath the tin ready.

I took my finger off the hole and at the same time started the stop-clock. My partner watched the water level in the cylinder and I watched the stop-clock. Each time the water passed a 25 cm3 mark, I wrote down the time taken from the start of the experiment.



Results

Volume of water collected (cm^3)	Time in seconds to collect this much water (s)				Volume of water left in tin half-way between times
	Experiment 1	Experiment 2	Experiment 3	Average	
25	5.68	5.84	5.75	5.76	238
50	14.45	14.30	14.06	14.27	213
75	25.34	~~35.44~~	25.54	25.44	188
100	39.0	38.7	38.1	38.67	163
125	54.9	54.6	54.7	54.63	138
150	80.6	80.5	80.1	80.47	113
175	114.1	114.3	113.9	114.12	88
200	170.8	170.6	170.7	170.72	63
225	264.0	263.0	263.0	263.~~10~~ 3	38
250	The last bit of water was so slow we didn't count it				



Conclusion

The graph showing time for the water to flow out shows that the water flows faster if there is more of a ‘head’ of water above the hole. Because the line slopes downwards and is curved, I can’t say that the rate of flow is proportional to the height of water above the hole.

Gravity pulls water (and everything else) down. So, the water at the top of the tin has weight (a downward force) and presses on the water underneath. This also has weight, so the pressure on the next layer down is more and so on. The extra pressure caused by the ‘head’ of water in the tin is proportional to the height of the column of water. So if the water in the can is twice as deep, the pressure on the hole will be twice as much, so the water would run out twice as fast.

This means that the rate should be proportional to the amount of water left in the can. But I haven’t measured rate, I have measured how long it takes, so my graph is upside down and not straight.

Because of this, I decided to work out how fast the water was flowing out at each stage. Each stage shows the time for 25 cm3 of water to flow out. So 25/time=rate of flow in cm3 per second. Because some of the numbers would be small, I multiplied each answer by 10 so they would show up better on the graph.

I wanted the average flow rate and this would be at the middle of each time, so this is why I used the middle average figure for the amount of water left in the tin.

Time interval	Average volume of water in tin (cm^3)	Time taken for 25 cm^3 to run out (s)	10 x Rate of flow (cm^3 per second)
1^{st}	238	5.7~~5~~	43.5
2^{nd}	213	8.5~~2~~	29.3
3^{rd}	188	11.1~~7~~ 2	22.4
4^{th}	163	13.2~~3~~	18.9
5^{th}	138	~~15.96~~ 16.0	15.7
6^{th}	113	25.8~~4~~	9.7
7^{th}	88	33.~~85~~ 7	7.4
8^{th}	63	56.6	4.4
9^{th}	38	92.~~38~~ 6	2.7

This graph slopes up, because if there is more water in the tin, there is more pressure pushing through the hole, so the rate of flow is faster. I thought it would be a straight line, because I thought the rate of flow would be proportional to the height of water in the tin.

Evaluation

Although we wiggled the nail a lot, it wasn’t possible to get a really smooth round hole, and the edges weren’t quite flat. This might have affected how the water ran out and could be why the graph isn’t straight.

The level of water in the measuring cylinder was moving all the time and it was very difficult to decide just when it went past the 25 marks. Because the stop-clock was going all the time I couldn’t tell the last number, so we put down to just 10th of a second. Also, the water splashing in made the surface bounce up and down and splash, so it was hard. The first two experiments gave very bad results, then we found that if we got the tin position just right, the water would run down the inside of the glass of the measuring cylinder and it didn’t splash so much. So we ignored the first two experiments and did three more.

The third result in the second experiment was wrong. I think I wrote down the wrong time. So we didn’t count that one in the average. All the other results agreed with each other, so the range of results each time was small which means the results are reliable.

I am not sure why the graph is not straight, but I am very confident that with so many good results I can say certainly: “The deeper the water above the hole, the faster it will run out”

To get a better set of results, it would be better to make the hole in the bottom of the tin with an electric drill because it would be smoother and rounder. You could also put the measuring cylinder on an electronic balance that sends the weight to a computer so that you could make a graph of weight of water against time straight away. Then you don’t need readings just every 25cm3 you could have them all the time.

