OCR ADVANCED SUBSIDIARY GCE
IN PHYSICS B (Advancing Physics) (3888)

OCR ADVANCED GCE
IN PHYSICS B (Advancing Physics) (7888)

Teacher Support: Coursework Guidance

This Teacher Support: Coursework Guidance booklet is designed to accompany the OCR Advanced Subsidiary GCE and Advanced GCE Physics B (Advancing Physics) specifications for teaching from September 2000.

Contents

1 General introduction

This guide has been written to assist teachers in setting suitable coursework tasks and in assessing candidates' work. The guide should be read in conjunction with the OCR AS/A Level Physics (B) Advancing Physics specifications. However, all sections of the specifications relating to coursework assessment are included here.

While this guide is concerned with the assessment of coursework, it cannot be emphasised too strongly that before candidates are assessed on their communication, research, experimental and investigative skills, these skills must be taught and candidates must have opportunities to practise and to develop their abilities.

In the Advanced Subsidiary GCE course candidates carry out three short tasks: an **Instrumentation task**, **Research and presentation** and **Making sense of data**. Together these comprise Unit 2862: Physics in Practice.

In the A2 half of the Advanced GCE course the coursework consists of two more substantial pieces of work, recognising the more developed skills and maturity of candidates by this stage. The candidates tackle a **Practical Investigation** (Unit 2863, Component 02) and produce a **Research Report** (Unit 2864, Component 02).

In AS Unit 2862, marks contribute towards aspects of Assessment Objectives AO1: Knowledge with Understanding; AO2: Application of Knowledge and Understanding, Synthesis and Evaluation; and to the complete assessment of Assessment Objective AO3: Experiment and Investigation.

In A2 Unit 2863, Component 02, marks contribute to Assessment Objective AO3: Experiment and Investigation.

In A2 Unit 2864, Component 02, marks contribute to Assessment Objectives AO1, AO2 and AO4: Synthesis of Knowledge, Understanding and Skills. There is assessment of AO4 because candidates are required to use physics knowledge and understanding from other modules of the specification in planning their research, in analysing evidence and drawing conclusions.

Coursework provides many opportunities to develop key skills and to collect evidence that may contribute towards the assessment of key skills. Full details are given in Appendix A of the specifications and links are identified throughout the content of the specification booklet. Teachers are advised to discuss such opportunities with colleagues and with the students concerned.

2 Coursework Assessment

The purpose of coursework assessment is to ascertain the value of the work carried out by the candidate using the criteria for assessment. The criteria provide the framework within which impartial and informed decisions can be made which result in ratings which fairly reflect the level of performance, are internally consistent and comparable with those produced in other Centres. The person responsible for teaching the students should normally carry out the assessment. Where several teachers in a Centre are involved, it is expected that arrangements will be made to ensure that they are all interpreting the criteria in the same way.

Each task is assessed internally out of 40 marks. For the assessment of coursework there are four strands, each divided into two aspects. These aspects will be assessed out of 5 marks, giving 10 marks per strand and 40 marks in total for each task. Descriptions of the assessment criteria for each strand are given at the levels appropriate for ratings of 5, 3 and 1. Ratings 2 and 4 are to be interpolated. Choice of rating is by best fit to the criteria.

These criteria are generic for **all** the coursework in *Advancing Physics,* both AS and A2. Since they cover different tasks these formal criteria inevitably concentrate on some important general areas of the candidates' performance.

It is important to realise that the coursework can be fairly and effectively assessed at this general level, without becoming immersed in detail. By using the more specific guidance in this *Teacher Support: Coursework Guidance* booklet, the exemplar material provided by OCR, and with experience of moderation, teachers will become increasingly confident and consistent in their application of the criteria.

The assessment is recorded by annotation of the work. The teacher is asked to write down the mark and to justify that mark by writing a few words about the evidence they are taking into account, both from personal observation and from the written outcome. The record of personal observation should be brief and factual, and will certainly be recollection rather than verbatim reporting.

It is an important feature of the coursework that it is assumed that teacher and student will work closely together throughout. This must be done in such a way that it is possible for the teacher to work closely with a student *and* allow room for the student to perform at all levels.

The submission of proposed coursework tasks for approval by OCR is not a requirement of the scheme. However, Centres wishing to obtain guidance on whether a coursework task is suitable should send details to OCR. Guidance may also be obtained on the marks awarded to candidates' work prior to moderation by sending details of the task set, any background information and marked examples of candidates' work to OCR. Teachers are asked not to send large quantities of material.

A programme of INSET meetings is arranged to provide detailed guidance on coursework assessment. Details are circulated to Centres and a contact number for OCR Training and Customer Support is given in Section 10.

2.1 Assessment and Moderation

All coursework is marked by the teacher and internally standardised by the Centre. Marks are then submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures. The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre.

Coursework submissions should be clearly annotated by the Centre to support the marks awarded to the candidates.

The sample of work that is submitted to the Moderator for moderation must show how the marks have been awarded in relation to the marking criteria.

2.2 Minimum Coursework Requirements

If no work is submitted by a candidate for a coursework component, the candidate should be indicated as being absent from that component on the coursework mark sheets submitted to OCR. Any work submitted by a candidate should be assessed according to the mark descriptors and marking instructions and the appropriate mark awarded, which may be 0 (zero).

2.3 Authentication of Coursework

As with all coursework, the teacher must be able to verify that the work submitted for assessment is the candidate's own. Sufficient work must be carried out under direct supervision to allow the teacher to authenticate the coursework marks with confidence.

2.4 Special Arrangements for Coursework

For candidates who submit some coursework but are unable to complete the full assessment, or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases, advice should be sought from OCR as early as possible during the course.

2.5 Differentiation

In coursework, differentiation is by task and by outcome. Candidates will undertake assignments which enable them to display positive achievement.

3 Introduction to the tasks

3.1 AS Coursework

The tasks in the AS course arise directly out of the students' own learning and it is expected that they will be tackled at the appropriate place in the course. Each task would be expected to take not more than five hours, including time in class.

3.1.1 Instrumentation Task

This task involves one of the following activities:

- building and testing a sensor;
- exploring the characteristics of a given sensor;
- designing and putting together a system to make a measurement

together with a written report on the work done. This task comes directly out of the work they will be doing in Module 2860: Physics in Action: *Communication*. The assessment will reward practical, experimental and constructional skills.

Managing the Instrumentation Task

The time allocated to this task is three hours of teaching time; this will be spent in the laboratory on setting up and experimental testing. Students should spend about two further hours writing their report.

To complete in this time, an outline plan and apparatus list will need to be discussed and agreed in advance. This can be arranged after students have met some sensors, and been introduced to the remainder of the school stock of devices, or those easily ordered from catalogues. Full performance data is available on CD-ROM from several suppliers (RS Components and Maplins), and could be available as datasheets or calibration graphs, to help guide planning.

What students should be expected to achieve?

The time allocation for this sensor project sets a modest bound on what is expected for students to achieve. The experience should build on practical coursework skills developed at GCSE, and should be the practical climax to study of the first AS module, and has been prepared for by similar tasks carried out in teams. The open choice of task should allow students to follow their own interests and to demonstrate planning, as well as practical and analytical skills. It is hoped that the experience will be enjoyable as they learn to manage their own time productively under guidance.

What to cover

Thorough briefing will help students to achieve the aims of this task. They will need to be aware of the assessment criteria in the specification, and a general briefing sheet is provided on the *Advancing Physics* Student's CD-ROM. This contains many suggestions of sensor projects that might be appropriate, but is not meant to restrict students' choice. Teachers will want to develop their own list of successful ideas as experience develops.

How to introduce the task

- Remind students of their previous experience of practical coursework from GCSE.
- A lively introduction to the task develops naturally from one of the sensor demonstrations described in the course, and the team tasks proposed.
- An array of sensors available and some information on their characteristics will enable students to assume responsibility for the first, difficult stage of their work - choosing the task they will undertake.

Topic choices

Before commencing their project, each student will need to discuss his/her choice with the teacher. The teacher should ensure that the student:

- chooses a task appropriate to his/her interests and abilities;
- has a reasonably clear idea about the limits and expectations of the task;
- has an appropriate apparatus list and circuit diagram.

Context

Three slightly different contexts are offered, involving one out of:

- building and testing a "home-made" sensor;
- testing and evaluating a commercial "off the shelf" sensor;
- putting together a measurement system, then making and evaluating a measurement.

There is no intention to restrict students' choice of sensor or what quantities can be measured, though clearly most will restrict themselves to devices which do not rely on electromagnetic effects taught in the A2 year of the course.

Report

Students should be encouraged to demonstrate ICT skills, particularly graphical communication, annotation and analysis when preparing their reports.

Monitoring progress

Early work in task identification and planning will pay dividends when it comes to the busy practical stage of getting circuits working and delivering meaningful data. Difficulties in the lab will be obvious and students can be guided by good questioning or prompting if necessary. This will help the teacher to assess initiative and independence, and the quality of data achieved. The writing of the report to internal deadlines may also need monitoring.

3.1.2 Research and Presentation

This task involves researching the nature and use of a material, and making a presentation about it. The presentation may use any publicly available medium suited to the audience e.g. an illustrated talk, a web page, or a poster. New materials offer a wide variety of stimulating choices, but the choice of material is not restricted to novel materials. The presentation should show relationships between the properties and uses of the material. It should give wider value to the information found by setting it in a context.

The context may be chosen from:

- applications, economic value or benefits and disbenefits;
- historical or social contexts: causes and/or consequences of developments;
- personal context e.g. the involvement of discoverers, inventors or exploiters;
- processes of discovery, invention or exploitation.

This task comes directly out of the work students will be doing in Module 2860: Physics in Action: *Designer Materials*. The assessment will reward their independent learning and presentation of physics in a non-written format.

Managing the Research and Presentation

The time allocated for this is two hours of teaching time, this includes that required for students' oral presentations to the whole class. Students should use around three further hours for research and writing.

What students should be expected to achieve?

This should be the highlight of *Designer Materials*. By the time the student reaches the Research and Presentation, their understanding and vocabulary should have developed significantly from the GCSE background with which they started the course. They should feel confident to access and make use of information from a variety of sources, and be extending their study in a direction which interests them.

It is hoped that they will enjoy careful research, and consider their fellow students as the audience in the preparation of their research material for the presentation.

What to cover

Teachers will need to brief students about the nature of their task. As well as the specification description of the task, the *Advancing Physics* Student's CD-ROM provides a general briefing sheet with more guidance about the assessment strands, and nine sample 'starter' sheets to stimulate interest and suggest research sources. These are not meant to restrict students' choice of topic. Teachers may want to add extra 'starters' of their own in a similar format, perhaps building them up year on year as students produce unexpected new suggestions.

How to introduce the task

- Remind students of the many times they have previously sought and made sense of information - as part of this course and previously.
- Draw them into the spirit of the task in an imaginative way - perhaps making a visit, seeing demonstrations or hearing a lecture by a materials specialist - or use the collection of images, 'materials: yesterday and tomorrow'.
- Provide them with just sufficient printed information to enable them to assume responsibility for the first, difficult stage of their work - choosing a topic.

Topic choices

As well as the briefing sheets provided, students may get their ideas from a wide range of sources: television, radio, websites, magazines, pamphlets, newspapers, videotapes, manufacturers or retailers, a professional scientist or engineer - and of course from their observations of the material world.

Before they start their research, each student should discuss her/his choice so that the teacher can ensure that the student:

- chooses a topic appropriate to her/his abilities and interests;
- is reasonably clear about the limits of the topic;
- has a starting list with good sources of information.

Analysis

Students will need to sift through their sources to extract the essentials. They should give full bibliographic details for sources used, including page references for quotations and key ideas. It is a good idea to give them practice with, or at least examples of, both of these skills.

Mark descriptors for Strands A (use of resources) and B (understanding of physics) should be discussed in class so that all understand the importance of re-working information and incorporating their own thinking and are aware that simple 'cut and paste' will not be sufficient.

Context

This too should be discussed in class. There is a choice of *types* of context, again so that students can choose one which most interests them.

Presentation

Students should be encouraged to think the presentation is integral to the task, and not an artificial extra. Practising scientists, engineers and other professionals all expect to present information to others, perhaps to influence their thinking. It will help if students have earlier in the course been given non-assessed practice with presentations of various types.

Monitoring progress

The teacher will need to monitor students' research and preparations from the time the task has been set. In this way they can offer appropriate help and encouragement, and prevent some students from falling behind. Students will not expect the teacher to be a materials science expert, so teachers should not expect it of themselves. Once the students have chosen a topic, their likely difficulties will arise with finding sources, deciding what is relevant information, and making decisions about their presentation. They will appreciate a teacher who can both listen and question carefully.

Material from the research for the presentation must be available in a folder which can be sent to the Moderator (not including computer disks).

3.1.3 Making Sense of Data

The task is to analyse a set of data, and write a report showing what can be understood from the data, in relation to the physical principles involved. Data may come from a variety of sources. The student may have performed an experiment; have seen a demonstration which provides the data; have taken data from a video of an experiment or event; have found data from an outside source. In all cases the student must be in a position to understand and report on how the data were obtained, on the physical principles involved, and on features of the experiment which are needed to understand the results, including possible sources of error.

This task provides an opportunity for students to be rewarded for the practice they will have had in presenting and analysing data throughout the AS course.

Managing the Making Sense of Data Task

The time allocated for this is two hours of teaching time, this includes time required for collecting the data. Students should use the same amount of time again in analysis of the data and writing their report.

What students should be expected to achieve

Making sense of data is intended to allow students to show their skills in drawing meaning out of a collection of data, by presenting the data clearly, identifying patterns and trends, suggesting explanations for those findings and discussing the validity of their conclusions in light of the experimental technique used. This task will most likely be assessed towards the end of the AS course, after the student has had the opportunity to interpret data from a variety of experiments and has developed the skills of data analysis being used.

It is important to realise that it is these skills of data analysis that are being assessed, **not** practical skilfulness in collecting the data itself. Each student must begin the task with a good set of data, however that is achieved. The purpose of collecting the data, or seeing the data collected, is to ensure the student is familiar with the origin of the data.

What to cover

The teacher will need to brief students about the nature of their task. As well as the specification description of the task, a general briefing sheet with more guidance about the assessment strands and some sample tasks can be found on the *Advancing Physics* Student's CD-ROM. It is likely that some of these will have been used earlier in the course.

How to introduce the task

It is important, before becoming immersed in the specific detail of a set of data, to be sure that students are secure in their understanding of the task.

- Remind students of the many times they have previously made sense of data - as part of this course and previously. Such examples can be used to illustrate a discussion of the good and bad features of a report.
- Remind them of the important ingredients of a successful report, for example:
    - a concise and clear description of the design of the experiment;
    - a clear understanding of the underlying physics of the experiment;
    - making decisions about how to present the data (charts, tables, graphs and calculations) to draw meaning from it;
    - discussing the validity of any conclusions, with reference to discrepancies or anomalies in the data, and the experimental technique used.
- Discuss how such a report will allow the work to be assessed successfully using the general criteria and the more specific guidance.

How to introduce the data

The data can be presented to candidates in one of a number of ways. They may be able to collect it, individually or in groups. They may watch a demonstration (either live or on video) during which data is collected. What is essential is that they have every opportunity to discuss and question their understanding of the purpose of the experiment, the details of the experimental technique and any underlying physical principles. This background to the origin of the data will be needed if they are to make proper sense of it and particularly to discuss the validity of their findings.

However the data is collected, each student must begin the task with a good set of data. Therefore if students are gathering data for themselves the teacher must have a good set of data available to hand to the student if their data is unlikely to allow them to gain the highest marks. Note that a 'good set of data' for this purpose is likely to include some anomaly worth noting and discussing.

Monitoring progress

The teacher will need to monitor students' work from the time the task has been set and the data has been introduced. In this way the teacher can offer appropriate help and encouragement, and prevent some students from falling behind. It will also give confidence that the student is producing their own piece of work.

One way to manage this task could be to use the 2 hours of lesson time and the equal amount of study time in the following way (starting after all the necessary introduction of the task has taken place):

First hour (in class)

- Introduce data, and have a preliminary discussion with students

Second hour (out of class)

- Student begins report

Third hour (in class)

- Student continues report writing in class and has further discussion with teacher

Fourth Hour (out of class)

- Report is finished and handed in.

Such a system will allow a teacher to assess the students' thinking about the task, to encourage and guide before it is too late, and to be confident that the student understands the work they are producing at home. It will also help students to understand that the task is not large and to avoid the production of unnecessarily long pieces of work.

3.2 A2 Coursework

The two elements of coursework in the A2 course are clearly at a higher level than those in the AS course. Students have a higher degree of autonomy in their choice of physics to study and a longer time over which to carry out the project.

There are two elements to the coursework in the A2 course – each requiring 10 hours of teaching time and the accompanying homework time.

Practical Investigation: The practical investigation should be carried out on any aspect of physics of interest to the student. It is anticipated that students will use a wide variety of experiments and techniques in this extended investigation.

Research Report: This consists of a written report based on the individual work of a student on a topic of physics of his or her own choosing. The work is expected to be exploratory, with the aim of collecting and analysing information about an issue in which physics is significant. The report should also consider the wider context of the physics, considering social, historical, economic, or environmental issues.

3.2.1 Practical Investigation

For this task each student should carry out an investigation of a practical problem related to physics or its applications. It is anticipated that students will use a wide variety of experiments and techniques in this extended investigation. The most suitable topic is a clearly defined problem, which offers scope for genuine investigation, rather than routine, mechanical and unimaginative work. The topic should afford the student the opportunity to use physics at an A level standard.

What students should be expected to achieve

One of the central features of the course is the emphasis placed on learning physics through the interplay of theory and experiment - so that students understand where ideas come from, how they make sense and how they may be used. This is made possible through the range and variety of illustrative experiments, practical demonstrations and investigations which students meet during the course. But the importance of the experimental work extends beyond the fulfilment of this objective. Many students will study more science when they leave school or college, and there are some whose careers will involve science. An ability to investigate an unfamiliar situation in a sensible and scientific way will be an asset not only to these students, but to all in tackling practical problems in everyday life. To this end, it is hoped that the development of experimental and investigative skills will be a significant feature throughout the course.

To reinforce this aim the Practical Investigation offers students opportunities to display and be rewarded for the skills they have developed.

The assessment will reward such skills as:

- working independently and with initiative;
- formulating and testing hypotheses ;
- designing, planning and safely carrying out experiments;
- selecting the most appropriate apparatus for a purpose;
- appreciating the significance of results and observations;
- translating and interpreting information;
- critically analysing and evaluating experimental data and methods;
- applying knowledge and understanding to explain trends and patterns in results;
- communication skills.

The outcome of the task is a written report which describes the process of the investigation and discusses the conclusions which may be drawn from the practical work done.

The time allocated for this component of the examination is about 10 hours of ‘physics teaching’ and the equivalent amount of ‘homework’ time.

Management of the Practical Investigation

To begin, the student chooses an interesting topic for investigation and carries out some preliminary research – analysing the topic, getting 'a feel' for the relevant factors, considering the selection of appropriate apparatus and measuring techniques, carrying out a literature search, if appropriate – with a view to deciding upon an experimental design which will allow the first set(s) of readings to be taken.

The next stages are to carry out the investigation in the laboratory, to write up the findings of the experimental work, in the form of a daily diary, and then to submit the finished report to the teacher for assessment.

The assessment should be based on observation of the work done, and on discussion with the student, as well as information revealed in the written report. Ratings must be based on the actual work done, and must **not** be influenced by impressions of what the student might have been expected to achieve, whether this is less or more than is actually achieved.

Errors in physics which have been noted in arriving at the assessment must be marked on the report.

It is inevitable, and indeed sensible, that students should seek help or advice from outside sources and it is important that teachers find out about the nature and extent of this assistance, so that in making their assessments they can make due allowance for it. Credit should only be given for the way in which the student *makes use* of the help or advice received. All sources used, printed or otherwise, should be acknowledged e.g. in a bibliography.

Reports, which should be in an appropriate style of writing, should be legible and organised. Arguments should be clear and logical, and coherently presented using appropriate conventions of spelling, punctuation and grammar.

The fact of having spent a longer time on the work should not, in itself, earn a higher assessment for the student concerned. The work should be judged on its quality with respect to the total time spent. Students who work effectively for the normal allotted time must not be put at a disadvantage. On the other hand, students who spend little time should not be awarded a high rating.

In order to minimise the effect of good or ill luck in the choice of topic, or while the work is in progress, a Practical Investigation which fails in its initial objective should be rated equally with one which happens to succeed, provided that they are performed equally well.

Excessively long reports should be strongly discouraged.

3.2.2 Research Report

This component is designed to assess the ability of a student to find information from a variety of sources, to compare and analyse information obtained and to use this material to discuss an issue and draw conclusions. Students may choose a topic from any area of Physics that interests them.

The Research Report gives each student an opportunity to display, and be rewarded for, the skills they have developed during the course. The emphasis here is on the testing of such skills as:

- working independently;
- drawing together ideas from different aspects of physics;
- selecting and extracting information from a variety of sources;
- applying knowledge and understanding of basic ideas ;
- translating and interpreting information;
- placing physics ideas in a wider human or social context;
- communicating scientific ideas in continuous prose using good English;
- using published material as part of research.

The information is expected to be obtained from the student's own research from a suitably representative range and variety of sources. These sources might include books, journals, pamphlets, surveys, interviews, libraries, data bases and web sites on the Internet.

The outcome is a written report based on the individual work of a student on a topic of physics of his or her own choosing. The topic must be approved in advance by the class teacher. The teacher should ensure that the student chooses a topic which will enable them to demonstrate their skills in drawing together a variety of physics ideas.

It is expected that the report will be between 2000 and 4000 words long.

The work is expected to be exploratory, with the aim of collecting and analysing information about an issue or problem in which Physics is significant. It is hoped that students will take the opportunity to deal with issues of a technological, social or economic, or historical nature. The information used need not be original, but should be independently researched by the student. It may come from published material and/or from surveys or observations made in the commercial or industrial world. However, most weight will be given to the quality, treatment and presentation of the information, rather than the technical processes by which the information may be gained.

Managing the Research Report task

To begin, the student chooses a suitable topic for research and then spends some time collecting relevant information from a suitably varied range of sources. Clearly it is impossible for a student to consult all existing sources and so the immediate task ahead is to locate and consult a range of relevant source material in order to obtain as representative a sample of the information available as is possible. This initial phase of the research may be spread over several weeks, and carried out in the students' own time. During this period, the teacher may designate a single period of 'physics teaching' time each week to allow time for supervision of the students' progress and so that the internal assessor is familiar with each student's work at all stages. Internal assessors are encouraged to monitor the student during the project and to offer tactful advice at any stage during the work, so that the latter becomes fully aware of how to maximise his/her performance. If help is asked for it should be given, as far as possible, in a way which allows students to gain credit for using such advice in their own way.

The next stage is to select an interesting aspect/issue/application/problem which has arisen from the material surveyed and to research it more thoroughly. The student then summarises the findings of the research in the form of a written report or article addressed to scientifically knowledgeable readers. Students should be encouraged to use word-processing and other IT packages. The time allocated for making sense of the information collected *(analysis)* and for writing the scientific article *(communication)* is about 10 hours of 'physics teaching' and the equivalent amount of 'homework' time. All information sources consulted must be accredited, and published material used should be given full references.