Investigation 5 commentary

Title of investigation: Water pressure and water flow

Strand	Aspect of performance	Level of performance related to mark scale									Mark for Strand
		0	1	2	3	4	5	6	7	8	
S	Complexity and demand of task							✓			6
	Techniques used								✓		
	Autonomy and independence							✓			
C	Identification and control of interfering factors							✓			6
	Extend and design of data							✓			
	Quality/precision of manipulation							✓			
I	Graphical processing of data								✓		6
	Numerical processing data										
	Summary of evidence						✓				
	Explanations suggested								✓		
E	Evaluation of procedures							✓			5
	Reliability of evidence							✓			
	Reliability of conclusion					✓					
P	Description of work planned and carried out							✓			7
	Recording data								✓		
	Labelling tables and units										
	Observations										
	General quality of communication								✓		
	Overall total mark for the investigation										30

Aspect	Mark	Comment
Strand S: Strategy		
(a)	6	A straightforward task approached by the student but which involved gathering a good range of data
(b)	7	Student selected and adapted the appropriate equipment
(c)	6	From the evidence provided the task is defined by the student from a more general brief
Strand C: Collecting Data		
(a)	6	Volume of water and size of hole controlled
(b)	6	No preliminary tests to establish range however regular repeats
(c)	6	Sound techniques and data of good quality
Strand I: Interpreting Data		
(a)	7	Graph plotted correctly with best fit line and clear key for multiple data set but no error bars.
(b)	5	Pattern identified but no quantitative relationship attempted
(c)	7	Conclusion explained using good scientific knowledge and understanding
Strand E: Evaluation		
(a)	6	Limitation in the technique recognised and improvements suggested e.g. drilling hole of constant diameter and continuous monitoring
(b)	6	Anomalous result recognised and scatter between repeats used to assess reliability
(c)	4	Relates reliability in the data to confidence level of the conclusion
Strand P: Presentation		
(a)	6	Clear purpose and procedures described
(b)	7	Raw data and repeat measurements recorded to a suitable level of accuracy.
(c)	7	Spg very good and appropriate scientific terminology used.

Appendix D: Cover Sheet Including Record of Marks Awarded (A220)

	Additional Science J631 ***Unit A220 Investigation***	**200_**

Student Name: …………………………………………… Candidate No: ………………

Title of Investigation: ………………………………………………………. Date: ……………………

Marked by: ………………………………………………. Centre No: …………………..

This completed form should be attached to the front of the investigation report

Strand	**Aspect of performance**	**Level of performance related to mark descriptors**									**Mark**	**Moderator**
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
S	Complexity & demand											
	Techniques chosen											
	Autonomy/independence											
C	Control of other factors											
	Range & design of data											
	Quality of manipulation											
I	Graphical display											
	Processing data											
	Conclusions											
	Explanations											
E	Evaluating procedures											
	Evaluating the data											
	Judging reliability											
P	Description of the work											
	Recording data											
	Labeling and units											
	Qualitative observations											
	Quality of communication											

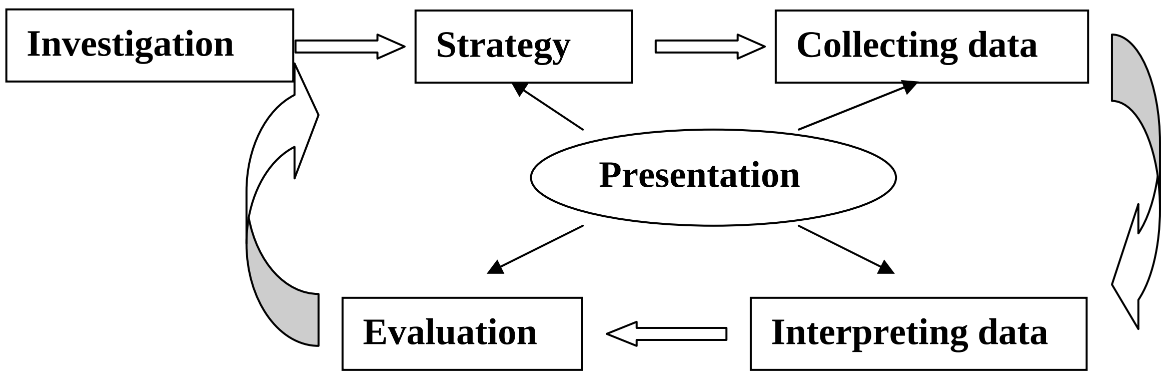
Moderator comments	**Total mark (sum of strand marks)**		

Appendix E: Guidance for Students' - Investigations

During this science course, you will be asked to design experiments to investigate many practical questions. The assessment of the course includes marks for how well you can complete an investigation. Any of the investigations you do could be used to judge these marks. The mark you are given at the end of the course will be the total mark for your most successful investigation.

This part of the investigation counts for one-third of the total marks for the whole subject, so it is really worth-while learning how to carry out and record investigations as well as possible.

For the assessment, marks are awarded for each of five 'strands' in the investigation:



Each strand is marked out of 8 marks so the maximum mark possible is 40.

Read through and consider the following advice and guidance.

Strategy (Strand S)

Do not rush this part; your whole investigation depends on how good your strategy is!

- Your teacher will introduce investigations which could be used for assessment. You may be allowed some choice of what to investigate, and you have to decide how to set about the task!
- Look at the information in the topic(s)/module(s) that is (are) relevant to your investigation. Find out what sort of things (factors) might affect the results you get.
- If you ask your teacher what to do then you might not be able to obtain the highest marks in this strand. The more ideas you have yourself the higher marks you might be able to achieve. If you write the title to your investigation in terms of a question this sometimes helps to provide a clear focus for your work and makes you answer it when writing your conclusion!

Initial method

- Think about the factors involved; select the one you are going to change and how you are going to control the others. Think about the range of values you are going to use for the factor that you might change.
- Think about how to make sure that the data you collect is accurate and reliable so that you have good quality evidence on which to base your conclusion. Write down your thoughts.
- Do some preliminary work to get a 'feel' for what you will do before committing yourself to a detailed plan.
- Include reasons why you have selected the particular apparatus that you have done.

- Draw diagrams as appropriate. If you are only using simple apparatus and techniques then you may be limiting yourself to the maximum mark that you can obtain.
- Record your results, do an initial interpretation and evaluation and modify your method as appropriate.

Collecting Data (Strand C)

Make sure you keep a record of all your results, including results of preliminary tests

- Describe the factors involved.
- Identify the factor you are going to investigate and record the measurements of the others that you have controlled.
- On the basis of your preliminary work include the range of values you have chosen for the factor you are changing.
- Make sure that the data you collect includes enough measurements, is accurate and reliable, repeating any measurements that you think necessary, so that you have data of the best quality.
- Record your data in a suitably labelled table, paying attention to units and numbers of significant figures.
- Whilst you are doing the experiment think about any problems that you are having and note them down for the evaluation stage.

Interpreting Data (Strand I)

Process your data, identify patterns, draw conclusions and explain them using your scientific knowledge and understanding

- Process your data by doing some analysis using calculations and/or plotting your data on a line graph. Consider the errors on each point, drawing error bars if you can before you draw a line of best fit. Is the best fit line straight, a curve or something else? You can produce a graph using a computer but it is probably best to draw the line of best fit yourself. If a line graph is not appropriate then draw a histogram, bar chart or scatter graph.
- Record trends and patterns in your data doing mathematical calculations if this helps in any comparisons that you make.
- Make a conclusion and try to express it in a quantitative way if this is appropriate.
- Look carefully at the scatter in your data to see if it limits your conclusion in anyway.
- Explain your conclusion using your scientific knowledge and understanding.

Evaluation (Strand E)

This area is generally regarded as the most difficult. It is probably best to focus on your data and methods separately and then discuss any limitations and confidence levels you have in your conclusion pointing out what further data you could collect.

Evaluating the data that you have collected

- How many results did you collect – were these enough to draw a conclusion?
- How accurate were your results?