3.3 Health and Safety

In UK law, health and safety is the responsibility of the employer. For most establishments entering candidates for GCE AS and Advanced GCE this is likely to be the local education authority or the governing body. Employees, i.e. teachers and lecturers, 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 micro-organisms 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* (see below). 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;

Safeguards in the School Laboratory, 10th edition, 1996, ASE ISBN 0 86357 250 2;

Hazcards, 1995, CLEAPSS School Science Service*;

Laboratory Handbook, 1988-97, CLEAPSS School Science Service*;

Topics in Safety, 2nd edition, 1988, ASE ISBN 0 86357 104 2;

Safety Reprints, 1996 edition, ASE ISBN 0 86357 246 4.

Preparing COSHH risk assessments for project work in schools, SSERC, 1991

Hazardous chemicals: a manual for science education, SSERC 1997

* 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 school or college 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.

Where project work or individual investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or micro-organisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting the CLEAPSS School Science Service (or, in Scotland, SSERC).

When candidates are planning their own practical activities, whether in project work or more routine situations, the teacher or lecturer has a duty to check the plans before practical work starts and to monitor the activity as it proceeds.

4 Notes for Guidance on Coursework Submission and Assessment

4.1 Assessment of coursework

The purpose of the assessment is to ascertain the value of the work carried out by the student using the criteria for assessment. The criteria provide the framework within which fair-minded and informed decisions can be made which result in ratings which fairly reflect the level of performance, are internally consistent and comparable with those produced in other Centres. The person responsible for teaching the students must carry out the assessment. Where several teachers in a centre are involved, it is expected that arrangements will be made to ensure that they are all interpreting the criteria in the same way and that their marking is internally standardised.

These criteria provide a consistent framework of assessment for **all** the coursework in *Advancing Physics*, both in AS and in A2. Since they cover different tasks these formal criteria inevitably concentrate on some important general areas of the student's performance.

It is important to realise that the coursework can be fairly and effectively assessed at this general level, without becoming immersed in detail. Through INSET, using the more specific guidance in this *Teacher Support: Coursework Guidance* booklet, the exemplar material, and with experience of moderation, teachers will become increasingly confident and consistent in their application of the criteria.

The specific criteria and mark descriptors for each task are outlined in Section 5 of this booklet.

The students' work is assessed using criteria which are grouped in four strands:

- Strand A: Initiative and independence: planning and use of resources
- Strand B: Use of knowledge, skill and understanding of physics
- Strand C: Quality of communication
- Strand D: Meeting the demands of the particular task

The same strands are used in each of the assessment tasks. However, on each occasion the emphasis is different and the different demands of each task allow students to demonstrate different strengths.

The teacher is asked to mark the 'best fit' descriptor for each of the aspects shown within a strand. These judgements are then used to determine the mark out of five awarded for that aspect of the work. If necessary, teachers are invited to write a few words about the evidence they are taking into account, both from personal observation and from the written outcome. The record of personal observation should be brief and factual, and will certainly be recollection rather than verbatim reporting.

It is an important feature of the coursework that it is assumed that teacher and student will work closely together throughout. This must be done in such a way that it is possible for the teacher to work closely with a student *and* allow room for the student to perform at all levels.

4.1.1 Marking Candidates' Work

The marks awarded should be based on both the final written work and on the teacher's knowledge of the work carried out by the candidate. The marking should take place as soon as possible after receipt of the work in order to complete the task efficiently and fairly. Written work should be read and marked as any other written work, with annotations to inform decision making and to inform the Moderator. Presentations might be marked using a checklist based on the criteria. Significant errors or, for example, particularly good pieces of analysis should be highlighted.

4.1.2 Quality of Written Communication

Coursework must include an assessment of candidates' quality of written communication. At Level 3, candidates are required to:

- select and use a form and style of writing that is appropriate to the purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate;
- ensure the text is legible and that spelling, grammar and punctuation are accurate, so that the meaning is clear.

The relevant mark descriptors have been written to include these requirements.

4.2 Moderation of Coursework

The purpose of moderation is to ensure that the standard for the award of marks in coursework is the same for each Centre, and that each teacher has applied the standards appropriately across the range of candidates within the Centre. For all coursework components there are two stages in the moderation procedure: Internal Standardisation and External Moderation.

Internal Standardisation

The purpose of internal standardisation is to check that the work of all candidates from the Centre has been assessed to a common standard, in keeping with the criteria. To produce a single reliable set of marks for each coursework component, the Centre will conduct internal standardisation of the coursework marks if more than one teacher is involved. It is the responsibility of the Centre to ensure that internal standardisation is carried out effectively, and to provide evidence of this process.

Some possible schemes of internal standardisation, which have been effectively used by teachers in Centres, are listed below:

- marked work is circulated between colleagues, re-read, and the ratings confirmed;
- work from different batches, which have been given the same ratings totals, are re-read and checked for comparability;
- presentations are observed by two teachers, one of whom 'overlaps' to observe other groups.

Once the process of internal standardisation has been completed it then remains for the marks to be submitted to OCR by the specified date, as published by OCR for each examination session.

Annotation of Coursework

The sample of work which is submitted to OCR for moderation must show how the marks have been awarded in relation to the marking criteria.

The writing of comments on candidates' work can provide a means of communication between teachers during internal standardisation of coursework. The main purpose of writing comments on candidates' coursework is, however, to provide a means of communication between teacher and Moderator.

Annotations should be made at appropriate points in the margins of the text. The annotations should indicate both where achievement for a particular skill has been achieved and must also indicate where errors in physics have been noticed.

External Moderation

Coursework marks are submitted to OCR by a specified date, after which postal moderation takes place in accordance with OCR procedures.

4.3 Special Arrangements

For candidates who are unable to complete the full assessment or whose performance may be adversely affected through no fault of their own, teachers should consult the *Inter-Board Regulations and Guidance Booklet for Special Arrangements and Special Consideration*. In such cases advice should be sought from OCR as early as possible during the course.

5 Criteria for the Assessment of Coursework

The marks awarded should be based on both the final written work or presentation and on the teacher's knowledge of the work carried out by the candidate. In assigning a mark, attention should be paid to the extent of any guidance needed by, or given to, the candidate.

A mark of zero should be awarded where there has been an attempt to address the skill but the work does not meet the requirements of the lowest defined mark level.

The teacher is asked to mark the level of achievement (1, 3 or 5) achieved on each aspect of a criterion. The mark for that criterion is arrived at by considering the overall picture. Interpolation to award a mark of 2 or 4 would be sensible where there is a discrepancy between aspects.

5.1 AS Coursework

5.1.1 Instrumentation Task

This task provides an opportunity for candidates to demonstrate their practical, experimental, planning and investigational skills. This task, together with the Data Handling task, gives the opportunity within the AS course to assess the practical aspects of the assessment objective AO3 Experiment and Investigation.

Students should be able to:

- show initiative and independence in carrying out experiments and investigations;
- use knowledge and understanding of physics to devise and plan experimental activities, selecting appropriate experimental techniques;
- demonstrate safe and skilful practical techniques;
- make observations and measurements with appropriate precision and record these methodically;
- communicate the results of experimental activities using knowledge and understanding of Physics.

This assessment objective is addressed in the four strands of the assessment.

Mark Descriptors

STRAND A: Initiative and Independence: Planning and use of Resources

During the task the teacher should work closely with the student. Discussions should be framed to allow the student to show initiative, personal involvement and interest.

Independence: Is the task interesting and challenging? Did the student show initiative and work and plan independently? Did the student carry the project through to completion? Did the student make good use of advice asked for?

1 The student attempted a simple project. Significant help or direction was needed to get started, and to continue. Part of the work is completed. Difficulties are recognised only if they are pointed out.

3 The student chose a suitable, but not necessarily challenging, project, perhaps with some guidance. With help and direction, most parts of the project are attempted, if not always completed. Any plan is simple and straightforward, alternatives generally not being considered or explored. Some difficulties are noted, and with help attempts are made to deal with them.

5 Initiative and independence is shown in choosing a suitable and challenging project. The work is largely done independently, making constructive use of any advice given. The project is carried through to completion. The student formulated a plan, adapting it if necessary, making appropriate decisions. Alternatives are considered and explored. Difficulties are recognised and dealt with.

Resources : Did the student make good use of the resources available? Are the practical methods, apparatus and techniques chosen with due regard for safety?

1 It was necessary to direct the student to relevant resources. Some resources are used, not necessarily to great effect. Safety measures are somewhat basic.

3 Some resources are put to good use. Materials and devices used are mainly appropriate. Some attempt is made to address safety matters.

5 Resources available to the student, are identified and used well and appropriately. Equipment and methods are chosen with care and thought, and with due regard for safety.

STRAND B: Use of Knowledge, Skill and Understanding of Physics

In completing the task the student will need to use the physics they have studied and their understanding of that physics, as well as the skills they have acquired during the course to develop a strategy for tackling the task. Throughout the task the student should have a critical and cautious attitude to information and data, identifying discrepancies.

Devising a strategy Has the student put their knowledge and understanding of physics to good use in devising a strategy? Did the student have a strategy, make decisions and consider alternatives? Does the student use their knowledge and understanding of physics to anticipate what might happen?

1 The work is largely empirical, ‘try it and see’. There was little advance preparation.

3 Knowledge and understanding of physics is used in thinking about parts of the work. Straightforward effects are anticipated, perhaps only qualitatively.

5 Knowledge and understanding of physics is used in devising and/or testing a sensor or in setting up a system to make a measurement. Thought is given to the physics of the proposed system; for example rough calculations are made to anticipate what might happen.

Practical skills and techniques Does the work show practical skill and ingenuity? Have effects which might interfere with the results been considered and acted on?

1 Basic physical ideas are used to describe effects seen, if their relevance was pointed out. Interfering effects may not be noticed. Some construction work is carried out and parts of the system worked.

3 Some practical skill is shown, perhaps after help was given, so that the work was mainly competent. Interfering effects are noted, but may not have been dealt with.

5 Practical knowledge and skill is put to good use. Any construction work is skillfully and deftly done, showing knowledge of techniques and an understanding of the materials in use. Effects which might interfere with results are considered, and steps are taken or suggested to avoid them.

STRAND C: Quality of Communication

The task ends with a written report. In doing this the student is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting.

Record of observations: Did the student carry out observations and measurements to an appropriate precision? Were all the effects observed and recorded? Was a methodical record kept using appropriately labelled tables?

1 There is a written report of the activities undertaken. Some observations or data obtained are reported.

3 Most measurements and observations are recorded and presented in labelled tables.

5 Observations were made with appropriate precision and recorded methodically.

Report presentation: Does the report go beyond descriptive reporting? Does the report show evidence of critical and connected thought? Are results meaningfully presented? Is the report well presented? Are appropriate tables or graphs included? Does the report communicate the work done effectively? Is the quality of English good?

1 Some data obtained are reported. There are some tables or graphs, but their meaning may not be clear. The quality of English is adequate to express simple ideas clearly.

3 Some tables or graphs are used to communicate the meaning of results. There are attempts to use illustrations to help communicate. The quality of English is adequate to express some more complex ideas.

5 Measurements and observations are clearly documented. The report is appropriately illustrated. Results are meaningfully presented in well-chosen and well-constructed tables or graphs. The quality of English is good.

STRAND D: Observation and Measurement

The Instrumentation task particularly focuses on the student's practical, experimental and investigational skills. This final strand concentrates on the skills of observation and measurement.

Systematic measurement : Has the student made observations and measurements carefully? Is there a suitable range of measurements? Has the student checked results when necessary and identified any anomalies?

1 A basic test was carried out. At least one measurement or observation is made.

3 A fair range of measurements and observations are made in a reasonably organised and methodical, if not carefully planned fashion. Some limited cross-checking of measurements and observations is made. Any anomalies may be noticed, but not pursued.

5 A good and appropriate range of relevant measurements and observations are attempted to a systematic plan. Appropriate rough tests or trials are made. Measurements and observations are checked or repeated when appropriate. Values are reported to an appropriate precision. Any anomalies are noted, and checked or discussed.

Fitness for purpose : Have the measurements and observations been made purposefully and with due attention to evaluating the instrumentation in use?

1 There is some reference to the properties of the sensor or instruments used.

3 Some aspect of the fitness for purpose of the system is considered or tested. The precision of at least some values obtained is considered.

5 Relevant qualities for fitness for purpose of the system (e.g. resolution, response time, systematic bias or drift, sensitivity, random variation) are considered and investigated.

5.1.2 Research and Presentation

This task provides an opportunity to assess the candidates' independent learning and presentation of physics in a non-written format. The assessment addresses in particular aspects of AO1 Knowledge with understanding and AO2 Application of knowledge with understanding, synthesis and evaluation.

These assessment objectives are addressed in the four strands of the assessment.

STRAND A: Independence and Initiative: Planning and use of Resources

During the preparation of the presentation the teacher will work closely with the student. Discussions should be framed to allow the student to show initiative, personal involvement and interest. The task requires the use of resources, probably both ICT and paper-based.

Planning: Did the student show independence and initiative in finding and selecting from the sources?

1 The research was guided with little planning. Substantial guidance or direction may have been needed, not always acted upon.

3 A plan was made before research began. Advice and direction may have been needed, but is acted upon.

5 An appropriate research plan was made and carried through. Thought is given to what information is needed, to guide a search. Constructive use is made of any advice.

Use of resources: Did the student use a good range and variety of information sources? Was good use made of available resources?

1 A definite choice of material was made, and information about it is collected and presented. Only one main source may have been used. Little link between the source and the report.

3 Information about a material has been obtained from more than one source, and is been presented in an organised way, with some selection of relevant aspects to highlight. There is some indication of how the sources were used.

5 The choice of material to research is sensible and interesting. Initiative and independence are shown in seeking information and following up sources. A variety of sources covering different aspects of the material is used. Good judgement is shown in selecting and organising the information found. A link is made between the sources and their contribution to the final report.

STRAND B: Use of Knowledge, Skill and Understanding of Physics

In completing the presentation the student will need to use the physics they have studied and their understanding of that physics, as well as the skills they have acquired during the course to develop a strategy for tackling the task. Throughout the coursework the student should have a critical and cautious attitude to information and data, identifying discrepancies.

Thinking about the physics: Does the student use their knowledge and understanding of physics to understand and interpret information found? Is there evidence of significant re-working of the information found?

1 Some simple physics is mentioned, often cited directly from a source without explanation.

3 There is some attempt to understand and interpret information found. Physical principles are used to explain some aspect of the behaviour of the material.

5 The work is guided by a drive to explain and understand. Knowledge of physics is used to understand and interpret the behaviour of the material. Questions are raised and attempts made to answer them.

Critical and cautious approach: Does the student evaluate the sources used, showing a critical or cautious attitude?

1 Information is largely presented directly as found. Properties and behaviour of the material are reported directly, without real explanation.

3 Some attempt has been made to re-work information found and to interpret or comment on it from the student's own point of view. Some aspects of information found are questioned or commented upon.

5 Information found is treated with appropriate caution or critical thought. Any discrepancies between sources are noted and discussed. Calculations or arguments are attempted which test or go beyond the information found.

STRAND C: Quality of Communication

The task culminates in a presentation of the research findings. In doing this the student is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting.

Content: Does the presentation add to the value of the work? Is the presentation appropriate to its audience?

1 A presentation was made, providing some information about the material. The presentation provides little more than a collection of facts.

3 The presentation is competent and informative. Information is reasonably clear. There is a focus for the report.

5 The presentation is appropriate to its audience, and interested and informed the audience. Helpful analogies or comparisons are used. Information is sensibly and appropriately selected.

Presentation of the report: Was the report well presented and illustrated with appropriate examples? Was there a concern to communicate with the audience?

1 Only one communication technique is used. Little concern was taken to consider the effect on the audience. The quality of English is adequate to express simple ideas clearly.

3 More than one communication technique is used effectively (e.g. illustrations in addition to talk). The quality of English is adequate to express some more complex ideas.

5 The quality of the presentation (oral, web site, poster etc.) adds value to the work as a whole. Information presented and explanations given are clear and accurate. Illustrations are well-chosen and well-constructed. An appropriate range of communication techniques is used. ICT and other resources are used well and appropriately. The quality of English is good.

STRAND D: Context and Evidence

The Research and Presentation task provides an opportunity in the course to consider how physics relates to a broader context. The student should give wider value to the information found by setting it in a context. The student should provide some documentary evidence of the research that was carried out, together with any documents used for the presentation: in the case of a talk it is expected that there may be some notes, handouts or overhead transparencies; web pages or a computer based presentation might be printed out; a poster could be folded and form part of the portfolio.

Context: Does the student add value to the ideas by placing them in a wider human or social context?

1 Some aspect of a wider context is mentioned, but without detail, discussion or comment. It adds little to the value of the presentation.

3 Information about the wider context is provided, but often taken directly from a source, and limited to descriptive reporting without discussion or comment.

5 Value is added to the presentation by placing the ideas in an interesting wider context. There is a synthesis of ideas, with discussion and comment showing the student's own thinking.

For example, does the task include any one of the following:

- There is a discussion of potential applications of the material, and of possible economic benefits or disbenefits.
- The material is seen in an historical or social context which helps to account for its use or invention, or which brings out social consequences the use of the material may have or have had.
- There is an account of the persons involved in the discovery, invention or exploitation of the material, and of their individual character or circumstances.
- There is a discussion of how the material came to be invented, discovered or exploited.

Evidence: Has the student provided good evidence of the research and of their presentation?

1 There is some documentation to show the research that was carried out. A folder documenting some of the research and planning for the presentation is provided.

3 A list has been made of the sources used and there is evidence of how they link to the final report. A folder containing the essential parts of the planning and research for the presentation is provided.

5 There is a clear record of the research carried out, sources are listed and linked to their contribution to the final report. A comprehensive folder reflecting the planning and research for the presentation is provided.

5.1.3 Making Sense of Data

Assessing the Making Sense of Data Task

This task provides an opportunity for students to demonstrate their practical, experimental and investigational skills. This task particularly assesses the final two objectives in AO3 Experiment and investigation:

Students should be able to:

- interpret, explain, evaluate and communicate the results of experimental activities using knowledge and understanding of Physics.
- communicate the results of experimental activities clearly and logically in appropriate forms e.g. prose, tables and graphs, using appropriate specialist vocabulary.

These assessment objectives are addressed in the four strands of the assessment.

STRAND A: Initiative and Independence: Planning and use of Resources

During the task the teacher should work closely with the student. Discussions should be framed to allow the student to show initiative, personal involvement and interest. The task may require the use of ICT resources if available.

Planning: Did the student show initiative and independence in the analysis and report writing? Does the student determine what calculations and plots are needed and analyse the data in a methodical manner?

1 Considerable advice and direction may have been needed. Help is needed in making calculations and in constructing plots. Some analysis is done, and a report is submitted.

3 Some questions and conclusions are independently formulated, perhaps needing modification after discussion. Parts of the analysis and report writing are done independently, often following advice or direction, which is understood and acted upon. Help is needed for the student to identify and describe the essentials of the experiment. Calculations and plots are made independently, but only following advice or direction.

5 The analysis and report writing is carried out independently, showing initiative. The student could identify and describe the essentials of the experiment without help. The student independently decides what questions to ask and what conclusions to draw. Appropriate decisions are made about how to proceed. The student chooses independently what to calculate and plot. Alternatives are considered and explored. Constructive use is made of any advice. Critical thought is given to anomalies or discrepancies in the data.

Use of resources: Was good use made of available resources? Were ICT and calculators used well?

1 Simple resources are used. ICT may be used but with little thought.

3 Some of the available resources are used effectively.

5 Available ICT and other resources such as calculators are used well.

STRAND B: Use of Knowledge, Skill and Understanding of Physics

In completing the task the student will need to use the physics they have studied and their understanding of that physics to understand the experiment, to look for the important relationships in the data, and to account for difficulties or discrepancies.

Devising a strategy: Did the student's knowledge and understanding of the physics inform the way they approached the problem? Did they begin by making rough graphs and calculations?

1 The approach was largely mechanical, with little planning ahead.

3 Straightforward relationships were anticipated, although there was some attempt to link the data to the physics.

5 Knowledge of physics and initial graphs and calculations informed the progress of the work.

Experiment: Was knowledge and understanding of physics used to understand the experiment? Was this knowledge used to interpret the results?

1 The experiment and its purpose is described without basic errors in physics. The link between the physics of the experiment and the results of the data analysis was weak.

3 The experiment is correctly described, and some aspects of the physics underlying it are clear. Some aspect of the experiment is discussed in explaining the results.

5 The report demonstrates an understanding of the experiment. The essential physics behind it is clearly and concisely discussed. The experiment is clearly but briefly described, drawing attention to aspects likely to be important in understanding the results.

STRAND C: Quality of Communication

The data handling task ends with a written report and collection of evidence. In producing this the student is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting.

The content of the report: Was the report interesting, concise and clear? Does it show evidence of a concern to make sense of the data?

1 A report is provided, containing basic material: description of experiment, recorded data, and some conclusion. The description of the experiment is basic. The data tables may lack significant details.

3 The report has some attempt at all the main important features: account of the experiment and the physics behind it; records of data; some processing of data; some display of relationships in graphs or tables; some conclusions supported by the data.

5 The quality of the report adds value to the work as a whole. The work is guided by a concern to make sense of data from the experiment. The outcome of the analysis is clear. Graphs or tables are well-constructed so as to display their message effectively, for example through good choices of scale. Captions to graphs or tables communicate the meaning to be drawn from them.

The presentation of the report: Is good use made of language, layout and graphics? Has the student taken trouble to communicate results clearly and with impact? Is the quality of the English good?

1 The work may be untidy or disorganised, lacking clarity of expression with arguments muddled. Little thought has been given to the impact of the report. Graphs are constructed without thought for their appearance. The quality of English is adequate to express simple ideas clearly.

3 Work is generally neat and orderly, and the language is intelligible. Some available ICT or other resources have been used. Graphs are basic, but neat and without distracting elements. The quality of English is adequate to express some more complex ideas.

5 The report is concise, interesting to read, and presents results with impact and clarity. Available ICT and other resources for report writing and graphics have been used thoughtfully. The quality of language, layout and artwork is good. The quality of English is good.

STRAND D: Analysis: Mathematical Skill and Care

The data handling task provides an opportunity for students to demonstrate appropriate and skilful use of mathematics and of forms of representation of data (e.g. graphs and tables) to support the analysis and extract meaning from the results.

Graphs and tables: Were appropriate forms of representation of data (e.g. graphs and tables) used to support the analysis and extract meaning from the results? Are units correctly used? Was appropriate mathematics used with skill and accuracy? Does the student consider and try to estimate the size of errors in the data?

1 Some graphs or tables relevant to the experiment are provided. Some labelling of graphs and tables is done, with some units. Quantities considered are usually direct from measurement. Little acknowledgement is made of errors.

3 Attempts are made to choose the most appropriate plots or quantities to tabulate. Lines or curves are fitted when appropriate. Most quantities are given with units. Some correct calculations of relevant derived quantities are made. Some mention is made of possible errors.

5 Graphical plots are well-chosen, e.g. plotting powers or logarithms of quantities when appropriate. Any line or curve fitting has a valid basis in the physics. Inferences are made from plots, e.g. using the slope, intercept or area under a plot. Quantities are given correct units. Unit conversions are well-chosen and correctly made. Graphs and tables are correctly labelled. Appropriate mathematical relationships are used, and appropriately and correctly manipulated. Orders of magnitude of quantities are considered and used to check results. Magnitudes of possible errors are estimated and represented on plots.