- Do all your results clearly fit a trend/pattern or do some look wrong e.g. look at your graph, the best fit line and identify any anomalous results.
- Are there any results that you think should be repeated?
- If some of your results didn't fit the trend/pattern can you explain why?
- Look at the differences between your repeat measurements. Are the differences important or do you think your results are sufficiently reliable?
- Does your conclusion explain all your results or did you leave some out?
- Have your results covered a big enough range to support a firm conclusion?
- Have you collected a sufficient number of accurate and reliable results to support a firm conclusion?

Evaluating your method/procedure

- Did you have any problems with your method?
- Was your equipment appropriate for the task?
- How well did you control the other factors that you didn't investigate – did they vary during the experiment?
- How precise were your results e.g. did you judge by eye or use an instrument?
- How big were the divisions on the scale of the equipment and were they adequate for the readings needed?
- How accurate can the readings be from the equipment you used?
- What improvements to your method would you suggest to make the results more accurate and reliable?

Reliability of conclusion

- What extra measurements might you do to make your conclusion more certain?

Presentation (Strand P)

Your report must be organised and presented clearly with full details of all aspects of your investigation using relevant scientific words with good spelling, punctuation and grammar.

- Make sure that your tables of data have suitable headings with units and your data is correctly recorded to the appropriate degree of accuracy with the correct numbers of significant figures.
- Make sure your graph has a title, is of a suitable size (no miniature Excel graphs), labelled axes with units and points correctly plotted.

Investigation checklist

Strategy	• Topic(s) reviewed and investigation suggested • Investigation is of appropriate complexity • Strategy includes attention to accuracy and reliability • Equipment and techniques are justified
Collecting data	• Factors involved identified and either controlled or varied • Range of values of factor under investigation established from preliminary work • Modifications to method made if required • Data collected is sufficient, accurate and reliable • Anomalous results repeated
Interpreting data	• Data is processed using graphs or mathematical methods • Graphs have axes labelled, correct units, accurate plotting, line of best fit and estimate of errors • Mathematical methods involve comparisons between results and possibly statistical or inverse relationships • Trends and patterns identified in the results • Qualitative or quantitative relationships stated as a conclusion • Limitations to the conclusion due to scatter in results are identified • Conclusion explained using scientific knowledge and understanding
Evaluation	• Problems in method affecting quality of results are described • Improvements to method are suggested and justified • Results are assessed for accuracy and reliability • Anomalous results are identified and explained • Level of confidence in the conclusion is described
Presentation	• Aim of investigation is clear • Report is well organised with all procedures described in detail • Observations and measurements are fully and clearly recorded with labelling and units correct • Data recorded to appropriate degree of accuracy • Scientific terminology is relevant and correctly used • Spelling, punctuation and grammar are correct

Appendix F Support for Very Weak Students to Carry out an Investigation

Value of preparation for weak candidates

The preparation of extra materials and the careful administration needed to support very weak candidates should be given a high priority within the Science Department, because these resources can also be used in cases of extended staff absence, or for candidates who miss the normal opportunities for preparing their coursework in lessons. As the coursework is worth a high proportion of the marks for the whole GCSE it is very important that all candidates attempt every component.

Organising the work

A strict timetable improves the pace of work. A clear, achievable outcome for each lesson builds confidence and makes supervision and guidance much more manageable. An A4 or A3 tick chart for each group can be displayed and updated to confirm completion of each outcome and to indicate work that is incomplete or missing.

Collecting all work in each lesson for checking helps to ensure an appropriate rate of progress. Rough work should also be collected as it may prove useful later. Support staff can help to ensure that all work is named and handed in. A brightly-coloured and clearly labelled folder for coursework emphasizes its value and significance.

Weak candidates need a familiar topic for their investigation so that they know how to carry out the practical task and how to interpret the results.

Worksheets with detailed writing frames can be used to guide candidates through each stage in their work, but the work for assessment must be their own.

It is important to check that individual support staff understand the internal assessment; and especially that they understand that it is the candidates' own work that is being assessed, so that doing work for them, may stop them from getting marks. It would be helpful to have clear instructions on how to support individuals who may have particular difficulties with practical tasks.

Choosing a topic

The work should involve a very simple practical task. The meaning of the results should be very clear to the candidates; for example, if you soak a piece of potato in a glucose solution, its mass changes. It is better to avoid tasks where candidates have to think about the meaning of the quantity they measure; for example, measuring pH; because if they do not understand the scientific idea, they cannot interpret the results.