Analysis: Did the student look for the important relationships in the data? Were difficulties or discrepancies accounted for?

1 Data are presented mainly in raw form. Some conclusion relevant to the data is drawn.

3 Tables and graphs show significant relationships, and are given some interpretation. Any anomalies or discrepancies are noted. Conclusions consistent with the data and with basic physical ideas are drawn.

5 Knowledge and understanding is brought to bear on accounting for anomalies or discrepancies. Graphs and tables are interpreted in terms of the relevant physics. Knowledge and understanding is used to develop a model or make predictions. The analysis reveals correctly the underlying mechanisms at work. Relationships proposed are consistent with the evidence and with basic physical ideas.

5.2 A2 Coursework

5.2.1 Practical Investigation

The Practical Investigation provides an opportunity for students to demonstrate their experimental and investigational skills. The assessment addresses all aspects of AO3 Experiment and investigation:

Practical investigations are assessed under each of four headings:

STRAND A: Initiative and Independence: Planning and use of Resources

During the planning and execution of the Practical Investigation the teacher will work closely with the student. Discussions should be framed to allow the student to show initiative, personal involvement and interest. The student should have the opportunity to devise a problem which they are capable of dealing with, within their own physics skills, knowledge and understanding. The investigation requires a sensible choice of, and the safe use of, apparatus.

Initiative and independence: Does the student analyse the problem? Has the problem been reformulated in a way that can be investigated? Have relevant variables been identified and considered? Have appropriate variables been selected for investigation? Is there a suitable plan?

1 The problem has been defined in simple terms. Help and advice given were usually acted upon. There is some evidence of planning.

3 The definition of the problem is sound but lacks some detail. The student's own ideas are sound, and advice given was acted upon. A reasonable plan was made.

5 There is clear analysis of the problem. Appropriate variables are selected for investigation. A thoughtful plan was constructed. Personal responsibility was taken for plans and decisions. Advice and sources were well used. The student's own ideas played a significant role. The work shows evidence of coherent development.

Resources and safety: Are experimental methods, apparatus and techniques chosen with due regard to precision, and safety? Do experiments develop and relate to one another?

1 Procedures and apparatus chosen are generally sound, but lack finesse. Safety measures are somewhat basic. There is little evidence of care for reliability of results.

3 The selection of apparatus and procedures is adequate. Some attempt is made to address safety matters and the need to generate reliable results. The experimental work bears upon the problem.

5 Experiments are designed or chosen with a view to what they will suggest or test. Apparatus and methods are chosen with some care and thought, and with due regard to precision and safety.

STRAND B: Use of Knowledge, Skill and Understanding of Physics

In carrying out the Practical Investigation the student will need to use the physics they have studied and their understanding of that physics, as well as the skills they have acquired during the course to develop a strategy for tackling the task. Throughout the task the student should have a critical and cautious attitude to information and data, identifying discrepancies. (Collection of data may include detailed recording of non-numerical observations.)

Appropriate activities: Are the range, and variety, of experiments performed appropriate in the context of the investigation? Does knowledge of physics inform decisions about the progress of the investigation? Is the physics at an Advanced GCE standard?

1 The experimental work relates to the task, but is limited in certain important respects. The methods used are largely empirical.

3 A related set of experiments is used, or several aspects of one long experiment are investigated. Some of the potential of the work has been developed. There is some evidence of experimental design. Useful methods have been improvised and used with reasonable skill. Ideas formulated show use of knowledge of physics.

5 There is a good range of experiments, showing progression and development. The potential of the experimental work has been fulfilled. Knowledge of physics is used to inform decisions and guide analysis.

Practical skills and techniques: Is there effective improvisation of methods or equipment? Are experiments well, carefully and thoughtfully done? Is due account taken of effects which may affect the results?

1 The experimental methods used are basic and straightforward. Little knowledge of physics is brought to bear. Effects which might affect results are not considered.

3 There is some evidence of experimental design. Useful methods have been improvised and used with reasonable skill. Some account has been taken of effects.

5 There is evidence of experimental design. Practical knowledge and skills have informed the design of the experiments. Effects which might affect the results are seen and dealt with. Techniques are improved or changed, as necessary, to improve accuracy and reliability.

STRAND C: Communication

The Practical Investigation culminates in the written report. In writing this the student is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting.

Record of observations: Is the collection and recording of data well organised? Are the number and range of results sufficient? Are results recorded to an appropriate and consistent degree of accuracy? Are ways sought of making the results more reliable and accurate?

1 Observations and measurements made are those expected for the task, but may be lacking in detail, range or precision. Some attempt may have been made to reduce uncertainties in results, but the purpose may not be clear.

3 The collection and recording of data are satisfactorily achieved. Observations and measurements are recorded clearly. The number and range of results are satisfactory. Some steps are taken to minimise uncertainties and, where appropriate, to deal with anomalies in results. The reasoning is reasonably clear.

5 The collection and recording of data are well organised. Observations and measurements are recorded to an appropriate degree of precision. The number and range of results are appropriate. The limitations on accuracy, imposed by different apparatus, are appreciated. Steps are taken to minimise uncertainties.

Quality of report: Is the report clear, well structured and well argued? Does the report communicate the work done effectively? Are data (tables, graphs, charts) well presented? Is the English of a good standard?

1 The report is essentially a summary of the work done. Tables and graphs are presented, perhaps without much comment. The quality of English is adequate to express simple ideas clearly.

3 There is some analysis of results, perhaps plotting an appropriate graph to test a relationship, or fitting data to formal relationships (e.g. finding a power law). The quality of English is adequate to express some more complex ideas.

5 The work is guided by a concern to explain, interpret or understand results. Tables and graphs are well presented. Graphs are chosen for the information they convey. The quality of English is good.

STRAND D: Evaluating Evidence and Drawing Conclusions

This strand assesses the student's ability to take a critical look at the work done.

Evaluation: Is an attempt made to make sense of the results? Are meaningful relations between results or observations sought? Is any theoretical explanation developed or considered? Are the conclusions valid and clearly linked to the supporting evidence? Is there good understanding of the underlying physics?

1 There is some attempt to identify trends and patterns in the data, but the analysis lacks depth. Results are presented directly, and not always in the most appropriate form. Expected relationships are assumed to be present though they may be unsupported by the evidence. Discrepancies are largely ignored. There is little awareness of the limitations of the methods used.

3 General trends and patterns in the data are established using appropriate graphical techniques, but more complex patterns or trends may not be identified. Relationships proposed are consistent with the evidence, and supported by underlying principles. Some discrepancies or anomalies are commented upon. The main limitations of the experimental procedure are appreciated.

5 The results are well analysed, either graphically or by mathematical tests, to reveal the underlying relationships. Discrepancies or anomalies are dealt with. Error bars may have been used effectively on graphs to reflect the uncertainties in the data. Qualitative results are interpreted with care and insight. The limitations of the experiment are fully appreciated.

Conclusions: Does the report show evidence of critical, connected thought? Are results interpreted with care and insight? Are conclusions drawn with due regard to the limitations of the methods and the uncertainties in the results?

1 The work is mainly empirical in nature. The progress of the task was not affected by the effects observed. Conclusions, which may be qualitative, are limited and focus on the more obvious results.

3 The work shows progression and development. Results are given some physical interpretation, even if this reveals minor misunderstandings. There are few errors in basic physics. Conclusions, though supported by the evidence, may not be qualified as necessary.

5 The report shows evidence of critical, connected thought. Relationships proposed are consistent with the evidence. Knowledge and understanding of physics are used to account for relationships. The uncertainties inherent in the data are reflected appropriately by the tentative nature of the conclusions. Basic errors in physics are avoided. The work is interesting, achieving results new to the student.

5.2.2 Research Report

This task provides an opportunity for students to demonstrate their research, analysis and communication skills. At this level, in A2, students are expected to be able to draw together ideas from different parts of physics, to synthesise their ideas and place the physics in a wider context. The assessment addresses some aspects of AO1 Knowledge with understanding and AO2 Application of knowledge with understanding, synthesis and evaluation. But in particular this task gives an opportunity within the A2 course to assess the objectives of AO4 Synthesis of knowledge, understanding and skills:

Students should be able to:

- bring together principles and concepts from different areas of physics and apply them in a particular context, expressing ideas clearly and logically and using specialist vocabulary where appropriate;
- use the skills of physics in contexts which bring together different areas of the subject.

Research Reports are assessed under each of four headings:

STRAND A: Initiative and Independence: Planning and use of Resources

During the preparation of the presentation the teacher will work closely with the student. Discussions should be framed to allow the student to show initiative, personal involvement and interest. The task requires the use of resources, probably both ICT and paper-based.

Initiative and independence: Is it a sensible topic? Does it have sufficient scope for relevant physics? Are there opportunities to show how a variety of ideas in physics used? Has the student contributed his/her own ideas? Has the student worked independently, taking responsibility for decisions?

1 A definite topic has been chosen, and appropriate choice made of what to study. Simple physical ideas are used. Guidance was needed at all stages; there is little evidence of personal involvement or commitment to the task.

3 The topic has interest and potential, and some of this is developed, incorporating a variety of relevant physics. The work has some plan and development and some improvisation of ideas. Some independent decisions have been made; help given or sources suggested to be used have been considered and acted on appropriately.

5 The Research Report as a whole is a sustained, interesting, worthwhile study of relevant physics, achieving results, some of which are new to the student. A variety of physics ideas are incorporated in the report. Personal responsibility has been taken for decisions.

Resources: Has the student explored physics relevant to the topic chosen? Has the student used a good variety of information sources, or, alternatively, a few sources well? Has the student acknowledged the sources and identified which source provided which information in the report?

1 At least one source of information is used. The information gained is relevant to the issue.

3 Several sources are used. Some reference is given to the sources (e.g. publication information, web-site location, dates and places of interviews with named people).

5 There is evidence of wide reading. Sound judgement is displayed in choosing between the variety of sources available. Sources are acknowledged and the way in which each source relates to the report is made clear.

STRAND B: Use of Knowledge, Skills and Understanding Physics

In completing the Research Report the student will need to use the physics they have studied and their understanding of that physics, as well as the skills they have acquired during the course to develop a strategy for tackling the task. Throughout the coursework the student should have a critical and cautious attitude to information and data, identifying discrepancies.

Use of physics: Does the student use their knowledge and understanding of physics to interpret the information? Does the student draw on a variety of concepts in physics?

1 There is some variety of ideas in physics, but at a simple level.

3 Relevant theories, models or arguments are presented but without much comment, and may be quoted verbatim without evidence of much understanding. There is recognition that a variety of physics ideas are involved.

5 Theories and arguments are logically introduced or developed. The student shows a significant understanding of a range of physics ideas.

Analysis and interpretation: Does the work go beyond descriptive reporting? Has any attempt been made to make sense of the results or information obtained?

1 The report is entirely descriptive with no attempt at analysis. There is recognition of some of the various ideas but connections are not made.

3 Data and observations are presented directly. There is some attempt to explain them using a variety of physics ideas.

5 There is good and clear analysis of any data, observations or arguments, and the conclusions drawn are clearly stated and linked to the supporting evidence. The links between the different aspects of physic are drawn out.

STRAND C: Quality of Communication

The task is to produce a written report. In doing this the student is encouraged to add value to the work by showing critical and connected thought, moving beyond descriptive reporting.

Content of the report: Is the report interesting, concise, clear and well argued? Does it effectively communicate the work done? Are data and arguments well presented? Does the report have a clear structure, so that it is easy to refer to?

1 The report is a straightforward factual account of the work done. The logic or development is hard to follow, with the structure perhaps dictated by the sequence in which evidence was gathered.

3 The report is interesting to read. There is some continuity in the development of ideas, and the relationships between different aspects of the topic are clear.

5 The report is clear, logical and interesting. There is a particularly good organisation of difficult ideas or complex data, and arguments are made easy to follow.

Presentation : Does the report provide evidence of thought and planning with regard to its presentation? Are charts, tables, graphs and diagrams clear, well constructed and appropriately positioned? Is the English of a good standard?

1 Graphs and other illustrations may be unclear or inadequate, lacking or irrelevant and are not integrated into the text, either physically or by sensible indexing. The quality of English is adequate to express simple ideas clearly.

3 There is evidence of structure and organisation which makes it easier to follow. Illustrations are relevant, generally clear, and contribute to the communication of ideas. The quality of English is adequate to express some more complex ideas.

5 The report is well structured, makes an impact (for example particularly good and relevant illustrations) and summarises the main argument or ideas clearly at the beginning or end. It is not excessively long or verbose. The quality of English is good.

STRAND D: Evaluation and Connections

The Research Report provides an opportunity for students to consider where information is found and how reliable it is. They should consider physics in the wider human context, for instance it may be the historical setting in which a particular piece of physics was done; the impact a discovery in physics had on society, technology or the environment.

Evaluation of sources: Are the sources relevant and, if necessary, up to date? Does the student evaluate the sources in terms of their suitability or reliability?

1 The student accepts the information collected, with little attempt to check reliability.

3 Some attempt is made to evaluate the accuracy and reliability of the sources, even if at a superficial level. The student makes use of more than one relevant source of information. Sources are used which complement each other.

5 There is good evaluation of the reliability, accuracy or suitability of the sources. The student may comment on any difference in views or ideas from the sources. A good range and variety of relevant sources are used, with full documentation. It is made clear which sources provide which information.

Connections: Does the student place the physics ideas in a wider human or social context? Does the student make connections between different aspects of the physics?

1 Some aspect of the wider context for the physics is mentioned, but without detail or discussion.

3 Information about the wider context is mentioned, but is limited to descriptive reporting without discussion or comment. There is some attempt to identify the various aspects of physics.

5 There is interesting material from the wider context, which is related thoughtfully to the other concerns of the report and deepens or illuminates the account. The way in which the various aspects of physics work together are discussed.

6 Frequently asked questions (FAQs)

1. Is there any size or word limit on coursework submissions?

   No, ***but*** *there is absolutely nothing to be gained by submitting particularly large volumes of work for assessment. The time guidance given for each task includes the time for writing up the report. Students should be discouraged from spending longer and should be warned that excessively long reports may reflect a lack of clarity. Moderators will be looking at the quality of the work rather than the quantity and for clear evidence that candidates have achieved the criteria listed under each skill.*

2. Do Centres need to show evidence of marking on candidates' work?

   Yes; the more comments are clearly written on submitted work, the easier it is for Moderators to judge whether candidates have been fairly assessed. Additional comments may also be helpful in justifying the marks awarded.

3. How do I grade candidates' work which does not fit exactly into one level within a strand?

   You should use the marking matrix to obtain a 'best fit' mark out of 5 for each strand, interpolating as necessary.

4. Some candidates find coursework very difficult. What advice can you offer which will increase candidates' prospects of achieving good marks?

   It is clearly important that candidates are taught the skills and given opportunities to practise, before being assessed. Candidates may find it helpful if staff go through a worked exemplar, showing how they themselves would tackle a particular topic, provided that candidates are not allowed to produce work on the same topic for submission. Candidates should be made aware of the descriptors used to assess their work, so that they can ensure that all aspects of the descriptors are addressed.

5. I am having trouble deciding whether the tasks offered properly address the demands of the skills listed in the specifications. What advice is available?

   A proposed task may be submitted to OCR and a response on its suitability will be provided. INSET courses are provided each year; details are sent to Centres, and a contact address for the Training and Customer Support section is also given in Section 10.

6. Does every candidate have to carry out different tasks for the Instrumentation Task and the Making Sense of Data task?

   Not necessarily, but they do need to work independently to score highly and it is the Centre's responsibility to ensure that each candidate's work is their own.

7. Can candidates use the Internet during their Research and Presentation and Research Report?

Yes; there is some excellent material available and the highest mark descriptors require candidates to draw together material from several sources. All URLs should be listed (with any other sources) in a bibliography

8. Will candidates improve their chances of achieving high marks by making extensive use of Information and Communication Technology in their reports?

Computer-generated material is not in itself worth any more marks than hand-written work. However, if the use of I.C.T. enables the mark descriptors for any of the skills to be more effectively addressed, then candidates could gain extra credit. It should be noted that many graph-plotting packages, if not used expertly, may not produce the most appropriate graphs.

9. Does all coursework have to be carried out under the direct supervision of the teacher?

No; in order to meet the requirements of the Research tasks candidates will need to carry out research which may require the use of library facilities, the Internet etc... Also, it may not be possible to devote sufficient time in the laboratory/classroom to allow candidates to write up their work. However, sufficient work must be completed under direct supervision to allow the teacher to authenticate the marks awarded, and this is left to the discretion of the Centre.

10. How much help can I give students with their coursework?

This is a difficult question to answer. Candidates should be given the opportunity to demonstrate their ability to work independently, but if they are in difficulty they will need sufficient guidance to enable them to produce something worthwhile. The first mark descriptor relates to the initiative and independence of the student and provides an opportunity to reward students appropriately.

In some circumstances it may be necessary to give direct help to students, for example to ensure that they are working safely or to get them through a difficulty. Such help should be taken into account in the award of marks and details must be provided to the Moderator.

When students choose their own coursework tasks, guidance should be given by the teacher to ensure that that the tasks are of appropriate demand and likely to generate results capable of analysis. In a whole investigation it is suggested that the draft plans are submitted to the teacher for an initial assessment to be made of the suitability of the strategy. Such assistance is acceptable without penalty provided that candidates are not given direct guidance about what to do.

11. Can I take in the work of my students, mark it, and then give it back to them for any errors to be corrected before taking it in again for a final mark to be awarded?

No; once the work has been handed in for marking, the marks awarded should stand.

*Assistance can be given to students while they are carrying out their work provided that it is limited to the identification of aspects of the assessment descriptors that have not been addressed. However, it is suggested that work for Skill **P** should be collected in for an assessment of its suitability to be made before any practical work has been carried out, though Skill **P** should not be marked until the whole assessment has been completed.*

12. Can work completed in the AS year be submitted for assessment for A2?

Yes; though the work submitted for A2 must be at an appropriate standard for A level Physics. This means that candidates will need to draw on the knowledge and understanding at an appropriate level in order to plan, carry out and analyse the physics of the Investigation or Research Report. Teachers should be aware of the need to encourage students to choose a task of appropriate demand for A2.

13. If Units 2863 or 2864 are re-taken, can the coursework marks be carried forward?

*Yes; an entry for one of these units is for the written paper and the coursework. Entry options for these units are provided for coursework marks to be carried forward, but it should be noted that marks for the written paper may **not** be carried forward.*

7 Suggested Tasks

7.1 Instrumentation Task

There is a choice of task: Build and test your own sensor, Test and evaluate a sensor; or Use a sensor to make a measurement.

Build and test your own sensor

For example sensors to monitor:

- liquid level based on flotation and a rotary potentiometer
- the angular position of a door or window, as it opens and closes
- *x* and *y* positions of a plotting device using two linear variable resistors
- proximity of an object, using a photodiode to detect light from an LED reflected from the object
- small displacements using moiré fringes and light detector
- temperature using a thermocouple
- temperature using change of resistance of a metal, or of a thermistor
- infrared radiation using a photodiode
- sound level using a microphone
- force using a spring and a linear variable resistor
- rotational frequency of a motor (for example using light detector and a slotted disc)
- airflow from a fan with a hot wire anemometer
- airflow from a fan using a hinged flap and angular variable resistor
- liquid flow by cooling effect on a self heated resistor
- acceleration using a spring, inertial mass and linear variable resistor

Test and evaluate a sensor

Typical kinds of sensor available are:

- airflow sensors
- optical switches
- vibration sensors
- pressure sensors (low pressure, high pressure)
- proximity sensors (capacitative, optical, ultrasonic)
- speed and position sensors
- strain sensors
- temperature sensors
- light dependent resistor
- photodiode
- thermistor

Use a sensor to make a measurement

Examples of quantities to measure include:

- pressure (e.g. water pressure in a tank, gas pressure in a pump)
- temperature (e.g. surface temperature of radiators)
- strain (e.g. bending of a beam)
- force (e.g. forces exerted during a collision)
- radioactive decay rate (e.g. background radiation, strength of a source)
- frequency (e.g. of a whistle, of vibrations due to traffic)
- optical reflectance or transmittance of a surface, or optical absorption by a filter
- absorption of ultraviolet (e.g. efficiency of sun-block cream)
- time interval (e.g. time occupied by a collision)

7.2 Research and Presentation

Possible titles:

Biomimetics

Hip replacements

Contact lenses

Metal alloys:

Cakes, confectionery and chocolate

Environmentally friendly plastics

Disaster! Titanic and Challenger

Paper versus plastic

Light-bulb filaments

Toughened glass

Composite materials in skis

Titanium for bike frames

Bullet-proof glass

7.3 Making Sense of Data

Experimental data is required from some work which is in the context of the AS course. For example:

Data for a trolley down a runway – e.g. height of ramp and speed at end of runway

Force and resulting extension on a copper wire

Distance and time data for a trolley pulled by a falling load

Variation in resistance of different batches of resistors

Power output of a radio resistor at different currents and pds

Variation of intensity of light from a source

Variation of intensity of light from extended sources as parts are covered

Amount of light reflected from a surface; variations with angle

emf of a thermocouple with temperature

Change in resistance of a strain gauge with strain (and temperature)

Variability of tear strength of strips of paper, dependence on width or thickness

Deflection against load for a flexible strip

Variation of conductance of thermistor with temperature

Variability of conductance of batch of thermistors

Brightness of an image from a lens varying with aperture

7.4 Investigation

Energy from waves

Electromagnetic flowmeters

Sedimentation

The flight of shuttlecocks

Electromagnetic braking

Stability of slopes

Vortices in fluids

Heat exchangers

Why do flags flap?

The physics of squash balls

Stability of high-sided vehicles in cross-winds

The acoustic properties of double-glazing

Crash barriers

Ski jumps

River meanders - a question of chance?

Corona discharge

Piezoelectric effect

Behaviour of water drops on hot plates

7.5 Research and Report

Digital electronics and the electrocardiograph monitor

Modern control technology in farm machinery

Speech synthesis and recognition

Guitar electronics

Human fitness monitoring

Methods of traffic control

Automatic flight control or fly-by-wire

Artificial intelligence and neural networks

Robotics

The CT scanner

Electronic weather recording

Satellite communications

Autofocus systems in cameras

The Sun, the largest fusion reactor in the Solar System - but for how long?

What decides the surface temperature of planets?

Combined heat and power

Power from waste

8 Exemplars

One piece of work for each of the five coursework tasks is illustrated in this section.

8.1 Instrumentation Task: Airflow from a fan with a hot-wire anemometer

INSTRUMENTATION task

A copy of this sheet must be attached to each candidate's work as a record of the assessment.

Centre No .