Organising the work

Allow a series of at least six lessons to prepare for the investigation. In this time several candidates are likely to have short absences, and the rate of progress will vary, so careful management is needed.

One example of a suitable investigation is to study a 'leaking container'. The rate of flow of water out of a hole in a container depends on the water level above the hole. This works well with a large (300 ml) polystyrene drinking cup with a small puncture hole in its base. It is filled with water and the water which leaks out in 30 seconds is collected when the cup is full, half full and almost empty. The time of 30 seconds does not demand quick reactions for the timing and collection, but is not too long for keeping attention on the task. Water with food dye added could be provided for easier measurements.

In the introductory lesson, the scientific ideas should be revised. In this case these would be ideas about pressure. It would be sensible to give the opportunity to practice using appropriate vocabulary such as ‘pressure’, ‘depth’, ‘force’ and ‘gravity’. The idea of ‘rate’ is very difficult so it is better to talk about how much water leaks out in a set time. A demonstration such as the ‘water fountain’ could be used to link these ideas with the ideas of the investigation.

A low-level explanation of the observed effects can be based on prior experience, so the introductory lesson should always include demonstrations of the effect to be studied and reminders of any everyday applications which may be familiar to the students.

Strand S: Strategy

A task like this can be based on highly structured worksheets. If the candidate follows these instructions, they can gain credit at 2 marks if the work is of very limited precision or reliability.

Strand C: Collecting Data

Each candidate must record their own data. Make sure no-one relies on a friend to do this, and ensure that the data is collected for safe keeping. If candidates follow the given practical procedure and record their own results, they may earn 2 marks in Strand C.

It is advisable for the teacher to prepare some sets of data for use in Strands I and E as it is likely that the data collected by weak candidates may not be good enough to interpret.

Strand I: Interpreting Data

The candidate’s own work should ideally be used for this, but it may be of very poor quality; the teacher’s data should then be used as well as, or instead of, the candidate’s results.

Aspect (a): graphical or numerical processing of data

The candidates must display results in a table, chart or graph. A template for a graph, with the appropriate axes and scales, can be prepared by the teacher and duplicated for use by weaker candidates.

Aspect (b): summary of evidence

The candidate needs to compare the results from two different situations. Two individual results can be compared.

The differences in the results must be recorded.

Aspect (c): explanations suggested

Weak candidates struggle to explain their observations using scientific knowledge. They should be encouraged first to write an explanation based on previous experience. When that has been completed, they could describe simply the scientific idea underpinning the test.

In the case of the leaking can, this would be the fact that pressure increases with depth and that that more pressure causes a faster flow.

If they succeed in relating the conclusion to scientific ideas the score would be higher than a mark of 2.

Strand E: Evaluation

Aspect (a) evaluation of procedures

Most candidates find it hard to evaluate their procedures and very weak candidates may be unable to make a comment about how the data was collected. They could be helped by being given incomplete sentences to finish, and rewarded with a single mark for doing this successfully.

Aspect (b) reliability of evidence

Candidates can be prompted into writing an opinion by being given a menu of options, for example, ‘I think my data is very reliable / reliable / not very reliable’. They could then be asked to give a reason for their opinion. A sensible opinion, which does not refer appropriately to the data, would be worth 2 marks.

Aspect (c) reliability of conclusion

A question such as “Are you sure your conclusion is right?’ can be used to help candidates consider the reliability of their conclusion. This can be followed with other questions, for example, ‘What did you do, to make sure you got a good result?’

Pilot Centres have found the Evaluation to be the hardest part of the Investigation and weak candidates have often scored 1 in this Strand.

Strand P: Presentation

Very weak candidates will need worksheets or writing frames to remind them to include all aspects of their task in their report. At the level of two marks, complete descriptions are not expected.

The assessment is on the communication skills used to present the work. Many candidates like to make their work look pleasing, and this can encourage them to work carefully. However, they are not assessed on the appearance of the report.

Aspect (a) description of work planned and carried out

The description of the work has been attempted, but is incomplete.

Aspect (b) recording of data

The data has been recorded, but labelling, units and observations may be incomplete.

Aspect (c) general quality of communication

Candidates should be encouraged to use the scientific words relevant to the test, and to check their work for spelling errors. However, at the level of 2 marks there is no penalty if they are unsuccessful.

Appendix G: Advice to Centres on Preparation of Sample for Moderation

Specification J631: Assessment unit A220

This is to remind you of the stages in preparation of a sample of coursework for moderation. If you have any further queries about coursework, or any aspect of the assessment, please contact the science team, tel. 01223 553311.

The notes which follow summarise the materials and evidence required for moderation of the coursework assessment, and explain how to use the documentation which is also enclosed.

Unit A220: Practical Investigation

Each candidate is required to complete a practical investigation. The evidence for this will consist of a written report. Candidates may complete more than one Investigation, but the final mark is the mark for the best single piece of work. It is **not** permitted to aggregate part marks from different pieces of work.

The centre will be provided with self-carboning mark sheets (MS1). The top copy of the completed MS1 form is sent to OCR, the second copy to the moderator, to arrive not later than 15th May, and the third copy is retained by the centre.

The moderator will ask for the work of a sample of candidates. The work of these candidates should be sent as quickly as possible to the moderator. The list will identify the names and candidate numbers for each candidate whose work is required by the moderator. This list may be kept to provide a record for you of what work has been sent.

The sample sent to the moderator should contain:

- Brief notes about the activities used for assessment.
- A description of procedures used within the centre to ensure internal standardisation of marking
- The sample of work (one investigation) for each candidate in the sample.
- A completed cover-sheet for each candidate in the sample.

Recording of marks for assessed work

The cover sheet may be photocopied to make sufficient copies to provide for each candidate in the sample. The sheet should be used by the teacher to record marking decisions when marking the work. The pages in each piece of work should be stapled together. A paper-clip provides a convenient way of linking the piece of work and the completed mark sheet.

It is essential that a completed sheet is sent for each sample of work which is called for moderation. Enter the centre name and number and the candidate name and number at the top of the sheet.

The sheet also includes spaces which should be left blank. These will be used as a working document by the moderator when checking the work. The sheets will be retained by OCR as a complete record of all judgments related to the moderation.

The centre should also keep its own record of the work done and marks awarded.

'Double counting' of marks for the data exercise

For candidates who are also taking Science A (J630) it is permissible to use the investigation to provide the marks for data interpretation and evaluation. If the same piece of work is called for from both specifications, tick the space on the cover-sheet to indicate this. Copies of the work should be included in both Single and Additional Science samples of work.

Special consideration candidates

If a special consideration application regarding coursework marks has been made for any candidate, the work of the candidate(s) concerned should be added to the sample, with a note to explain that they are for special consideration.

The sample of work will be returned to the centre, normally early in July. A report on the moderation will be sent with the notification of results.

Appendix H: Candidate Authentication Statement

Candidate Authentication Statement

The completed form should be retained within the Centre and should not be sent to the moderator or OCR unless specifically requested.

NOTICE TO CANDIDATE

The work you submit for assessment must be your own.

If you copy from someone else or allow another candidate to copy from you, or if you cheat in any other way, you may be disqualified from at least the subject concerned.

1. Any help or information you have received from people other than your subject teacher(s) must be clearly identified in the work itself.
2. Any books, information leaflets or other material (e.g. videos, software packages or Information from the Internet) which you have used to help you complete this work must be clearly acknowledged in the work itself. To present material copied from books or other sources without acknowledgement will be regarded as deliberate deception.

Declaration by candidate

Centre name ________________ Centre No ☐☐☐☐☐

Session ________________ Year ☐☐☐☐

Specification of Unit title ________________

Candidate Name ________________ Candidate Number ☐☐☐☐

I have read and understood the **Notice to Candidate** (above). I have produced the work without any help from other people apart from that which I have declared in the work itself.
I have acknowledged all source materials in the work itself.

Candidate's signature:

Date:

Notes:

The Candidate Authentication statement once completed should be stroed securely within the centre. A copy of this authentication form must be available upon request for each coursework/portfolio submission.