Candidate Name:

Candidate No

Initiative and independence:	**A** (i) Planning (ii) Use of resources and safety	Choice: Interesting and challenging Plan: Detailed and appropriate Approach: Independent and acted on advice Flexibility: Any difficulties dealt with Completion: All aspects	Suitable Satisfactory Independent, needing advice Any difficulties overcome with help Most aspects	Simple Guided Guided Kept to a simple plan Partial (i) 4 /5	Use of resources: To good effect Experimental design: Careful choice of equipment, methods and techniques Safety: Safety was given due regard. (ii) 4 /5	Some resources put to good use Equipment, methods and techniques are adequate Some attempt is made to address safety	Required direction Simple apparatus used in a direct way Safety measures are somewhat basic
Use of physics	**B** (i) Devising a strategy (ii) Practical skills and techniques	In devising the strategy: It is clear that a sound knowledge and understanding of the relevant physics has been used. Preparation: The approach has been thoughtful; initial experiments and rough calculations guided progress.	Some knowledge and understanding of physics has been employed, but some work is empirical. Straightforward effects were anticipated, and guided progress.	The approach is largely empirical. There was little advance preparation. (i) 4 /5	In executing experiments: Practical knowledge and skill are put to good use Conflicts: Effects which might affect results are seen and dealt with. (ii) 4 /5	Some practical skill is shown; the work is competent. Effects which might affect results are commented upon.	Apparatus used in a direct way Effects which might affect results are not considered.
Communication	**C** (i) Record of observations (ii) Presentation of report.	Observations: Observations & measurements made with appropriate precision Record of observations: Observations recorded methodically in appropriately labelled tables	Most effects were observed and recorded Tables of results were present but in some cases not correctly labelled	An incomplete record of the observations Tables of results lacked significant details. (i) 3 /5	Presentation: Well structured report; tables and graphs chosen to display results meaningfully. Use of English: The quality of English is good. (ii) 4 /5	Some structure, tables & graphs used to communicate results. The quality of English is generally adequate to express complex ideas	Data are reported, but the meaning of tables and graphs may not be clear. The quality of English generally adequate to express simple ideas
Analysis	**D** (i) Systematic measurement (ii) Fitness for purpose of system	Measurements: Sensible range of measurements taken methodically. Accuracy: Repeat readings as necessary, recorded to appropriate precision	Fair range, in reasonably organised way. Limited cross-checking of measurements	Measurements taken, limited in some important respect. Accuracy assumed. (i) 4 /5	Fitness for purpose: Relevant qualities of fitness for purpose are considered and explored. (ii) 3 /5	Some aspect of the fitness for purpose of the system is explored, or tested.	There is some reference to the properties of the sensor, or instruments, used.
					These qualities might include resolution; response time; systematic bias; systematic drift; sensitivity; random variation.		
RATING TOTAL				30 /40	Additional comments to support and explain ratings may be made overleaf.		

Assessors signature :

Date :

Airflow From A Fan With A Hot-Wire Anemometer

Brief

Undertake an individual instrumentation project as part of the assessed course work for the course. This project may involve one of:

Building and testing a sensor,
Exploring the characteristics of a sensor,
Designing and assembling a measurement system, and use the sensor to take measurements.

I have chosen to design and assemble a measurement system, using a sensor to take measurements.

Further Brief

Use a sensory device to put together a system to take measurements. The report of results should evaluate the measurements, giving evidence of how reliable it is likely to be.

Introduction

My point of research, is going to be to use a sensing device to measure the resistance of a hot-wire anemometer when subjected to different airflow rates.

To enable me to find the resistance I must take measurements of the current and the potential difference. With these measurements I will be able to calculate the resistance using the following formula:

$$\text{Resistance}(\Omega) = \frac{\text{Potential Difference(V)}}{\text{Current(I)}}$$

I am going to see how my measurements are effected by changes in airflow (temperature) over my hot-wire anemometer. This experiment is directly related to Ohm's law which states that:

"Conductance or resistance can be calculated at any given current or potential difference. If the current or potential difference changes, the conductance and resistance may change."

I predict that as my hot-wire anemometer's temperature increases, so the resistance will become higher than if it was cooled where a low resistance would be expected.

This is so because when it is heated no more electrons are free to move. When the temperature rises, the electrons move less freely creating lattice vibrations, which increase resistance.

When the hot-wire anemometer is cooled, the vibrations in the lattice subside allowing the electrons to move around more freely, giving a lower resistance.

This is also shown in the following calculations where a simple experiment was conducted using a 50cm long coil of copper wire connected to a 4.5 volt power supply. The wire was subjected to a high air flow and no air flow at all.

	Current(I)	Potential Difference (V)	Resistance(Ω)
Air Flow	2.5	0.829	0.3316
No Air Flow	2.2	0.901	0.4095

This shows that when there is no air flow and the hot-wire anemometer is at its highest temperature, it is 0.0779 Ohm's higher in resistance.

Taking this into account I predict that there will also be a higher resistivity when the wire is at its highest temperature. This is so also because the electrons would be vibrating faster. This is shown by the following calculations:

Resistivity at 0°C of Copper = $1.7\times10^{-8}\,\Omega m$

Resistivity of copper wire at σ °C = $P_o\,(1+\alpha\sigma)$

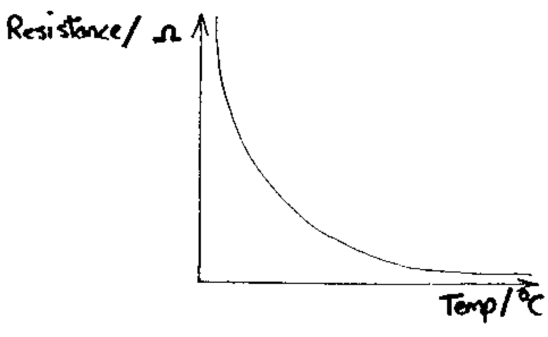
Resistivity of copper wire at 400 °C = $P_o\,[1+ (4\times10^{-3}(400)]$

$= P_o(1+1.6)$

$= 2.6\ P$

These calculations show that resistivity increases with temperature. Therefore as conductance is inversely proportional to resistivity conductance would increase as the temperature decreases.

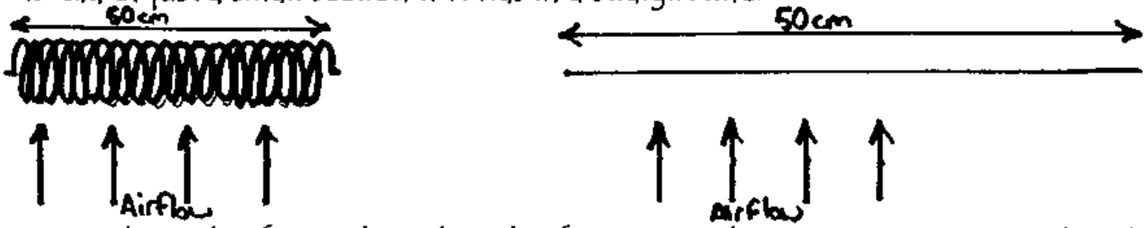
I would expect a graph of resistance over temperature to look like the following:



Before I prepare a plan, I must answer the following questions:

1. What length/diameter wire is suitable?
2. What size potential difference is suitable?

I have found from preliminary research that a coil will have to be used as it is able to occupy a smaller space allowing the air to completely flow over the wire instead of just a small section if it was in a straight line.



I have also found that a length of wire 50cm long gives adequate results. I have chosen the smallest diameter available to me of 0.274mm as it gives a higher internal resistance with the same potential difference, allowing the wire to reach higher temperatures. The resistance of my wire should be:

$$\text{Resistance (R)} = \frac{\text{Resistivity x Length}}{\text{CS Area}}$$

$$= \frac{1.7\text{x}10^{-8}(0.5)}{\pi(1.37\text{x}10^{-4})^2}$$

$$= \frac{8.5\text{x}10^{-9}}{5.896455252\text{x}10^{-8}}$$

$$= 0.1441544405\Omega$$

$$= \frac{1}{10\Omega}$$

The size potential difference to be used, is dependant on the length/diameter of the wire to be used. I carried out a brief experiment with a 50cm long coil of wire at a diameter of 0.274mm starting with a potential difference of 0V and progressing to a potential difference of 5V, where the wire fused and broke the circuit.

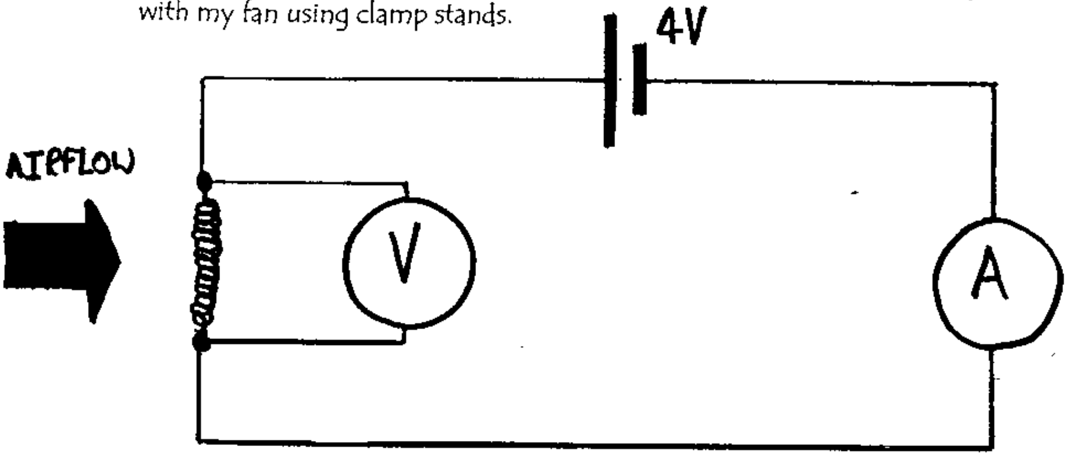
Potential difference/V	Condition Of Wire
0	Normal
1	No Change
2	Increased Temperature
3	Further Increased Temperature
4	Red Hot
5	Fused

From these results I have decided to use a potential difference of 4 volts. I have chosen this potential difference as when the air flow passes over the wire, suitable changes in current and potential difference would occur.

Plan

Knowing that resistance varies with temperature, I am going to use a fan and a hot-wire anemometer to vary temperature. I will then be able to take current and potential difference readings which allows me to calculate resistance

To do this I am going to assemble my circuit so that my hot-wire anemometer is connected to a power pack, a voltmeter is in parallel with my anemometer and a 5 amp ammeter in series. I am then going to line my anemometer with my fan using clamp stands.



I am going to use all six of the settings on the fan, 0 being no air flow and 6 being the fastest air flow. I will repeat my experiment three times to ensure of no discrepancies. I will then average my results.

I had the choice of two materials copper and Constantine. I discarded the Constantine as its resistance does not change when heated and so would not meet the parameters of my experiment.

I chose copper as its resistance varies with temperature, it has a high conductivity, and can easily be made into a coil. I am going to use a long coil as it is able to carry a high enough voltage to heat the wire.

I am going to use a 50cm long coil of copper wire with a diameter of 0.274mm, as it gives suitable current and potential difference readings and its temperature rises enough to make the cooling effects of the fan noticeable.

Results

Trial 1

Air Flow (Temperature)	Current/ I	Potential Difference/ V	Resistance/Ω
0	4.0	2.02	0.505
1	4.5	1.94	0.431
2	4.6	1.88	0.409
3	4.7	1.85	0.394
4	4.8	1.83	0.381
5	4.9	1.81	0.369

Trial 2

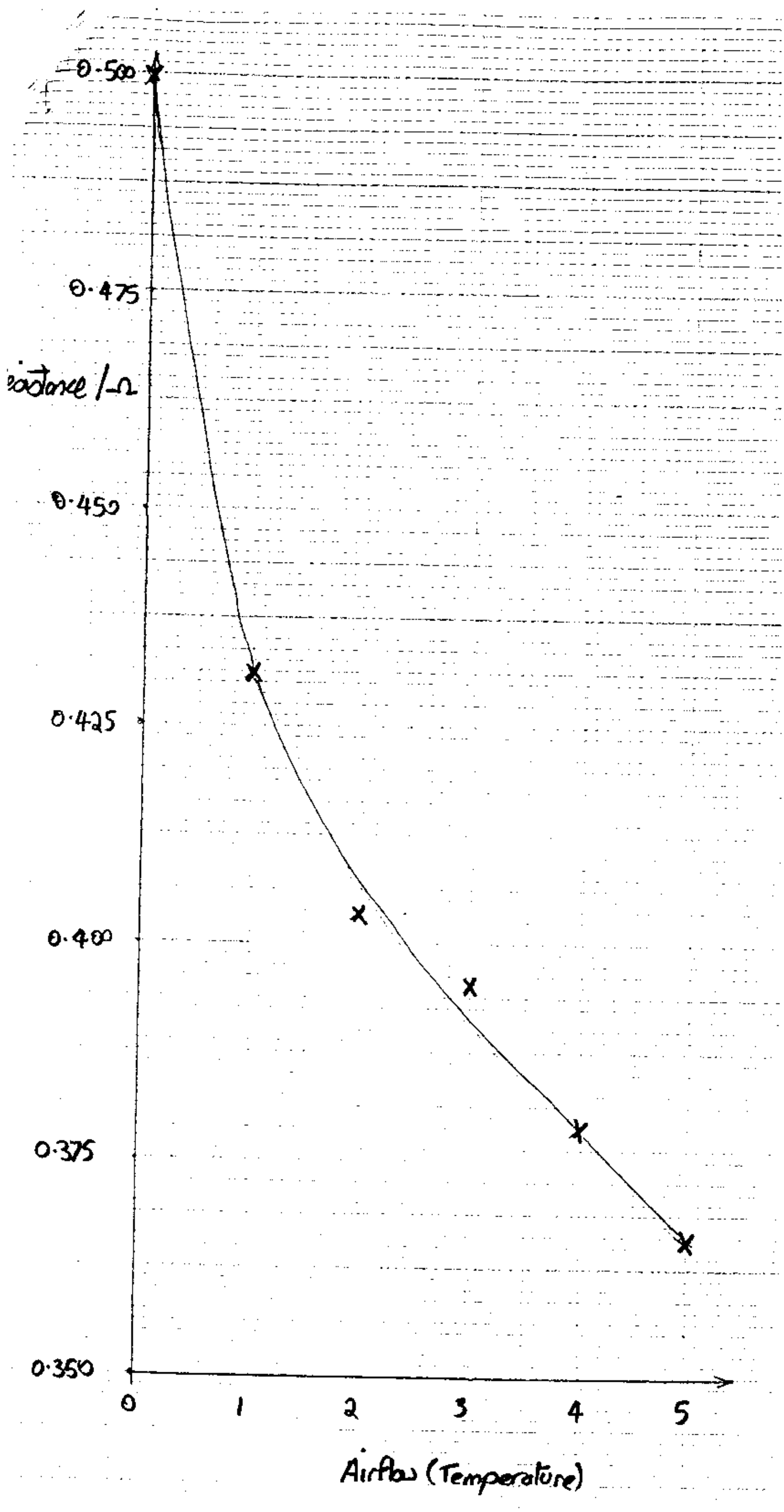
Air Flow (Temperature)	Current/ I	Potential Difference/ V	Resistance/Ω
0	4.0	1.99	0.498
1	4.4	1.92	0.436
2	4.6	1.89	0.411
3	4.7	1.85	0.394
4	4.8	1.83	0.381
5	4.9	1.81	0.369

Trial 3

Air Flow (Temperature)	Current/ I	Potential Difference/ V	Resistance/ Ω
0	4.1	2.04	0.498
1	4.5	1.94	0.431
2	4.7	1.88	0.400
3	4.8	1.84	0.383
4	4.9	1.83	0.373
5	5.0	1.80	0.360

Average Resistance Results

Air Flow (Temperature)	Resistance/ Ω
0	0.500
1	0.433
2	0.407
3	0.390
4	0.378
5	0.366


0·500
0·475
esistance / Ω
0·450
0·425
0·400
0·375
0·350
0
1
2
3
4
5
Airflow (Temperature)

Analysis

From my graph you can see that the curve begins fairly steep, but then begins to level off. This is because during the initial part of the curve, the air flow rate is slower. This gives the air more time to have a cooling effect on the hot wire.

During the leveling off of the curve, the air is flowing at too fast a rate to make a noticeable effect on the hot-wire.

In the initial steep part of my curve you can see that a small change in air flow gives a high change in resistance, this is because the sensors are more accurate during this part of the experiment as the air flow is slow enough at first, to make a large difference in the readings as its rate increases.

During the flattening of the curve the sensors lack the accuracy to read the difference in current and potential difference when a fast rate of air is flowing over the wire.

My graph also satisfies the hypothesis that as the temperature rises, the resistance of the wire increases also.

My resistance values are also higher than my predicted values, this was due to contact resistance, which caused the constriction of the current between the crocodile clips and the copper wire. My readings differed with the calculated resistance by a minimum of 0.222 of an Ohm, and a maximum of 0.356 of an Ohm.

I also seem to have a spurious result at the airflow setting of 3. The resistance of this reading seems to be higher than I would expect and is not in accordance with the surrounding results. This leads me to believe that either an error has been made in the recording of the data, or there has been an anomalous result created by the equipment used in the experiment.

Conclusion

I conclude that I successfully constructed and used a system that allowed me to take measurements. These results were limited in accuracy to the nature of the experiment, but were accurate enough to satisfy my predictions.

Points Of Improvement

1. Use the fan in a more accurate way, i.e. only use the settings between 0 and 3 and split these into further settings using the speed of the airflow, rather than the numbers on the dial. By this I mean instead of using the number settings on the side of the dial, measure the airspeed and use this as settings.
2. Use sensors that are able to read data more accurately. With this I mean why use sensors that are only accurate to two decimal places when I could use sensors that are accurate to three decimal places instead.

8.2 Materials: Research and Presentation: Website

MATERIALS: Research and presentation

A copy of this sheet must be attached to each candidate's work as a record of the assessment.

Centre No :

Candidate Name:

Candidate No :

A — Initiative & independence

(i) Planning
(ii) Use of resources

Plan:	Detailed and appropriate ✓	Satisfactory	Guided
Approach:	Independent and acted on advice ✓	Independent, needing advice	Guided
Flexibility	Any difficulties dealt with.	Any difficulties overcome with help ✓	Kept to a simple plan
Use of resources:	To good effect, with an indication of the contribution of each resource to the report	Resources put to good use with some indication of their contribution. ✓	Little linkage between resources used and the report
Selection of resources	Careful choice of a good range of different types of resources	Use of a slightly restricted range of resources ✓	Limited resources used in a direct way

(i) 4 /5 (ii) 4 /5

B — Use of physics

(i) Thinking about the physics
(ii) Critical and cautious approach

In the report:	It is clear that a sound knowledge and understanding of the relevant physics has been used	Some knowledge and understanding of physics has been employed, but some work is empirical. ✓	The approach is largely empirical.
In handling information	Assumptions are questioned, discrepancies between sources noted and an attempt is made to account for them.	Assumptions and discrepancies are mostly noted but not pursued	Information is accepted at face value and reported.

See notes

(i) 3 /5 (ii) 3 /5

C — Communication

(i) Content of report.
(ii) Presentation of report.

Structure of report	The structure of the report helps to show connections within the work by careful ordering of the information. ✓	Some care has been taken to order the account to help inform the audience	Information is presented without much concern for order
Focus of report	The focus of the report is clear and is competently addressed ✓	The report has a focus and there is an attempt to address it.	Factual reporting which lacks a clear focus
Presentation:	Resources are used to present concisely, with impact and clarity	Information is presented intelligibly, but lacks some audience impact ✓	Direct reporting of information with little concern to connect with the intended audience.
Use of English:	The quality of English is good.	The quality of English is generally adequate to express complex ideas ✓	The quality of English generally adequate to express simple ideas

(i) 4 /5 (ii) 4 /5

D — Context and evidence

(i) Context
(ii) Evidence

Context choice:	Interesting and challenging	Suitable ✓	Simple
Use of context	The work is placed clearly in the context chosen, which frames the report	The context is clear, but is not embedded in and connected with the report ✓	There is no obvious context related to the report.
Research	There is a clear record of the research carried out	A list has been made of the sources used ✓	There is some documentation to show the research carried out
Presentation	An appropriate paper record of the presentation is provided	An adequate record of the presentation is provided ✓	An incomplete record of the presentation is provided

(i) 3 /5 (ii) 4 /5

RATING TOTAL 29 /40

Additional comments to support and explain ratings may be made overleaf.

Assessor's signature

Date:

David Taylor – Web site

(A) Plan Well thought out, but no written plan produced. Overall structure of site shows planning. ~4

Approach Independent. Did not need advice, but accepted the offer of using Amato's "Stuff". – & acknowledged it ~5

Flexibility. Appeared to have no difficulties – or overcame them. Does 'relative simplicity' of project limit the mark? ~3

∴ Average (4)

Use of resources Used well & indicates where used ~4

Selection Most, web based; though understandable. Difficult to accuse this of being restricted, but background could possibly have used more written references ~4

Average (4)

(B) In the report
The physics is explained & used correctly. Not interpreted as well as could be ~3 (3)

Handling information. I find this hard. No discrepancies appear to arise, but he probably has not looked for them. I believe that he has only used information that seems sound. ∴ want to give much more than 1, suggest ~3 (3)

(C) Structure Well organised site, easy to navigate, with not too much information on each page, & cross links. ~4

Focus Clear focus in explaining what SMA's are & current uses – but not exceptionally challenging ~4 (4)

(C) Presentation Well made & good use of graphics, text & colour. Could be more entertaining ∴ ~4

Use of English Sound. David also led class through the site, clearly explaining the sections. ~4

(4)

(D) Context choice Suitable, but probably missed the opportunity to ask what the future could be. ~3

Use of context Clear & embedded, but can I give >3 if the context is not too challenging? ~3

(3)

Research References given and web resource pages copied. – I failed to ask for reference material until later! ~4

Presentation – Available as the web site http://home.clara.net/cash2/ ~4

(4)

David also answered questions on site with ease and knowledge.

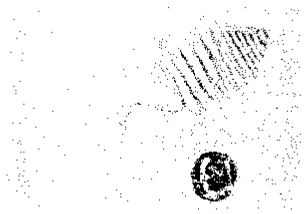
[signature]

Total (29/40)

Physics A-Level
Shape Memory Alloys

Introduction - Shape Memory Alloys.

Shape Memory Alloys is the term applied to those alloys that return to their previously defined shape or form when introduced to the appropriate heating procedures. These materials have great implications in the design in future inventions as well as current ones.



'Spiral' made from NiTi

These can usually be plastically deformed at a relatively low temperature, but will return to their original shape to before the deformation at much higher temperatures. These materials are known as one-way shape memory, the materials that undergo a return in shape upon recooling are known as two-way shape memory.

Shape Memory Alloys undergo a martensitic transformation which allows the alloy to be deformed using a twinning mechanism below the transformation temperature. This can be reversed when it is heated to the parent phase.

Although there are a wide variety of alloys which posess the shape memory effect, only those that can withstand great amounts of strain and/or that generate significant force upon changing shape are of commercial interest these have generally been the nickel (Ni) titanium (Ti) alloys and copper (Cu) based alloys - CuZnAl and CuAlNi. More on this in the properties and uses sections.

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Best viewed as original on 'web'
- Frames used to give 'reference' column on left hand side.

Physics A-Level
Shape Memory Alloys

Examples of Shape Memory Alloys.