Standard Candidate Autehntication Statement

Appendix I: Centre Authentication Form

OCR
RECOGNISING ACHIEVEMENT

Centre Authentication Form

OCR Advanced GCE GCSE Entry Level

One copy of this form must be completed for **each** unit or coursework component and signed by the appropriate person(s). The completed form **must** accompany the coursework or portfolios submission to the moderator/examiner or be inspected by the visiting moderator for Entry Level, GCSE, GNVQ, VCE and GCE qualifications.

It is now a requirement of the Code of Practice that this authentication form is signed.

'***Authentication of candidates' work*** – *The internal assessor must present a written declaration that the candidates' work was conducted under the required conditions as laid down by the specification.*'

Centre Name ______________________ **Centre No** ☐☐☐☐☐

Specification or Unit title ______________________

Qualification or Unit number/component code ☐☐☐☐☐☐

Session ______________________ **Year** 2 0 0 ☐

Moderated unit
(Please tick box if yes) ☐

In this case this form must accompany the sample posted to the moderator or inspected by the visiting moderator

or

Examined unit
(Please tick box if yes) ☐

In this case this form must accompany the packet of coursework which is posted to the examiner or assessed by the visiting examiner.

Signature(s) of internal assessor(s) – i.e. person(s) responsible for carrying out internal assessment and/or supervision (in the case of examined coursework) of work:

I/We the undersigned confirm that the candidates' work was conducted under the required conditions as laid down by the specification.

Signature:.. Print name:..

Signature:.. Print name:..

Signature:.. Print name:..

Please continue on a separate sheet if required.

In order to support internal assessors in authenticating their students' work an **example** of a standard Candidate Authentication Statement is provided on the OCR Website (www.ocr.org.uk). Alternatively centres may wish to continue to use their own internal arrangements for candidate authentication, but these must provide equivalence to the standard Candidate Authentication Statement.

Notes

In the case of private candidates or distant tutored candidates, the centre must ensure that:

- *the tutor/teacher has acquainted themselves thoroughly with the general standard of candidates' work before accepting coursework for Internal Assessment. Work submitted by candidates that is atypical or inconsistent with their general standard may raise concerns over authenticity.*
- *sufficient on-going regular monitoring of the candidates' examination coursework has taken place.*
- *Centres are reminded that they must comply with restrictions that may apply to entries e.g. the exclusion of Private candidates from a specification.*

CCS160 Revised July 2005 **Centre Authentication Form**

Oxford Cambridge and RSA Examinations

Appendix J: Health and Safety Information

In UK law, health and safety is the responsibility of the employer. For most centres entering candidates for GCSE examinations this is likely to be the Local Education Authority or the Governing Body. Teachers have a duty to co-operate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 1996 and the Management of Health and Safety at Work Regulations 1992, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must provide a risk assessment.

A useful summary of the requirements for risk assessment in school or college science can be found in Chapter 4 of Safety in Science Education. For members, the CLEAPSS guide, Managing Risk Assessment in Science offers detailed advice.

Most education employers have adopted a range of nationally available publications as the basis for their Model Risk Assessments. Those commonly used include:

- Safety in Science Education, DfEE, 1996, HMSO, ISBN 0 11 270915 X;
- Topics in Safety 3rd edition, 2001, ASE ISBN 0 86357 316 9;
- Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;
- Hazcards, 1995 with 2004 updates, CLEAPSS School Science Service*;
- CLEAPSS Laboratory Handbook, 1997 with 2004 update, CLEAPSS School Science Service*;
- CLEAPSS Shorter Handbook (CLEAPSS 2000) CLEAPSS School Science Service*;
- Hazardous Chemicals, A manual for Science Education, (SSERC, 1997) ISBN 0 9531776 0 2.

*Note that CLEAPSS publications are only available to members or associates.

Where an employer has adopted these or other publications as the basis of their model risk assessments, an individual Centre then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment. Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the candidates were insufficient to attempt particular activities safely.

The significant findings of such risk assessment should then be recorded, for example on schemes of work, published teachers guides, work sheets, etc.

There is no specific legal requirement that detailed risk assessment forms should be completed, although a few employers require this.

When candidates are planning their own investigative work the teacher has a duty to check the plans before the practical work starts and to monitor the activity as it proceeds.