The following are examples of Shape Memory Alloys:

AgCd - Silver Cadmium

AuCd - Gold Cadmium

CuAlNi - Copper Alluminuim Nickel

CuSn - Copper Tin

CuZn - Copper Zinc

CuZnXx (Xx - Si, Al, Sn) - Copper Zinc (Silicon, Alluminium, Tin)

InTi - Indium Titanium

NiAl - Nickel Alluminium

NiTi - Nickel Titanium

FePt - Iron Platinum

MnCu - Manganese Copper

FeMnSi - Iron Manganese Silicon

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Physics A-Level
Shape Memory Alloys

Properties of Shape Memory Alloys

The following is a list of the alloys and their properties:

Alloy	Transformation Temperature Range (°C)	Hysteresis (approx)
AgCd	-190 to -50	15°C
AuCd	30 to 100	15°C
CuAlNi	-140 to 100	35°C
CuZn	-180 to -10	10°C
CuZnXx	-180 to 200	10°C
InTi	60 to 100	4°C
NiAl	-180 to 100	10°C
NiTi	-50 to 110	30°C
FePt	approx -130	4°C
MnCu	-250 to 180	25°C
FeMnSi	-200 to 150	100°C

Xx = Si, Sn, Al.

Infromation taken from SMA-Inc

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Physics A-Level
Shape Memory Alloys

Uses of Shape Memory Alloys

The following are general uses for Shape Memory Alloys:

Force Actuators - e.g. in an electrical connector system, the shape memory alloy component is used to force open a spring when the connector is heated .

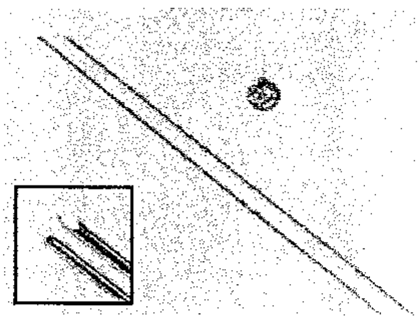
Proportional Control - e.g. in a valve which controls the rate at which fluid flows. By carefully heating the shape memory component the valve can be closed by desired amounts.

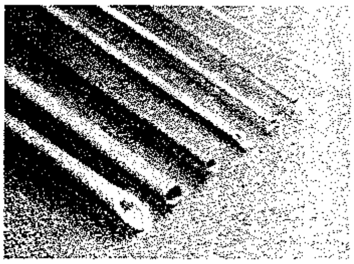
Superelastic Applications - e.g. recent glasses frames have been developed using the superelastic effects of NiTi. Most modern mobile phone, radio, etc. aerials are made from shape memory alloys that have the superelasticity effects.

More exotic \ common use of SMA applications:

Wire & Ribbon Based Components

Tapered tip guide wires
Formed wire and ribbon shapes
Formed stents
Centreless ground pieces
Cut lengths
Trocar and Rounded Points
Laser welded parts
Custom springs
Very small parts





Tubing Components

Stents
Formed tubing shapes
Beveled needle points
Cut lengths
Machined components
Laser welded parts.

Images and products are from sma-inc.com

Other Reported Uses:

"Memory Alloy Mends Bones"

"Anthony Anson of Brunel University has a method of connecting broken bones together by using a shape memory alloy bone plate.

A bone plate made of a shape memory alloy with a memory transfer temperature of 30 C is deformed from its original shape under heat treatment, which causes a change in its crystalline structure. The plate is then attached to both ends of a broken bone by means of screws, balls, rivets, springs or the like. When the plate is in place the normal body temperature of the patient (37 C) causes secondary heating of the plate, which will then try to resume its original shape.

The advantage of this bone plate over the stainless steel plates usually used to mend fracture is that the latter apply a compressive force only while the ends of the bone are being drawn together. Once this has been achieved the plate can exert no further force. In contrast, the shape memory alloy plate will continue to apply force as it attempts to resume its original shape." - Materials World

"Shape Memory Solar Array Gimbal"

"The shape memory solar array gimbal is a hardware technology. Shape memory metal is formed into a spring, and using a ball screw mechanism translates its linear motion into rotary motion to replace the motor typically used for this application.

A resistive heating element is integrated into the spring, along its surface. This heating element is used to control the timing and degree of transformation that will occur in the spring.

This technology was developed for spacecraft application. CLARK will be the first flight of this technology.

The purpose of the gimbal is to rotate solar arrays to track the sun, increasing the solar array effectiveness for operation of the spacecraft power supply system. This technology must supply enough torque to rotate the solar arrays (about 10 in-lb), it must track the sun at a certain rate, and it must be able to unwind during eclipse, so that it will be ready for the next orbit. Additional requirements include nominal telemetry-downlink data and 12 watts peak power.

This technology is operationally limited to certain temperature constraints, such that accidentally reaching the transformation temperature is avoided. Reliability is comparable to that for motors." - CLARK Technologies (Futron)

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Physics A-Level
Shape Memory Alloys

History of Shape Memory Alloys.

In 1932 the first recorded observation of the shape memory transformation was in AuCd by L.C. Chang and T.A. Read.

In 1938 theshape memory transformation was also noticed in brass (CuZn).

In 1951 the Shape Memory Effect was observed in the form of a bent bar made of AuCd which returned to the pre defined position after heating.

In 1962 W.J. Buelher, J.V Gilfrich and R.C Wiley discovered the effect in nickel-titanium (NiTi) which sparked the research into both the metallurgy and potential practical uses of this effect. Since then a number of products were on the market and advancement in the understanding of this effect has greatly advanced.

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Physics A-Level
Shape Memory Alloys

Future of Shape Memory Alloys

The future of these shape memory alloys is just begining. Experimental uses of rarer alloys which are known as "smart materials" are currently being experimented on. Future projects for these "smart materials" may include : -

"Smart Skin" - which can sense temperature, pressure, windspeed, even maybe onset of damage which may cause the material to react in the appropriate way e.g. acting like living tissue.

Movement compensation - which may be used to stop aircraft wings from shaking, or to stop buildings from toppling as the structure itself compensates for the movement of the ground, in earthquakes.

Shape changing - wings which can change shape in accordance with the current conditions and can be used to steer the craft hence removing the need for flaps.

Strengthening of weak areas - the smart material could reinforce weak areas on bridges, skyscrapers, submarines, etc. to preserve and make these objects safer.

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Physics A-Level
Shape Memory Alloys

Resources Used

Websites:

Shape Memory Applications Inc.

Materials World

- Materials World

- Department of Aerospace Engineering and Mechanics.

- Futron Technologies

Chemical Elements.com - Chemical Elements

Books:
"Stuff - The materials the world is made of" by Ivan Amato

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Original showed logos of all sources

Physics A-Level
Shape Memory Alloys

Glossary of Terms Used

Martensite : - The lower temperature phase in shape memory alloys. During this phase the alloy is more deformable.

Austenite : - The higher temperature phase present in shape memory alloys. During this phase the alloy is stronger.

Hysteresis : - The temperature difference between a phase transformation upon heating and cooling. It is generally measured between the temperature at which the transformation to austenite is 50% complete and the temperature at ehich the transformation to martensite is about 50% complete upon cooling.

Superelasticity : - The springy rubber like behaviour of shape memory alloys at the temperatures just above the transformation to austenite upon heating.

Parent Phase : - The phase between martensite and austenite that can form shape memory alloys.

One way shape memory : - a material that returns to its previous shape at high temperatures to before it was deformed.

Two way shape memory : - like one way shape memory materials but these return to their previous shape upon recooling.

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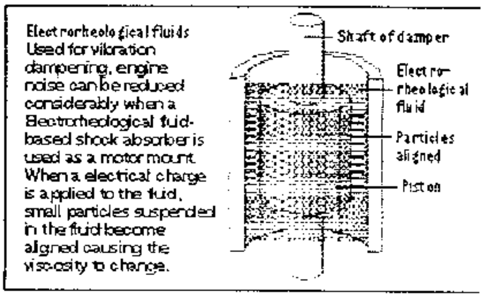
Sources used . . . .

Shape of 'smart' things to come

By Curt Suplee / The Washington Post

Some day soon, "intelligent" airplane wings may flex themselves like fish tails, autonomously changing shape to modify lift or drag. Bridges and telephone poles could "feel" when they're about to break, send out a warning and then reinforce their components automatically. Air conditioners may suppress their own vibration. Handguns may fire only when held by their owners. Tires could politely inform drivers when they need air. Sensitive artificial muscles could power robot -- or human -- limbs.

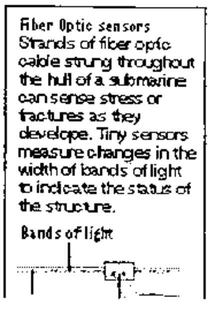


Those are only a few of the techno-marvels expected from the new science of "smart materials": structures that can sense changes in their environment and then respond accordingly, thanks to felicitous peculiarities in the way they react to pressure, voltage, magnetic fields or temperature.

Some smart systems already have crept into daily life. Self-adjusting auto suspensions detect alterations in road condition and modify their stiffness accordingly. Smart skis monitor vibrations and instantly generate counter-forces that dampen the shock, enhancing edge control. But many more applications are on the near horizon.

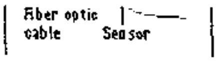
"The first thing that's going to happen," said James S. Sirkis of the University of Maryland's Smart Materials and Structures Research Center, is the advent of systems for "early warning about structural damage in bridges, buildings, airframes -- things that have a tremendous cost in human lives."

Several projects under way use fiberoptic threads as strain gauges on bridges: When the structure stretches or warps, the tugging motion alters a tiny grating in the fiber-optic system, which in turn changes the wavelength of light that travels along the fiber. Computerized detector modules translate those light shifts into stress units, providing advance notice of failure.



In the long term, diagnostic fibers might be coupled with ducts that would squirt epoxy or other strengthening material directly on the spot where a crack was detected.

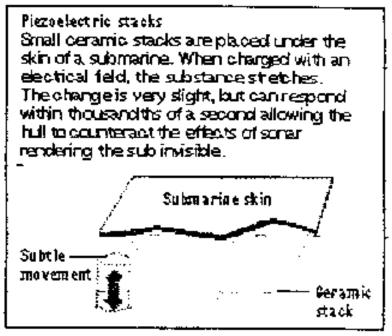
Within 25 years, many scientists believe, smart structures will drastically alter the shape of aircraft, which will have control surfaces that can reshape



themselves on the fly.

"If you want to get a single-engine fighter off the deck of an aircraft carrier without a catapult," said Bob Crowe of the Defense Advanced Research Projects Agency, "you need to improve the lift and you can do that by shaping the airfoil."

Such "adaptive" surfaces would replace stiff structures that are designed as a compromise among the ideal wing shapes for various maneuvers, Crowe said. Eventually engineers could "eliminate vertical tails and ailerons and stuff and have an airplane that has no (conventional hinged) control surfaces."



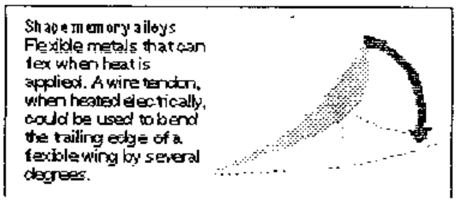
Piezoelectric stacks
Small ceramic stacks are placed under the skin of a submarine. When charged with an electical field, the substance stretches. The change is very slight, but can respond within thousandths of a second allowing the hull to counteract the effects of sonar rendering the sub invisible.

Already a "smart" one-sixth scale model of an F/A-18 fighter wing has aced its first round of wind tunnel tests.

"The performance enhancements," Crowe said, "turned out to be greater than expected. A 1.5-degree wing twist generated an 8-percent increase in lift."

By one Defense Department estimate, replacing current (and heavy) hydraulic control systems with lightweight, high-performance smart materials could increase aircraft payloads by as much as 30 percent and flight range by 50 percent.

To date, adaptive systems rely on three general classes of smart materials. One is made up of substances that expand, contract or twist when exposed to electric or magnetic fields. "Piezoelectric" materials -- ceramics or films that generate a voltage when stressed or, conversely, flex when a voltage is applied -- are particularly popular.



Shape memory alloys
Flexible metals that can flex when heat is applied. A wire tendon, when heated electrically, could be used to bend the trailing edge of a flexible wing by several degrees.

The Defense agency and the University of Maryland are using piezoelectric elements and fiber-optic sensors to design an "active" helicopter blade that can adjust its shape continuously to respond to vibration-engendering pressure changes in the air.

Those fluctuations "knock the machinery out of alignment," Crowe said, "and that causes a lot of down time. The maintenance schedule on a helicopter is 15 percent of its time or so."

In the helicopter project, piezoelectric patches on the blade surfaces function as both sensors and as actuators, or generators of counter-force. Researchers are experimenting by augmenting the system with fiber-optic sensors and polymer composites.

Piezoelectric sensors might also be employed on the grips of handguns that will only fire when they detect the unique pressure-pattern "signature" of the owner's hand. The materials are so sensitive that piezoelectric polymers or gels, formed into artificial muscles and skin, reportedly have been able to read Braille in laboratory tests.

Piezoelectric substances can respond within thousandths of a second, but they are capable of stretching only a fraction of 1 percent of their dimensions.

So researchers are testing them in combination with a second class of smart materials called "shape memory alloys" (SMAs). Much slower but far more flexible, these metals "remember" their original configuration even when deformed as much as 15 percent and return to it when heated. SMAs thus have enormous potential as force generators: An SMA wire "tendon," when heated electrically, could bend the leading or trailing edge of a flexible airplane wing by several degrees. SMA materials can also be built into spiral shapes as "torque tubes" that twist when activated.

The same kind of sensor-actuator technology may result in stealth submarines. Their acoustically hypersensitive smart skins would detect the pressure of an incoming sonar wave and automatically generate an equal but opposite counter-pressure that would cancel out the ping. With nothing reflected back to the enemy boat, the sub would be invisible. Similar systems can be used to damp vibration from large machinery, such as generators or air conditioners.

A third class of smart materials comprises electro- or magneto-rheological fluids -- weird liquids that change their viscosity (inherent thickness times resistance to flow) when exposed to electric or magnetic fields. You could stir one with a spoon effortlessly in its normal state; but run a voltage across it, and it suddenly becomes thick as concrete. Researchers believe the fluids will lead to new kinds of auto suspensions and transmissions, vibration damping systems and adjustable-resistance exercise equipment.

NiTi SMART SHEET™

#2

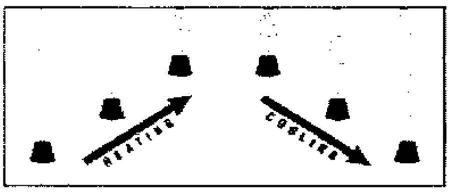
Introduction to Shape Memory and Superelasticity

Shape Memory Alloys, such as Nickel Titanium, undergo a phase transformation in their crystal structure when cooled from the stronger, high temperature form (Austenite) to the weaker, low temperature form (Martensite). This inherent phase transformation is the basis for the unique properties of these alloys -- in particular, *Shape Memory* and *Superelasticity*.

Shape Memory

When a shape memory alloy is in its martensitic form, it is easily deformed to a new shape. However, when the alloy is heated through its transformation temperatures, it reverts to austenite and recovers its previous shape with great force. This process is known as *Shape Memory*.

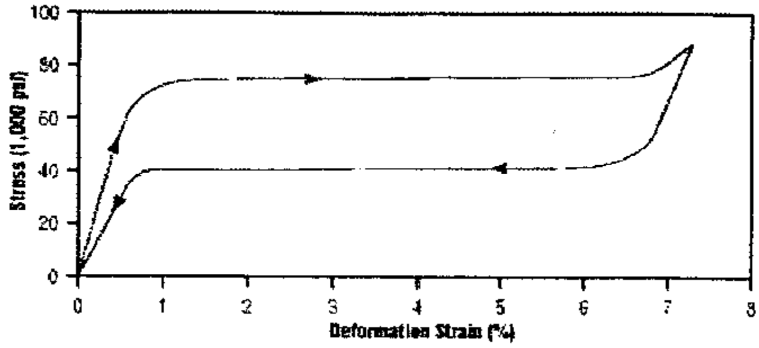
The temperature at which the alloy remembers its high temperature form when heated can be adjusted by slight changes in alloy composition and through heat treatment. In the Nickel Titanium alloys, for instance, it can be changed from above +100 deg.C to below -100 deg.C. The shape recovery process occurs over a range of just a few degrees and the start or finish of the transformation can be controlled to within a degree or two if necessary.



Schematic of the Shape Memory Effect

Superelasticity

These unique alloys also show a *Superelastic* behavior if deformed at a temperature which is slightly above their transformation temperatures. This effect is caused by the stress-induced formation of some martensite above its normal temperature. Because it has been formed above its normal temperature, the martensite reverts immediately to undeformed austenite as soon as the stress is removed. This process provides a very springy, "rubberlike" elasticity in these alloys.



Typical Loading and Unloading Behavior of Superelastic NiTi

Typical Properties of NiTi Shape Memory Alloys

Martensite is...

- **Fairly Weak:** 10,000 to 20,000 psi deformation stress
- Able to absorb up to 8% recoverable strain

Austenite is...

- **Strong:** 35,000 to 100,000 psi yield strength

Both forms of the alloy are...

- **Ductile:** elongation to failure over 25%
- **Strong:** tensile strength up to 200,000 psi
- Biocompatible and extremely corrosion resistant

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MORE EXPLORATIONS

Smart Materials

They will soon be in everything
from computers to concrete bridges.

Forget dumb old bricks and mortar: engineers are designing future devices from exotic materials that incorporate chemical switches or mechanical sensors to improve their performance. These "smart materials" are just starting to emerge from the laboratory, but soon you can expect to find them in everything from laptop computers to concrete bridges.

At a recent conference in San Diego, attendees were allowed a glimpse of a smart future still under construction. A hodgepodge group of physicists, chemists, computer scientists, civil engineers and even washing machine makers gathered to compare notes and to demonstrate for one another a host of inventions that stretch, twist, measure or respond in novel ways (the diversity is readily apparent from a quick glance at the conference program).Meanwhile, the conference's keynote speakers--most notably James S. Sirkis of the University of Maryland--wrangled over just how to define this new cross-discipline.

Unifying the field, the doyens concluded, is a shared goal to enhance ordinary objects or to create extraordinary ones by embedding sensors, processors or actuators into larger things. An alternative explanation, however, might be that the all-embracing label of smart materials provides an excuse for playful engineers to do cool things with polymers, fiber optics and microprocessors.

Certainly there was no lack of creativity in San Diego. Applications for smart materials covered a broad gamut. Jeff M. Melzak's group at Case

Western Reserve University is embedding silicon pressure sensors into Goodyear tires to improve fuel economy and reduce wear. Army researchers are placing piezoelectric crystals inside helicopter rotor blades; the crystals produce a feedback response intended to reduce the vibration and noise inside the cockpit.

Philip R. Troyk of the Illinois Institute of Technology has constructed wireless sensors no larger than a Rice Krispie. Implanted in a patient's muscle, the devices could relay information on local nerve activity via radio to an external computer. The devices could also receive power through magnetic induction and send out mild shocks that stimulate the muscle into action.

A few inventions demonstrated at the conference appear to offer considerable promise. Consider:

- Advanced liquid crystal displays may soon improve the quality of life of anyone who uses laptop and hand-held computers. A team at Kent State University was touting a new kind of liquid crystal technology; it should lead to flat color display panels that have much better resolution and lower cost than current state-of-the-art LCDs. The smart-crystal displays will also consume far less battery power, allowing portables to come closer to living up to their name.
- Artificial muscles that expand and contract in a controllable way could find numerous applications in robotics, medical implants, even virtual reality. At the smart materials conference, researchers at the University of New Mexico showed off an artificial muscle substance that is twice as strong as human muscles and contracts nearly as fast.
- Embedded sensors offer a way to monitor the health of structures that undergo a lot of wear and tear--concrete bridges and icebreaker propellers, to name just two examples. Engineers hope to save both money and lives with smart structures that warn their operators when the load becomes more than they can bear.

These projects may seem to have little in common with one another. But new areas of technology always emerge through chaos and confusion over their mission. Smart material researchers can at least take heart in the rapid changes in their field;

it will probably take only years, rather than decades, before their work starts yielding useful products.

–W. Wayt Gibbs, staff writer

FURTHER EXPLORATION:

Sandia National Labs
University of Michigan

Also See:

"Artificial Organs" by Robert Langer and Joseph P. Vacanti,Scientific American, September 1995

"Intelligent Materials" by Craig A. Rogers, Scientific American, September 1995

NiTi SMART SHEET™

#4

Two-Way Memory

The ability of shape memory alloys to recover a preset shape upon heating above its transformation temperatures and return to an alternate shape upon cooling is known as *two-way memory.* Two-way memory is unique in that the material "remembers" different high temperature and low temperature shapes. Much has been written about this unique phenomenon in the literature and it has triggered many ideas in the minds of product designers. Some examples of these potential applications include reversible fasteners, temperature-sensitive actuators, retrievable medical implants, and toys and novelty items.

Creating two-way memory in NiTi alloys involves a somewhat complex training process using one of the following approaches:[1,2]

- Overdeformation while in the Martensitic Condition.
- Shape memory cycling (Cool -> Deform -> Heat -> Repeat).
- Pseudoelastic cycling (Load -> Unload -> Repeat).
- Combined shape memory and pseudoelastic cycling.
- Constrained temperature cycling of deformed martensite.
- Constrained aging for long periods of time (to yield the All-Round Shape Memory Effect which is slightly different than two-way memory).[3]

However, there are a number of limitations which must be addressed before attempting to exploit two-way memory behavior[1,4], including:

- The amount of recoverable strain is generally about 2%, which is much lower than that which is achievable in one-way memory (6 to 8%).
- The transformation forces upon cooling are extremely low.
- The memory can be erased with very slight overheating (as low as 250 deg.C).
- The long-term fatigue and stability characteristics are not well known.
- The inherent temperature hysteresis between the heating and cooling transformations is still present.

Wherever possible, it is better to modify the device design to make use of one-way memory with a biasing force acting against the shape memory element to return it upon cooling. All of the above limitations are addressed by this approach except for the inherent temperature hysteresis, which remains. Two-way actuators using one-way shape memory elements acting against bias forces have demonstrated large strains, high forces in both heating and cooling directions, and excellent long-term stability up to millions of cycles. For further information, please consult the references below.

1. Jeff Perkins and Darel Hodgson, "The Two-Way Shape Memory Effect", in

Engineering Aspects of Shape Memory Alloys, ed. by T.W. Duerig, et al, (Butterworth-Heinemann, 1990), pp. 195-206.

2. Yinong Liu and P.G. McCormick, "Factors Influencing the Development of Two-Way Shape Memory in NiTi", *Acta Metallurgica*, **38**, (1990), pp. 1321-1326.

3. M. Nishida and T. Honma, "All-Round Shape Memory Effect in Ni-Rich TiNi Alloys Generated by Constrained Aging", *Scripta Metallurgica*, **18**, (1984), pp. 1293-1298.

4. T.W. Duerig and K.N. Melton, "Designing with the Shape Memory Effect", *MRS International Meeting on Advanced Materials*, **9**, (1989), pp. 581-597.

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8.3 Making Sense of Data: Ball Velocity

MAKING SENSE OF DATA task
A copy of this sheet must be attached to each candidate's work as a record of the assessment.

Centre No :

Candidate Name:

Candidate No :

Initiative & Independence	**A** (i) Planning (ii) Use of resources	**Plan:** The student chooses what to calculate and plot ✓ **Approach** Critical thought is given to the data. Works independently, showing initiative.	Calculations and plots are made after advice. Some questions are independently formulated, perhaps modified after discussion.	Some analysis is done with guidance Kept to a simple plan ✓ (i) 4/5	**Use of resources:** Available ICT and other resources such as calculators are used well. (ii) 5/5 ✓	Some of the available resources are used effectively.	Simple resources are used.	9.
Use of physics	**B** (i) Devising a strategy (ii) The experiment	**In devising the strategy:** A sound knowledge and understanding of the relevant physics has been used. **Preparation** Initial graphs and rough calculations guided progress.	Some knowledge & understanding of physics has been used, but some work is simply mechanical. Straightforward relationships were anticipated, and guided progress.	The approach is largely mechanical. There was little advance preparation 4 (i) /5	**Understanding the physics** The essential physics of the experiment is clearly and concisely discussed. **The results** Attention is drawn to aspects likely to be important in understanding the results. (ii) 3/5	Aspects of the physics underlying the experiment are made clear without basic errors in physics. Some aspect of the experiment which is likely to be key to understanding the results is mentioned	An attempt is made to describe the physics behind the experiment Little attention is paid to how the experimental procedure will influence the understanding of the results ✓	7
Communication	**C** (i) Content of report. (ii) Presentation of report.	**Account** of experiment is concise and related to data collected ✓ **Record of data** Data processing recorded methodically in appropriately labelled tables	The purpose of the experiment is briefly described Tables of results were presented but not always correctly labelled	The description of the experiment is not related to the data. Tables lacked significant details ✓ (i) 4/5	**Presentation:** The report is concise and presents results with impact and clarity. **Use of English:** The quality of English is good, (ii) 3/5	Work is generally neat and orderly. ✓ The quality of English is generally adequate to express complex ideas	Work may be untidy, arguments muddled. The quality of English generally adequate to express simple ideas	7
Mathematical care	**D** (i) Graphs and tables (ii) Analysis	**Plotting:** Graphical plots are well-chosen, to display results effectively. **Interpretation:** Line or curve fitting done has a valid basis in the physics. Inferences are made from plots. **Errors:** Outcomes are linked to possible sources of errors	Graphs are neat & without distracting elements. ✓ Curves are fitted when appropriate. Some correct calculations of relevant quantities are made. ✓ Some mention is made of possible errors.	Graphs are constructed without thought for appearance or usefulness. Quantities considered are usually direct from measurement Errors not acknowledged (i) 3/5	**Interpretation** Graphs & tables are interpreted in terms of the relevant physics. The analysis reveals correctly the underlying mechanisms at work. **Conclusions** Relationships proposed are consistent with the evidence and with basic physical ideas. (ii) 3/5	Tables & graphs show significant relationships, and are given some interpretation. Conclusions consistent with the data and with basic physical ideas are drawn.	Data are presented mainly in raw form. Some conclusion relevant to the data is drawn.	6
			RATING TOTAL	29 /40	Additional comments to support and explain ratings may be made overleaf.			
Assessor's signature					Date:			

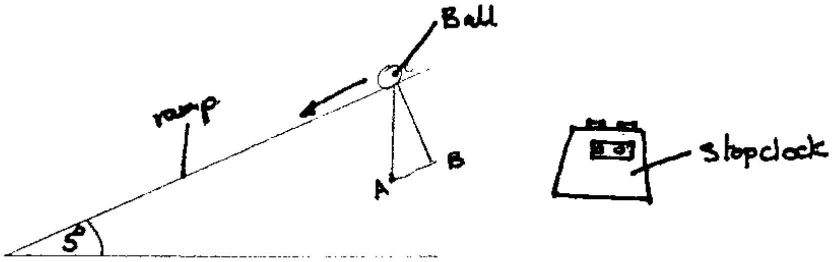
Physics coursework - Making sense of data

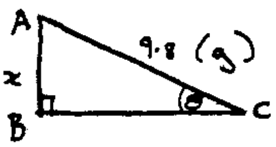
The Task

The task for this data coursework is to carry out an experiment to collect a series of data and then to analyze and gain a conclusion using my knowledge of physics. The task itself asks to relate average velocity of the ball with the length traveled along the ramp.

The experiment itself that had to be carried out in order to gain some results involved rolling a ball bearing of mass 28.28g down a smooth ramp at different heights ranging from 0.05m to 1.0m in 0.05m intervals. The ramp was placed at a fixed angle of around 5° and the bearing was rolled down, the time was recorded from when it was released to when it hit the bottom.

Diagram of apparatus:





$$\sin\theta = \frac{x}{9.8}$$

$$x = \sin\theta \times 9.8$$

$x =$ acceleration

A few trial efforts were taken with the apparatus at different settings in order to gain accurate results.

Results

Results were taken by using a stop clock of time step of 0.01 seconds but this was not necessary due to the human error of 0.1 seconds. A number of results were taken and then averaged to get the best results possible.

Here is a table of the original results;

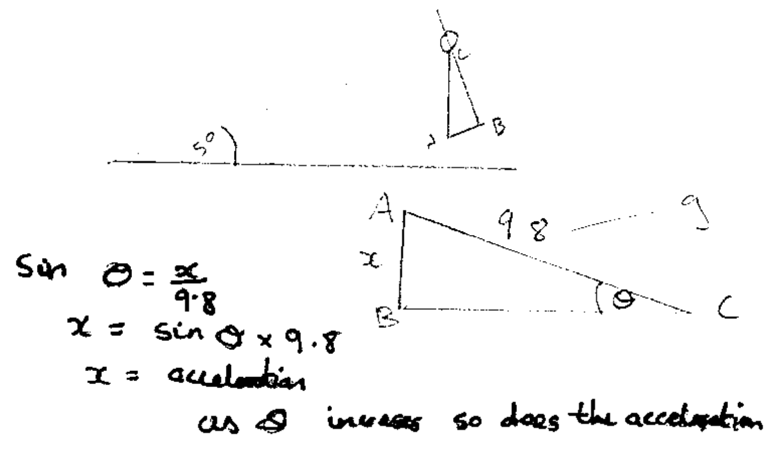
units ?✓

Distance/m	Time1	Time2	Time3	Average Time	Average Velocity
0	0	0	0	0	0
0.05	0.46	0.47	0.51	0.48	0.104
0.1	0.73	0.7	0.73	0.72	0.138
0.15	0.98	0.96	1	0.973	0.154
0.2	1.1	1.1	1.1	1.1	0.18
0.25	1.19	1.31	1.26	1.253	0.1995
0.3	1.33	1.41	1.33	1.356	0.22
0.35	1.47	1.59	1.57	1.543	0.227
0.4	1.61	1.64	1.64	1.63	0.245
0.45	1.67	1.65	1.72	1.68	0.268
0.5	1.88	1.79	1.88	1.85	0.27
0.55	1.88	1.95	1.93	1.92	0.286
0.6	1.97	2.02	1.99	1.993	0.3
0.65	2.06	2.09	2.11	2.086	0.3116
0.7	2.16	2.12	2.16	2.146	0.326
0.75	2.18	2.29	2.23	2.23	0.336
0.8	2.21	2.29	2.25	2.25	0.355
0.85	2.32	2.3	2.34	2.32	0.366
0.9	2.36	2.36	2.41	2.376	0.378
0.95	2.47	2.54	2.51	2.5	0.38
1	2.56	2.52	2.52	2.53	0.395

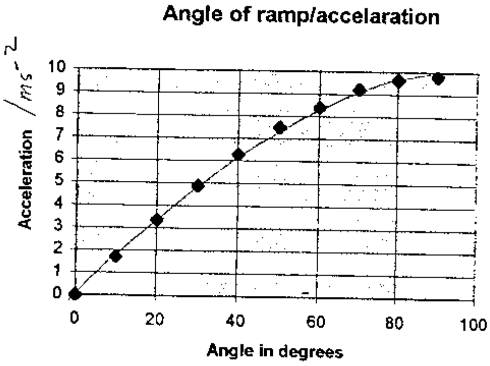
From these results that I managed to obtain I decided that it would be an extremely difficult task to analyze and draw a conclusion from the result in this format therefore I decided to graph some of the result to see if any trends could be found.

<u>Analysis</u>

Firstly a major factor that I investigated which I believed would effect the velocity of the ball throughout the experiment was the angle at which the ramp was set. This diagram shown shows how I calculated how different angles of the ramp has a huge effect on the acceleration of a particle, and in this case the ball:

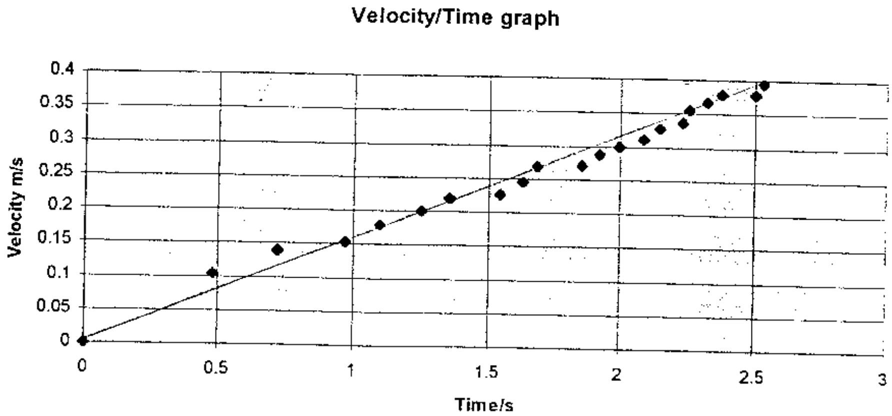


This graph shows the relationship between the angle of the ramp and the acceleration of the ball:



It can be clearly seen from this graph that as the angle increases so does the acceleration but in a decreasing gradient. This therefore shows that it affects the acceleration of the ball. This then leads onto the question of whether acceleration affects the velocity of the ball.

In order to gain the most from the results that I have obtained a number of equations need to be used, these equations however can only be used when the acceleration is a constant. This can be found by plotting a velocity time graph:



From the straight line graph of the best fit line it can be seen that acceleration is constant throughout the time at which the ball is let go, therefore equations such as these can be used:

S= 0.5ut ✗ $S = \frac{1}{2}at^2$ I believe he means (see table on next page)

$V^2=2as$ ✓

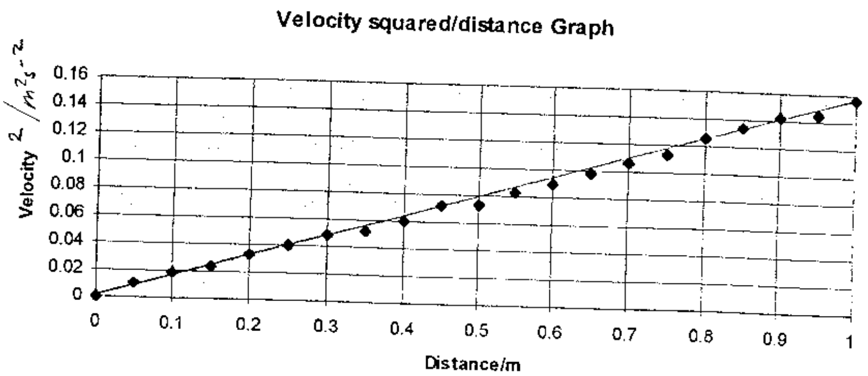
This table shows the average values and the new values such as V squared which was needed to be calculated to plot a graph using the formula shown previously: → units?

ie $s = \frac{1}{2}at^2$ being tested

but not used ✓

Distance m	Time s	Velocity m/s	V x V	T x T
0	0	0	0	0
0.05	0.48	0.104	0.010816	0.2304
0.1	0.72	0.138	0.019044	0.5184
0.15	0.973	0.154	0.023716	0.946729
0.2	1.1	0.18	0.0324	1.21
0.25	1.253	0.1995	0.0398	1.570009
0.3	1.356	0.22	0.0484	1.838736
0.35	1.543	0.227	0.051529	2.380849
0.4	1.63	0.245	0.060025	2.6569
0.45	1.68	0.268	0.071824	2.8224
0.5	1.85	0.27	0.0729	3.4225
0.55	1.92	0.286	0.081796	3.6864
0.6	1.993	0.3	0.09	3.972049
0.65	2.086	0.3116	0.097095	4.351396
0.7	2.146	0.326	0.106276	4.605316
0.75	2.23	0.336	0.112896	4.9729
0.8	2.25	0.355	0.126025	5.0625
0.85	2.32	0.366	0.133956	5.3824
0.9	2.376	0.378	0.142884	5.645376
0.95	2.5	0.38	0.1444	6.25
1	2.53	0.395	0.156025	6.4009

This constant acceleration can also be seen on this graph in which the previous equation was used, this graph shows V^2 on the Y axis and the distance on the X:

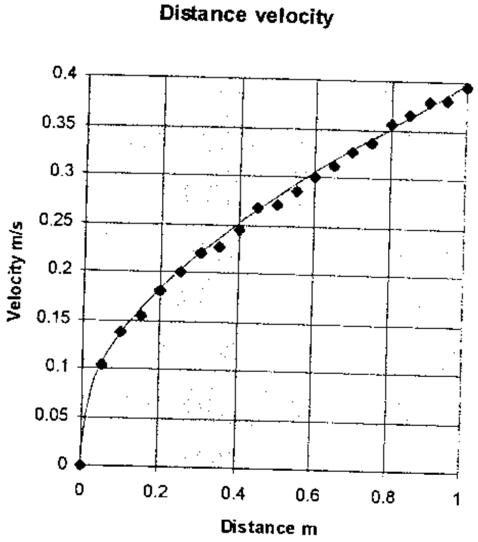


✓

This also shows a constant acceleration which also goes through the origin. This therefore means that throughout the time in which the ball is rolling down the ramp it is accelerating at a constant rate.

Bit dubious he quite understands what he is saying here.

To relate these results with the speed over the different distances here is a distance/velocity graph:



This does not really add anything ✓

From this graph it can clearly be seen that the velocity does increase over distance but it is not constant. This can be explained by each dot being the ball being let go, when the ball it let go at a small distance from the floor then it cannot get up to a large velocity because it does not have enough time to accelerate therefore not reaching a large velocity.

Conclusion

From these results and the way I have interpreted them I can conclude that the ball itself accelerates at a constant rate therefore depending on how long it has to accelerate it will increase its velocity. The longer it has to accelerate the greater the distance it will travel in a certain time. Therefore if it has a large distance to travel it will reach a greater velocity. But no matter how much distance it has to reach a certain speed it will do so at a constant acceleration unless the angle of the slope is increased as that would increase the rate at which it accelerates.

Some of the results that were recorded May have been down to human error such as some of the graphs may curve slightly at a decreasing gradient when the distance that the ball is released becomes greater because when the ball is let go from a small distance the reaction error is much greater. Another reason why the results may not be completely uniform may be due to the ball being let go by the human hand so a slight nudge or delay may have been caused by this. The only way in which this could be overcome could be by using light gates to record times and by using a mechanism to release the ball, but the results that were obtained were accurate enough to draw some conclusions.

8.4 Practical Investigation: Temperature and capillary rise

PRACTICAL INVESTIGATION 2863/02

A copy of this sheet must be attached to each candidate's work as a record of the assessment.

Centre No :

Candidate Name:

Candidate No :

Initiative and independence: **A**	(i) Planning (ii) Safety and resources	**Problem** There is clear analysis of the problem. Appropriate variables are selected for investigation. A thoughtful plan was constructed. **Independence** Personal responsibility was taken for plans and decisions	The definition of the problem is sound but lacks some detail. A reasonable plan was made. The student's own ideas are sound, and advice given was acted upon	The problem has been defined in simple terms. Some evidence of planning. Help and advice given were usually acted upon. (i) 4 /5	**Use of resources** To good effect; advice and sources were well used. **Experimental design** Careful choice of equipment, methods and techniques **Safety** Safety was given due regard (ii) 4 /5	Some resources put to good use Equipment, methods and techniques are adequate Some attempt is made to address safety	Required direction Simple apparatus used in a direct way Safety measures are somewhat basic
Use of physics **B**	(i) Appropriate activities (ii) Practical skills and techniques	**In devising the strategy** Knowledge of physics is used to inform decisions about the progress of the investigation **Experiments** A good range of experiments, showing progression and development. The potential of the experimental work has been fulfilled.	Some knowledge of physics was used in planning but some work was empirical. A related set of experiments is used, or some aspects of one experiment are investigated. Some of the potential of the work has been developed.	The work was largely empirical Experimental work relates to the task, but is limited in certain important respects. (i) 3 /5	**In executing experiments** Practical knowledge and skill are put to good use **Experimental design** There is evidence of experimental design. **Effects** Effects which might affect results are seen and dealt with. (ii) 3 /5	Some practical skill is shown; the work is competent. There is some evidence of experimental design. Effects which might affect results are commented upon.	Apparatus used in a direct way Little knowledge of physics is brought to bear. Effects which might affect results are not considered.
Communication **C**	(i) Record of observations (ii) Quality of report	**Observations** Observations & measurements made with appropriate precision The number and range of results are appropriate. **Record of observations** The collection and recording of data are well organised **Uncertainties** The limitations on accuracy, are appreciated. Steps are taken to minimise uncertainties.	Observations are recorded clearly. The number and range of results are satisfactory. The collection and recording of data are satisfactorily achieved. Some steps are taken to minimise uncertainties.	Observations are those expected for the task, but may be lacking in detail, range or precision. Tables of results lack significant details. Little attempt has been made to reduce uncertainties. (i) 2 /5	**Presentation** The report is concise and presents results with impact and clarity. **Graphs and tables** Graphical plots are well-chosen, to display results effectively. Graphs and tables are correctly labelled. **Use of English** The quality of English is good. (ii) 3 /5	Work is generally neat and orderly. Graphs are basic, neat and without distracting elements. Attempts are made to choose the most appropriate plots. The quality of English is adequate to express complex ideas clearly.	The report is essentially a summary of the work done. Tables and graphs are presented, perhaps without much comment. The quality of English is adequate to express simple ideas clearly.

CWTSA1

PRACTICAL INVESTIGATION A2 2863/02				Centre No :		
Candidate Name:				Candidate No :		
Evaluating evidence and drawing conclusions **D** (i) Evaluation (ii) Conclusions	**Analysis** The results are well analysed, to reveal the underlying relationships.	General trends in the data are established using appropriate techniques. ✓	There is some attempt to identify trends in the data, but the analysis lacks depth.	**Critical thought** The work shows evidence of critical and connected thought.	The work shows progression and development. ✓	The progress of the task was not affected by the effects observed
	Relationships Relationships proposed are consistent with the evidence and supported by underlying principles.	Relationships proposed are consistent with the evidence. ✓	Expected relationships are assumed to be present though they may be unsupported by the evidence.	**Physics** Qualitative results are interpreted with care and insight. Basic errors in physics are avoided.	Results are given some physical interpretation, even if this reveals minor misunderstandings. There are few errors in basic physics.	The work is largely empirical with little attempt to interpret the physics.
	Discrepancies Discrepancies or anomalies are dealt with. Error bars have been used effectively on graphs to reflect the uncertainties.	Some discrepancies are commented upon. ✓	Discrepancies are largely ignored.	**Conclusions** The uncertainties inherent in the data are reflected appropriately by the tentative nature of the conclusions.	Conclusions, though supported by the evidence, may not be qualified as necessary.	Conclusions, which may be qualitative, are limited and focus on the more obvious results.
	Limitations of methods The limitations of the experimental procedures used are fully appreciated	The main limitations of the experimental procedures are appreciated ✓	There is little awareness of the limitations of the experimental procedures used	The work is interesting, achieving results new to the student.		
			(i) 2 /5	(ii) 3 /5		
RATING TOTAL			24 /40			

Additional comments to support and explain ratings.

Assessors signature :

Date :

Aim

To investigate how the level of capillaration in glass capillary tubes changes as the temperature of the liquid in the tube changes.

Abstract

After completing initial research into capillaration I started my investigation by looking at how the capillary rise varies in glass capillary tubes as the temperature of the water is altered. This was achieved by setting up the apparatus as shown in Fig. 3 and measuring the differences in capillary rise as the water cooled down. After developing this method, before I repeated the experiment, I conducted a control experiment with cold water to see if capillary rise changes over time even without any changes in temperature. I came to the conclusion that there is very little, if any change in the level of capillaration in a glass tube if everything else is kept constant.

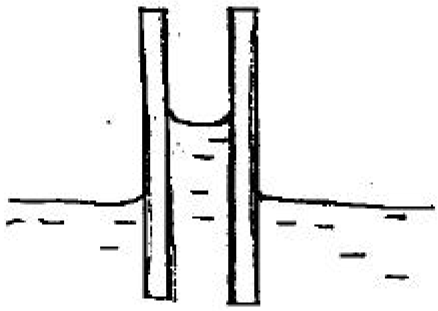
To achieve consistency a repeat of the initial experiment was carried and the results plotted on a graph with the results from the first experiment. There was found to be a decrease in the level of capillaration as the temperature rose. this was explained by the disruption of inter-molecular forces as the molecules gainec energy.

To investigate a situation where there are increased inter-molecular forces glycerol was used. It was found that there was no capillary rise with the more viscous liquid at room temperature. Although when the glycerol was heated capillaration occurred. Changes in the capillary rise as the temperature droppec was measured using the same apparatus as before. Another graph was plottec There was found to be less change in the level of capillaration with temperature than was found with water, probably because of the increased strength of the inter-molecular forces.

Introduction

Capillaration is an exception to the hydrostatic law that states that a liquid seeks its own level. It is most marked in capillary tubes [Latin *capillus*, 'hair'], that is, tubes of very small diameter. It is this effect I am going to investigate. Capillarity is an extension of surface tension effects, for instance when a capillary tube is dipped in water the water rises in the tube as shown in Fig. 1.

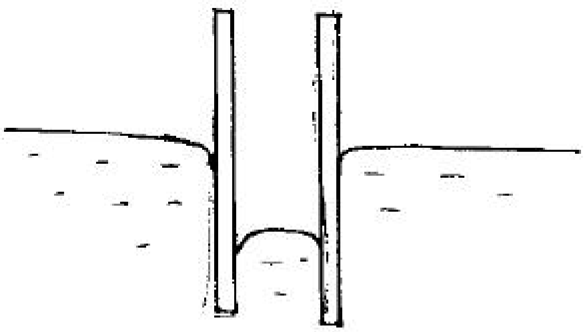
Fig 1. Rise of water in a capillary tube.



The action showed is typical of water, it occurs when the surface tension forces, cohesion within the water is less than the adhesion of the liquid to the glass [Webber 1.]. This causes the concave meniscus and the water to rise above its normal hydrostatic level [Encarta 2.].

The amount and type of capillaration depends on the ratio of the cohesional forces within the liquid to the adhesional forces with the solid. Different ratios, for instance in mercury where cohesion exceeds adhesion, will cause different effects. In this example the meniscus is convex and it the level falls below the hydrostatic level. Fig 2.

Fig 2. Mercury in a capilary tube.

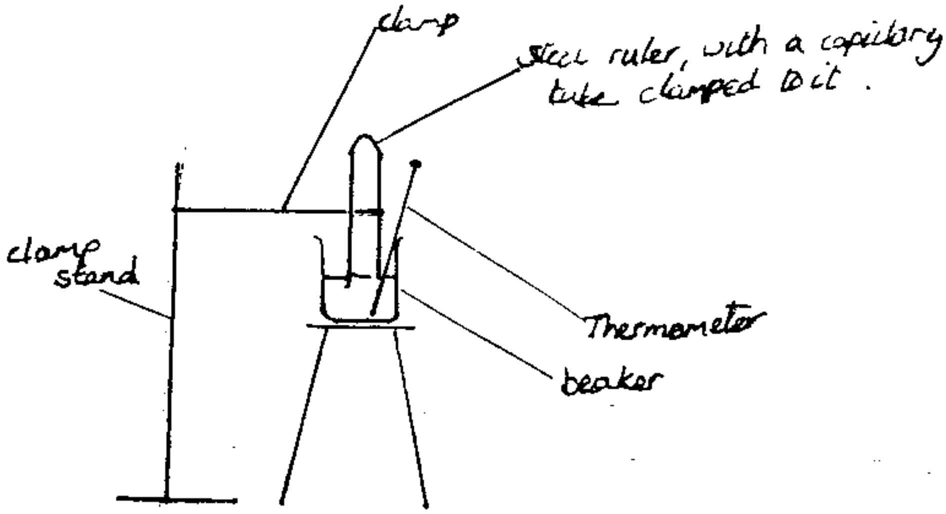


The internal forces of water are caused by Hydrogen bonding, a strong intermolecular force. [Ramsden 3.] It is because of these strong forces that water is a liquid at room temp, where as similar compounds, such as hydrogen-sulphide, are gaseous at normal air temperatures. [Taylor & Jones 4.] Like all inter-molecular forces they can be broken if the molecules are supplied with enough energy. As the temperature of water in the capillary tube rises, the Hydrogen bonds should be broken, this means the cohesional forces within the water will be affected so affecting the amount of capillary rise, the first part of my investigation will be to study this.

Wed 25th Feb

The main purpose of the day was to find an effective way of measuring the changes in the level of capillaration with temperature two methods were devised, the first involved clamping two capillary tubes to a ruler and then placing them in a beaker filled with 125ml of hot water with 5mm of the tubes submerged. See Fig 3. 5mm was considered to be the optimum length after trials were conducted.

Fig 3. Apparatus used to measure changes in capillary rise due to temperature.



Hopefully by keeping the level of liquid above the end of the capillary tubes constant and by using the same volume of water I will negate any effects caused by the pressure of the water, I will record the air pressure each day in case this affects the results.

Air pressure: 1050 milli-bars

As the water cooled the height of the water in the capillary tubes was measured. this was measured from the base of the capillary tubes The height and temperature was measured every 4 minutes.

Results

Temperature of water in beaker. /°C	Height of capillary rise in Tube A. /mm	Height of capillary rise in Tube B. /mm
20	18	17
20	18	17
20	19	17
20	19	17
20	20	19
20	21	19
20	21	19
20	21	19

The ruler is accurate to 1mm and the thermometer to 1 °C.

The results show no significant change in the level of capillaration over time especially when the margins of error are considered. When compared to the first results and the amount of change there, it is reasonable to assume that the change is due to the temperature change and not fluctuations that occur over time at a constant temperature.

The second method was developed to investigate how the level changes as the water is heated. I thought this may make a difference when compared to the differences when hot water cooled. It was impractical to heat water up with the capillary tubes in the beaker as these cracked because of the temperature change, and any bubbles produced disrupted the level of capillaration. I decided therefore to heat up the water and drop a known amount onto a glass microscope slide, a capillary tube was then placed on the slide and the level of capillaration measured.

This proved unsuccessful for an number of reasons. The water soon lost its heat when placed on the cold slide. The amount of water on the slide was inconsistent. as was its distribution. These factors lead to inconsistencies in the results even when the water was at a constant temperature. These inconsistencies may also be because as opposed to being clamped and stationary the tubes were moved by hand and it would be hard to repeat the experiment accurately.

Fri. 27th Feb

Air pressure: 1016-milli bars

A repeat of the experiment carried out on Wed. 25th was conducted.

Results

Temperature of water in beaker. /ºC	Height of capillary rise in Tube 3. /mm	Height of capillary rise in Tube 4. /mm
95	20	22
76	21	24
63	23	25
54	26	26
45	27	27
40	28	27

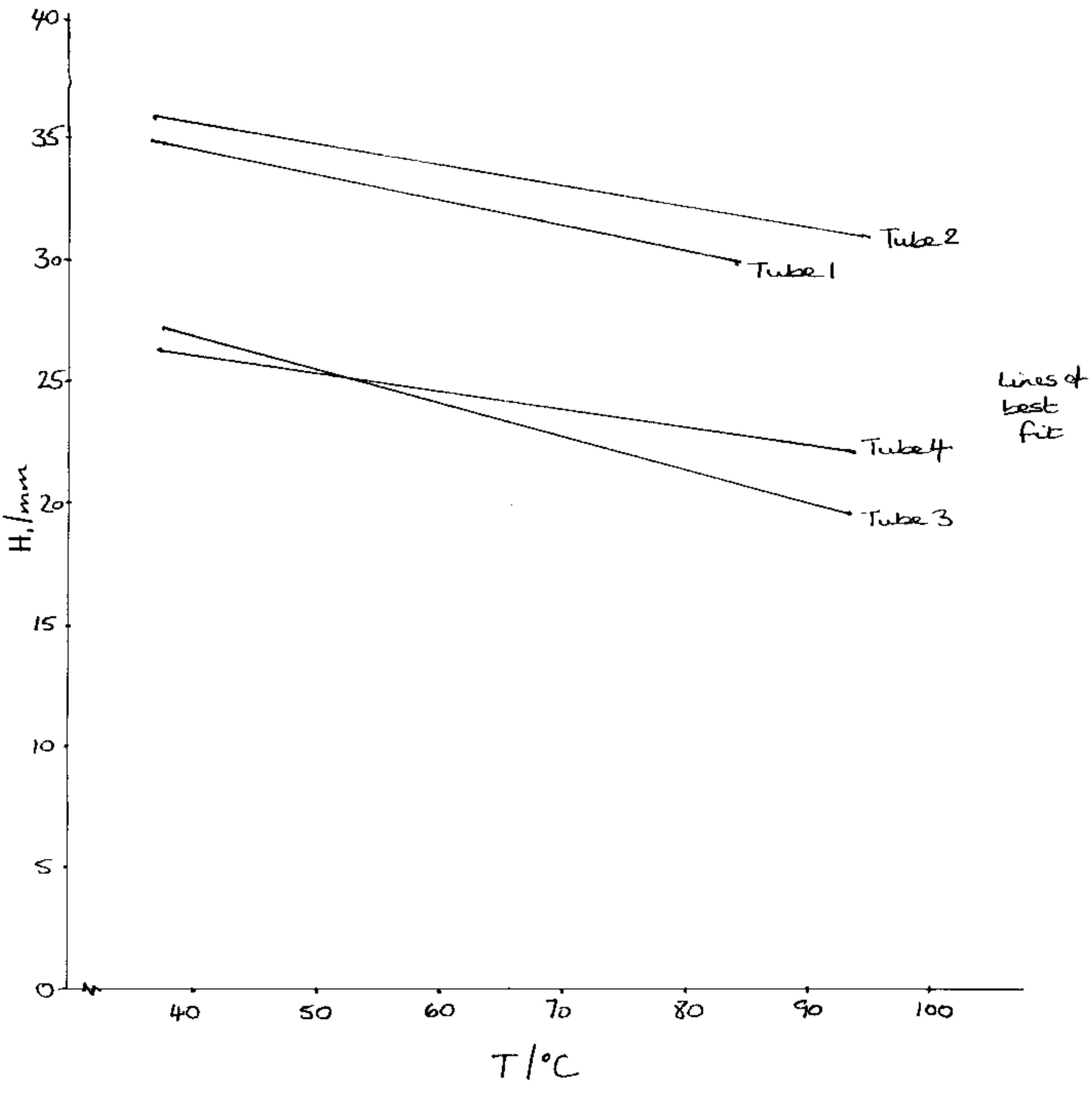
After the results from the repeat experiment were obtained a graph was plotted. As mentioned previously it is hard to repeat experiments with the same tubes, so different capillary tubes were used. Therefore I have decided not to calculate any averages but each capillary tube will be plotted on the same graph. Fig 5.

The ruler is accurate to 1mm and the thermometer is accurate to 1 ºC, both of which have been accounted for on the graph.

It can be seen from the graph that there is a clear linear decrease in the level of capillaration as the temperature of the liquid rises. All four capillary tubes show this decrease although the level of capillaration is not consistent between the tubes. This may be because of inconsistencies in the manufacture of the capillary tubes. The air pressure when the first experiment was carried out was 1040 milli-bars, this is higher than the air pressure when the second experiment was carried out probably causing the differences in the pairs of results. A greater pressure will cause a more capillary rise as more pressure pushes on the surface of the liquid, overall the level of capillaration was greater on the first day when the air pressure was greater.

As explained in the introduction the H-bonds in the water will be disrupted as the temperature rises, this will disrupt the cohesional forces within the water. At first this suggests that the capillary action should increase because as the ratio of cohesion to adhesion increases the capillary action decreases. This can be seen when comparing mercury. [Fig 2] where the cohesional forces exceed adhesion, with water, [Fig 1] where adhesion exceeds cohesion. As the water is heated the amount of Hydrogen bonding decreases so does the cohesion, the water should become steadily less like mercury so the capillary rise should increase. This is not what happens, however, as the temperature rises the amount of capillaration decreases

Fig.5 : a graph to show the relationship between the Temperature T_1 of the water and the Height H_1 of the capilliary rise.



The decrease in capillaration is because the disruption of inter-molecular forces affects both the cohesional and the adhesional forces. The ratio between the forces remains the same. Capillaration depends on both forces and as they are both disrupted the level of capillaration drops towards its normal hydrostatic level.

The extreme of this is when all of the H-bonds are broken and the water boils, here there is no capillaration due to the gaseous state of the water. It is to this that the water tends as it heats up, therefore the graphs would be expected to tend to zero. As observed the graphs do not tend toward zero, this is because most of the bonds are broken when the change of state occurs.

As the water is heated up some inter-molecular forces are disrupted as the molecules obtain more energy. When the change of state occurs the temperature remains constant as energy is used to break up the inter-molecular forces, this energy is called latent heat [Fullick 4]. This occurs in water at 100 °C, it is at this temp that most H-bonds are broken. Therefore before this temperature the changes in inter-molecular bonding are not proportional to the temperature so neither is the change in capillaration.

Mon. 2nd March

Air pressure. 1008 milli-bars

To extend the investigation I have decided to investigate the amount of capillaration when other liquids instead of water are used. As mentioned previously the strength of the inter-molecular forces in the liquid affect the amount of capillaration therefore I am going to use glycerol [propan, 1-2-3, triol]. Glycerol is a relatively small alcohol with three OH groups on a 3 carbon chain. The three OH groups mean there are three opportunities for H-bonds. this is more than in water so the inter-molecular forces are stronger. Glycerol because of its stronger inter-molecular forces is more viscous than water and has a very high boiling point [290°C]. This increased level of cohesion is why I am using it.

The apparatus was set up as on the 25th Feb, but using 125ml of glycerol at room temperature in the beaker.

No capillaration was observed when cold glycerol was used. This may be because of the viscous nature of the liquid. It may also be related to its properties as a solvent. Because of its high levels of hydrogen bonding glycerol is not a very good solvent, it is hard to break the glycerol to glycerol H-bonds and to get it to bond with the solute. This may lead to reduced adhesional forces as it is unwilling to bind to the solid. In this case cohesion would exceed adhesion, this would cause capillary fall like that shown for mercury. [Fig 2]. it was not observed.

Thus 5 March.

Air pressure: 1024 milli-bars

125ml of glycerol was heated up to around 100 °C and the level of capillaration was measured as it cooled down, this was done using the same method as was used for water. The experiment was carried out to see if capillaration occurred when the glycerol was less viscous.

Results

Temperature of glycerol in beaker. /°C	Height of capillary rise in Tube 5. /mm	Height of capillary rise in Tube 6. /mm
101	11	11
83	13	12
64	15	14
38	15	14
43	15	14
30	15	14

As for the water it was decided to repeat the experiment to try to achieve consistency.

Mon. 9th March

Air pressure: 1016 milli-bars

Just like the first experiment investigating the effect of heat on the capillary rise of water, a repeat experiment was carried out .

Results

Temperature of Glycerol in beaker. /°C	Height of capillary rise in Tube 7. /mm	Height of capillary rise in Tube 8. /mm
96	21	20
72	22	21
64	22	21
56	22	21
46	22	21

As before a graph was plotted with each tube being plotted separately. The error bounds were included on the graph the thermometer was accurate to 1 °C and the ruler to 1mm. Fig 6

The graph shows two pairs of results, like the pattern achieved for the water experiment. Again this could be explained after considering the air pressures on the two days. The air pressure was greater when the repeat experiment was carried out this may have caused the extra capillary rise. What is clear from the results is that capillaration does occur when glycerol is heated.

Upon heating, the glycerol becomes less viscous as the inter-molecular forces become disrupted. This could lead to capillaration for two reasons: the less viscous glycerol flows more easily, this may mean capillaration is possible. Also the cohesional forces would have decreased, they may have decreased below the adhesional forces which could have increased, if a situation occurred when the adhesional forces exceed the cohesional ones then capillaration similar to water could occur.

As the temperature drops there is very little change in the level of capillaration. In both cases there is no change below 64 ºC, this is probably because as the glycerol cools it becomes viscous again and doesn't flow along the tube very easily. The rise in capillaration as the temp drops between 100 and about 70 ºC is probably representative of the effect displayed by water and explained previously, however because the number of H-bonds are increased this effect is very small.

As well as linear patterns the graphs could also represent a curved relationship with the capillaration being fairly constant at low temperature and big changes in the level of capillaration occurring as the temperature gets closer to the boiling point of glycerol. However the curves shown are fairly unlikely because if extrapolated they seem to reach the x-axis long before the boiling point of glycerol [290 ºC]

Due to the limitations of my apparatus and because of safety considerations I was unable to heat the glycerol higher than 100 ºC. a possible extension to the investigation would be to investigate the changes in capillaration at higher temperatures nearer the boiling point of glycerol.

Limitations & Improvements.

As mentioned previously the main limitation of my investigation was the inability to repeat results with the same capillary tube. Perhaps if heating the tubes gently dries the tubes, by evaporating the water off, then repeats could be carried out. Because of this I assumed the tubes were uniform. The tubes however were not, even in the tubes I measured their were differences in the diameter. The level of adhesion in the tubes could be affected by irregularities in the surface of the glass. this would not be consistent from tube to tube. This assumption is probably fair but if more accurate measurements were to be taken then uniformity would have to be more guaranteed.

I have already mentioned the fact that I was unable to heat glycerol above 100 ºC.

It would also have been useful to investigate any changes in capillary rise as the liquids were heated as well as when they were cooling.

The air pressure did fluctuate during the investigation and it may have caused differences in the results from day to day, this variable could be eliminated by doing the experiment in a controlled atmosphere.

There are several possible extensions to my investigation. I have looked at the capillaration of liquids with varying levels of H-bonding, it would be useful to look at liquids containing other inter-molecular forces such as those held by only Van-der-Waals forces or dipole-dipole interactions.

Webber [6] states that capillarity effects may be avoided by employing tubes larger than 10mm in diameter, this could provide the bases for an extension, investigating the amount of capillaration in tubes of differing diameters. Changing the adhesional forces could also be looked into perhaps by greasing the inside of glass tubes or using tubes made from different materials.

Conclusions.

The results of the investigation show a clear relationship between the temperature of water and the amount of capillary rise it undergoes. This is because of the disruption of the H-bonds as the liquid heats up. By using glycerol which has stronger inter-molecular forces, more H-bonds, I have shown that increasing the cohesion forces also affects the amount of capillary rise in glass tubes.

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✓✓

8.5 Research Report: Wave Energy

RESEARCH REPORT Side 1 2864/02

A copy of this sheet must be attached to each candidate's work as a record of the assessment.

Centre No :

Candidate Name:

Candidate No :

Initiative and Independence:	**A** (i) Initiative and Independence (ii) Resources	**Scope** The report as a whole is a sustained, interesting, worthwhile study. ✓	The topic has interest and potential, and some of this is developed	A definite topic has been chosen.	**Use of resources** A good range and variety of relevant sources are used. ✓	More than one relevant source of information is used. The sources complement each other.	At least one source of information is used. The information gained is relevant.
		Variety The report covered relevant and varied physics, achieving results, some of which are new to the student. ✓	Incorporates a variety of relevant physics.	Simple physical ideas are used from more than one area of the subject.	**References** Sources are acknowledged appropriately in the report. It is made clear which sources provide which information ✓	Some reference is given to the sources (e.g. publication information, web-site location, dates and places of interviews with named people).	The source is clearly identified.
		Independence Personal responsibility was taken for decisions. ✓	Some independent decisions have been made; help given acted on appropriately.	Guidance was needed at all stages. (i) 5 /5	(ii) 5 /5		
Use of physics	**B** (i) Use of physics (ii) Analysis and Interpretation	**Ideas** Theories and arguments are logically introduced or developed. ✓	Relevant theories, models or arguments are presented but without much comment.	Simple physics ideas presented.	**Analysis** There is good and clear analysis of information, and the conclusions drawn are clearly stated and linked to the evidence. ✓	Data and information are presented directly.	The report is entirely descriptive with no attempt at analysis.
		Variety A significant understanding of a range of physics ideas. ✓	Recognition that a variety of physics ideas are involved.	There is a variety of physics ideas, but at a simple level. (i) 4 /5	**Links** The links between the different aspects of physics are drawn out. ✓ (ii) 4 /5	There is some attempt to explain ideas using a variety of physics ideas.	There is recognition of the variety of physics ideas but the connections are not made.

Additional comments to support and explain ratings **A** and **B**:

RESEARCH REPORT Side 2 2864/02

Centre No :

Candidate Name:

Candidate No :

Communication	**C** (i) Content of the report (ii) Quality of report	**Interest** The report is clear, logical and interesting. The main argument or ideas are clearly summarised at the beginning or end. **Structure** There is a particularly good organisation of difficult ideas or complex data, and arguments are made easy to follow.	The report is interesting to read. There is evidence of organisation which makes it easy to follow. There is some continuity in the development of ideas, and the relationships between different aspects of the topic are clear.	The report is a factual account of the work done. The logic or development is hard to follow, with the structure perhaps dictated by the sequence in which evidence was gathered. (i) 4 /5	**Presentation** The report makes an impact (e.g. particularly good and relevant illustrations). It adds value to the work done. It is not excessively long or verbose. **Illustrations** Illustrations are relevant, clear, and contribute to the communication of ideas. Graphical plots are well-chosen, to display results effectively. **Use of English** The quality of English is good. (ii) 3 /5	The report is neatly produced. Illustrations and graphs are basic, neat and without distracting elements. The quality of English is adequate to express some more complex ideas.	The report is poorly presented and detracts from the value of the work done. Illustrations and graphs may be inadequate, or irrelevant and are not integrated into the text The quality of English is adequate to express simple ideas clearly.
Evaluation and connections	**D** (i) Evaluation (ii) Connections	**Evaluation** There is good evaluation of the reliability, accuracy or suitability of the sources. The student may comment on any difference in views or ideas from the sources.	Some attempt is made to evaluate the accuracy and reliability of the sources, even if at a superficial level.	The student accepts the information collected, with little attempt to check reliability. (i) 3 /5	**Connections** There is interesting material from the wider context, which is related thoughtfully to the other concerns of the report and deepens or illuminates the account. **Synoptic aspects** The way in which the various aspects of physics work together are discussed. (ii) 4 /5	Information about the wider context is mentioned, but is limited to descriptive reporting without discussion or comment. The student identifies the different aspects of physics studied.	Some aspect of the wider context for the physics is mentioned, but without detail or discussion. There is some attempt to identify the various aspects of physics.
	RATING TOTAL			32 /40			

Additional comments to support and explain ratings **C** and **D**:

Assessors signature :

Date :

Statement of aim

With dwindling fossil fuel resources, wave energy could be the energy resource of the future. The aim of this report is to convey to the reader why the energy from waves is so useful and how scientists actually propose to extract this energy. ✓ Clear and succinct.

Statement as to how research was gained

I read an article in a New Scientist magazine (3rd October 1998) entitled "The Big Break". It was through this article that I decided to research further into the topic of wave energy. I set about using the New Scientist CD ROM to try to find further articles on this subject with the hope that they may give me some useful leads. At the same time I contacted a local company 'Gifford Brothers', who although unable to help suggested another company 'HR Wallingford' who were able to send me some information on their work. To locate useful material it was not the New Scientist CD ROM but the Internet that aided me most. Not only did it prove a valuable source of material but also pointed me in the direction of a number of books and leading researchers in the wave energy field. ✓ In particular I was able to contact a team from Edinburgh University by e-mail which included Stephen Salter and Jamie Taylor. The former was the inventor of one of the first wave energy converters- Salter's Duck, and sent me papers of his work. The latter proved to be my most useful contact. He sent me information, in the form of literature and a video of the work Edinburgh University carry out, was able to answer any questions I had, and also gave me the title of a book "Renewable Energy" (by Open University). I managed to locate a copy at Basingstoke library and it aided the progress of my report greatly.

Useful summary.
He was enterprising in tracking down some information and active in pursuing new sources. This summary provides evidence of the range + process of data collection and the analysis of that data.

Wave Energy
An Energy Resource Of The Future?

Introduction

It was the 'energy crisis' of 1973[1] that prompted an increased interest in renewable energy resources. It has only been since then that people have become more aware of the destruction to our surroundings, the depletion of our unrenewable resources, and the pollution of our environment. Since then we have, developed techniques of burning fossil fuels with minimal pollution to our atmosphere, but this does not in any way change the fact that our fossil fuel resources are not inexhaustible and will last only for a finite time. So scientists have set about researching alternative forms of renewable energy and thus, the exploration of wave power has increased dramatically over the past 26 years.

good, attractive start.

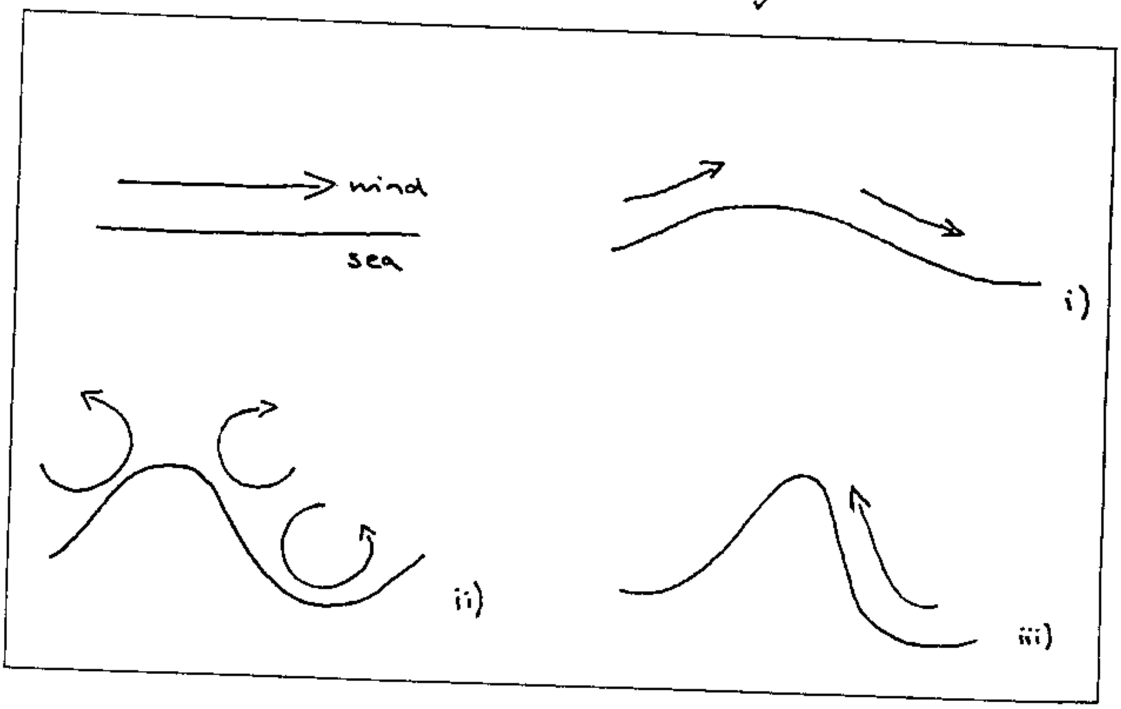
The energy contained in waves

The reason for the vast amount of time and research that scientists and politicians alike have put into wave energy projects is due to the large amount of energy contained in sea waves. To understand why, it must be made clear how waves are generated:

(i) wind passing over the sea exerts a tangential stress (a form of friction) on the water surface, resulting in the formation and growth of waves.

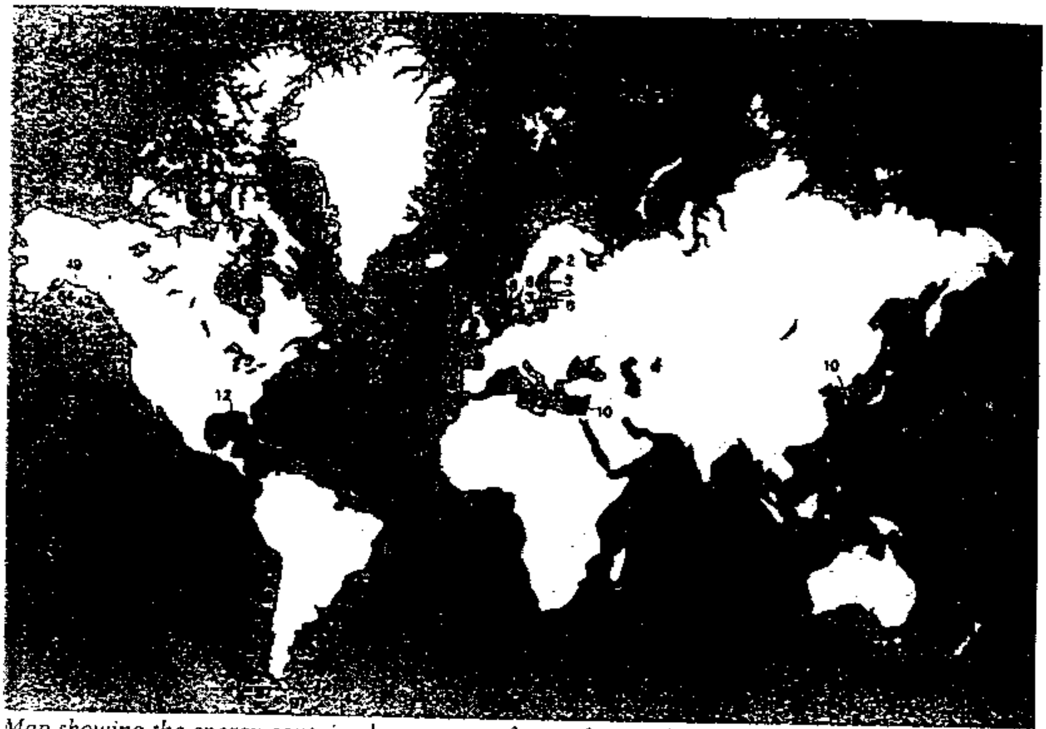
(ii) turbulent air flowing close to the water surface creates further rapidly changing sheer stresses and pressure fluctuations.

(iii) finally when waves have reached a certain size the wind can exert a stronger force on the upwind face of the wave causing additional growth[2].



It can be said that since wind is derived from solar energy we may consider the energy in ocean waves to be a stored form of solar energy. Thus wind energy and wave energy are of the same form - a specific form of solar energy. The differences between the two are two-fold. Firstly, water is many times denser than air and thus the possible energy stored per m^3 is greater in water than in air (this is because the number of molecules in a m^3 of water is much greater than those in a m^3 of air, meaning there are a greater number of molecules to store the energy). Secondly the theoretical maximum energy which can be extracted from wind is only about 59% whereas 99% of the energy of waves can in theory be harnessed (the theory behind this is described later) [11].

Wave energy is possibly the 'ultimate resource', since 70% of the Earth's surface is covered by water. However not all of this can be harnessed. The size of the waves and the energy they can contain depends upon three factors: wind speed (as faster moving air contains greater energy thus will exert a greater force on the water), its duration (the longer this force is in contact with the water, the greater the energy transfer), and the 'fetch' (or distance) over which wind energy is transferred into the ocean to form waves (again the greater the distance the greater the energy transfer). This means that sites for wave energy converters in the Atlantic and the Pacific Oceans are ideal, whereas choosing a site in the Mediterranean would be inefficient and far from cost effective, as the Mediterranean lies relatively inland and as a result sheltered from the strongest winds. In fact wave energy conversion is only really possible between the latitudes of 40 and 60 degrees in both the Northern and Southern hemispheres because this is where the winds are strongest. The only other suitable location is at the 30 degree latitudes where there are fairly regular Trade Winds prevailing[10]. The best locations, as a result, are along the West coasts of Europe (50-70kW/m), the west coasts of most northern North America (50-100kW/m) and most southern South America (50-100kW/m), and the coast of New Zealand (60kW/m). (Values in brackets are those taken from Fig.1 overleaf.)



Map showing the energy contained per metre of wave front in locations around the world
Reference 2 p.325 Fig.1

So, the energy contained in waves is as a result of the 3 previously named factors. This energy will be reflected in the size of the wave's amplitude H, and its period T. The power P contained in waves in deep water (water where the depth is greater than half the wavelength) in Watts/metre length is given by

$$P(kW/m) = \frac{\rho g^2 H^2 T}{32\pi}$$

where ρ is the density of water, and g is the acceleration due to gravity[3].

Checking this proposed formula by a test on the units:
RHS =

$$\frac{kg}{m^3} x \frac{m^2}{s^4} x m^2 s \quad = \quad \frac{kgm}{s^3}$$

Now power = (force x distance)/time
So power/per metre length = force/time
From Newton's 2^{nd} law F = ma

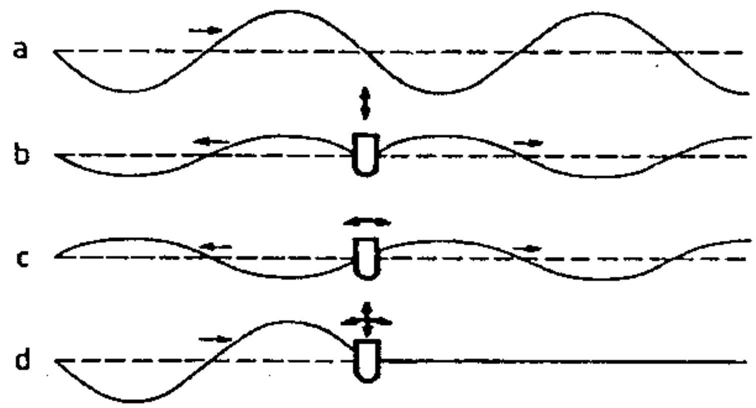
$$F = kg.\frac{m}{s^2}$$

what exactly a wave constitutes. The surface profile of the ocean is obvious evidence of waves, but what of the underwater nature of the waves. Waves themselves are a composition of orbiting particles of water which near to the surface in deep water are the same size as the wave height (see fig.2). The deeper you go below the surface, the smaller the orbits become (this is an exponentially decaying relationship as shown in the diagram for deep water below). Therefore if all the energy from waves is to be harnessed, a converter must be designed to envelope all of the orbiting parts of the waves. This however would be grossly impractical since the lowest orbits contain almost no energy at all. So when scientists are designing devices, it must be noted that 95% of the energy of the waves is contained in the layer between the surface and a depth equal to 1/4 of one wavelength[2].

So far, it reads very well, with information presented quantified and clear explanations.

The absorption of energy

In order to absorb energy, a wave energy converter must be able to generate waves by displacing water in an oscillating fashion in phase with the incident wave. Thus there must be a cancelling (or reduction if not all the energy is to be utilised) of waves which are passing the device. So the generated waves interfere destructively with the other waves. Complete absorption of wave energy is only possible if a body oscillates in both the vertical and horizontal modes in the optimum manner. That is, the radiated waves have to have exactly half the amplitude of the incident wave.



Curve a represents an undisturbed incident wave. Curve b shows the production of symmetric waves by up and down movements only. Curve c illustrates antisymmetric wave generation. Curve d represents the sum of these three waves above, and thus showing complete absorption of the incident wave.
Reference 4 p.2

This will result in the cancelling of the symmetric and antisymmetric radiated waves to the left. Furthermore, if 100% absorption is to occur the radiated waves must also be in phase with the incident wave, if the crests of the waves produced towards the right are to cancel with the troughs of the incident waves. Now about 1% of this absorbed energy will be lost to the surroundings in the form of heat and sound giving the quoted value earlier of 99%, being the theoretical energy that can be harnessed from the waves. If only one mode of oscillation is possible then only 50% absorption occurs as waves of half the

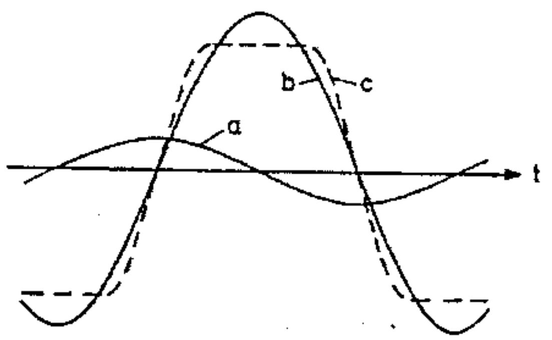
clarity

amplitude of the incident wave are reflected both left and right. From the equation for power in a wave front for an irregular sea

$$P = \alpha_s H_s^2 T_e$$

it can be seen that the energy in a wave is proportional to the square of the amplitude. This means that 25% of the incident wave energy will be reflected towards the left and 25% of it will be transmitted towards the right leaving a maximum possible 50% to be absorbed by the wave energy converter. Such a system happens to have the optimum phase condition when it is at resonance with the wave, so that the wave frequency is equal to the natural frequency of the oscillating system. The body will reach a steady state oscillation when the additional force up provided by the rising wave equals that of the weight pulling the body down. If optimum absorption is obtained by a body oscillating at resonance, it is important that the frequency of the body never falls outside the resonance bandwidth of the system (bandwidth is the range of frequencies in which resonance will take place). For large bodies, the bandwidth is broad, but for smaller size wave energy converters, in particular, the point absorbers, the bandwidth is narrow (quote?)

However, for maximum wave energy conversion an optimum oscillation amplitude is also required. This is though somewhat smaller than the amplitude gained as a result of resonance. So in order to limit the amplitude and to maintain the optimum phase, in particular for smaller bodies, phase control by 'latching ' is required.



Curve a is the elevation of the water as a result of the incident wave. Curve b shows the vertical displacement of a heaving body at resonance. Curve c shows the vertical displacement of the same body that is experiencing phase control. Reference 4 p.4

What latching does is twofold. Firstly, for some small fractions of a wave cycle some of the energy is returned to the sea. To achieve this, reversible energy converting machinery is required, for example high efficiency hydraulic machinery which can work either as a motor or as a pump. Secondly, if the wave periods are longer than those of the wave energy converter's natural period, the device can be kept in phase by clamping the motion for an instant normally around the time when the energy converter is at its greatest amplitude.

Wave energy converters

So scientists know and have known that the ocean waves are a suitable source of large volumes of energy. In order to design schemes to capture energy however, the entire makeup of the waves must be understood. That is, the surface profile of the ocean is obvious evidence of the waves, but what must also be considered is the subsurface nature of the waves. Wave energy converters can and have taken two forms:

(i) shore mounted ✓

(ii) floating and fixed seabed. ✓

Both carry their own benefits and drawbacks. The major drawback of the shore mounted devices is the fact that by being fixed to the coastline, they are in essence lying in shallow waters as there are few areas of the world where the shoreline is formed by a steep cliff which drops into reasonably deep water. ✓

Shallow waters result in a huge loss of energy. This due to a frictional force between the deeper water particle motion and the rising sea floor. Energy loss becomes greatly significant when the water depth is less than $\lambda/4$ since, as was outlined previously, 95% of the energy contained in waves exists in the top $\lambda/4$. ✓ However, a major benefit of shore mounted converters is that the energy from storm waves is weakened and thus shoreline devices are less likely to be destroyed. ✓

Storm waves are waves located close to where they are formed. They form complex irregular seas containing colossal amounts of energy. Over time they can travel from these areas to form swell waves with minimal loss of energy.

Floating devices lying away from the shore inhabit seas which contain a much greater amount of energy and thus the energy which can be generated is greater. However, being in these waters, they are more likely to be destroyed by storm waves, as was the case with the Osprey. ✓ (storm)

The Osprey was another wave energy converter. It was an OWC* that was designed to sit on the seabed. It was launched on 2 August 1995. Problems developed with the Osprey when the Osprey team were loading sand into the ballast tanks- it were these tanks that the designers believed would keep the Osprey mounted to the sea floor. The sea developed a 3 metre swell from Iceland and, as a result of the ballast tanks not being full, the Osprey was torn apart[5].

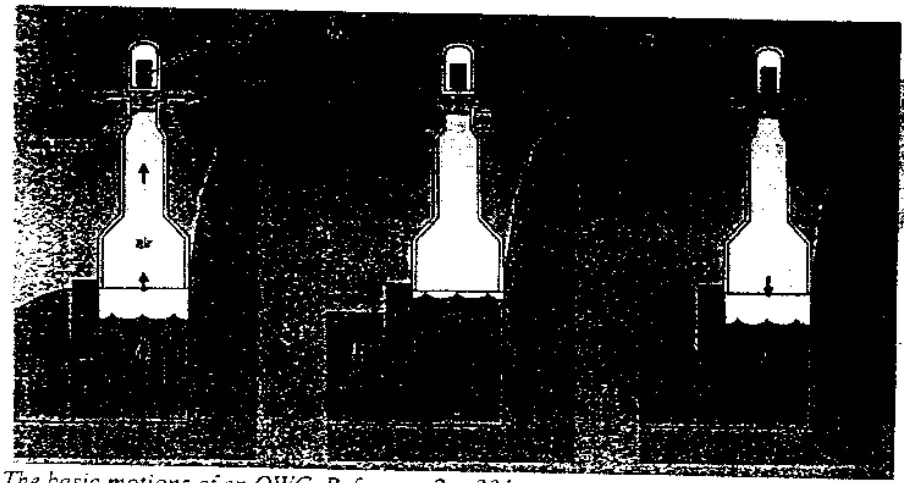
As far as affects to the environment go, wave energy converters are among the safest of all energy producing devices. Shore mounted and floating devices at most contain a small amount of lubricating oil which is carefully sealed form the enviroment meaning that the possibilities of chemical pollution is almost nil. Floating devices present a slight hazard to shipping. Such devices could influence the coastal environment if like the Japanese Whale (a floating OWC) they act as a break water as well as a wave energy converter. However, other floating devices are unable to extract all the energy from storm waves so the impact on the coasts will be minimal.

Interesting discussion on the relative merits of shore mounted, floating and fixed bed energy converters

The Oscillating Water Column

Over the past 26 years, many wave-energy converters have been designed by people from all over the world. One of the most popular devices being the oscillating water column (OWC). These can be floating or fixed mounted. The latter are at present the more successful with a working device on the Isle of Islay delivering 75kW of power[6]. It lies at the end of channel forming a natural estuary. This has the effect of accelerating the waves towards the OWC as the channel narrows.

In terms of energy the natural gully concentrates the energy per metre length by a additional 10-20kW/m. In deep waters off the coast of Scotland readings taken show the power in the waves to be up to 70kW/m, yet due to frictional forces, in shallow waters along the coast, the energy levels drop to 8kW/m. But with the gully the energy rose to 20-30kW/m[5].



The basic motions of an OWC. Reference 2 p.33

The principles behind OWCs are simple ones. There is an opening on one side of the column that admits the waves. As the waves outside the cylindrical chamber rise, the waters inside rise. In fact the water surface within the OWC will oscillate vertically in simple harmonic motion in conjunction with the waves outside. As the surface rises it exerts an upward pressure on the air contained within the OWC. A pressure difference results between the air outside and the air trapped inside so the air is displaced by the OWC through the path of a Wells' Turbine (in the case of the Islay device and almost all other OWCs) which is in turn used to generate electricity. As the water surface falls again, a partial vacuum is temporarily set-up causing air to be drawn back through the turbine into the column. This process repeats itself again and again. The Islay device comes complete with a butterfly shut off valve which blocks the gully when the waves are too high and threaten to swamp the machinery, or when repairs or maintenance work has to be carried out.

Applying the latching ideas to a shore mounted OWC, like the Islay device, energy can be taken from the waves at specific times to drive a hydraulic pump. This can in turn strengthen the force with which the water rises upwards causing the turbine to rotate faster and a greater amount of energy being produced.

OWC would not be what they are today without Professor Alan Wells, inventor of the Wells' Turbine. It is special as it can accept airflow in either axial direction. Previous to the development of such a turbine an intricate system of valves and pipes had to be used in order for the air to enter the turbine from one direction only (even when air is being drawn into the device or forced out. This resulted in high- energy losses. The Wells' turbine consists of a series of blades, which are symmetric about the plane of rotation, with zero pitch. The shape of the blade is extremely important as it will determine the values of the lift (F_L) and drag (F_D) forces and hence the magnitude of the forward thrust. At the shapes and sizes Wells' Turbines are employed, they can rotate at anywhere between 1500rpm to 3000rpm[2] so that an electrical generator can be attached directly to the drive shaft of the turbine. This means that there is no need for a gear box to increase the speed, which would result in a loss of energy.

(tone) not clear, how the Wells turbine can accept airflow in either axial direction?

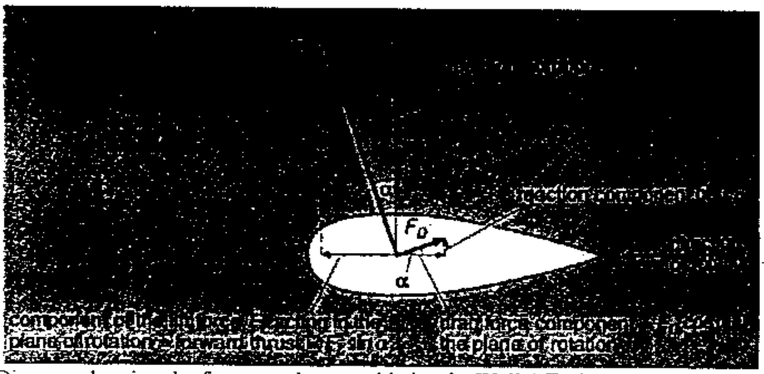


Diagram showing the forces acting on a blade of a Wells' Turbine.
Reference 2 p.330

The IPS (Inter-Project Services) Buoy

However, away from the simplicity of OWCs are the floating devices. Able to lie away from the coasts in deep waters, these energy converters, if successful, are able to generate huge amounts of energy. At present, there are a few floating energy converters that seem promising:

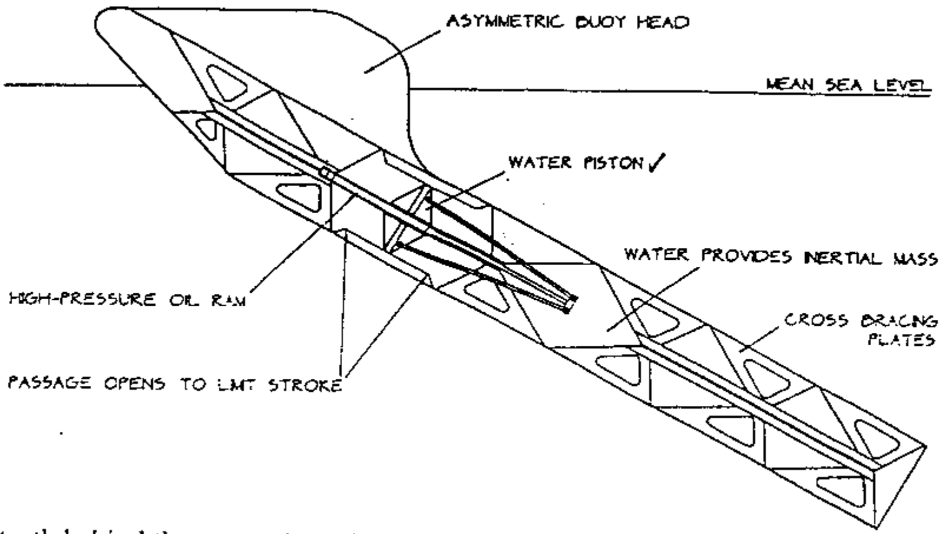
(i) The Japanese have devised a massive floating OWC they call 'The Whale'. It needs to be huge in order to maintain a stable point of reference which will allow the OWC to function properly.

(ii) The Clam consists of 12 interconnected air chambers arranged in a circular manner. Between each chamber is a Wells' Turbine. As waves pass, they cause the movement of air between cells causing the turbines to rotate.

(iii) In the past, the Edinburgh Duck was originally many cam-shaped bodies linked together by a long, flexible, floating spine. However, today interest centres on the case of a single Duck which will act as a point absorber. The Duck is able to move in both the vertical and horizontal planes and thus, as will be explained later, is one of the most efficient energy absorbing devices.

The last device was the brainchild of Stephen Salter of Edinburgh University. Salter and his Edinburgh team have now turned their interest to a similar device- the sloped IPS wave energy converter. Salter can however not take all the credit for this idea as it was a Swedish team responsible for its birth. What Salter has done is taken what he feels is possibly the way forward in wave energy and made it better.

A diagram of the IPS buoy. Reference 8 p.2



The truth behind the generation of energy by the IPS buoy is somewhat more complex than the shored mounted OWC. The buoy consists of an asymmetric head connected to a long body. Due to the shape of the head of the device, the buoy, like Salter's Duck is able to move in accordance to the motion of the waves thus able to absorb large amounts of energy. Inside the body are contained one or more large diameter tubes, open at the top and the bottom to the sea and house a short piston. As the whole IPS buoy structure rides around with the waves, there will tend to be some relative motion between the tubes themselves and the water inside them such that the piston experiences forces which tend to make them move up and down inside the tubes. The pistons are connected to high pressure oil hydraulic rams which drive hydraulic motors connected to electrical generators. One of the modifications to this system by the Edinburgh team is the 'belling out' of the tubes at either end, so that in big waves, as the pistons reach the end of their travels, water can pass around the piston. This means that the system is power limiting such that there is sufficient over-load protection in waves that could otherwise cause the buoy to ultimately destroy itself. Research carried out by David Pizer has shown that the IPS buoy performs best between the angles of 30 and 45 degrees to the horizontal. In comparison to a system operating upright he found that at these angles the forces involved on the system were smaller and the power output much greater. It has also been found that the performance of an IPS buoy is also improved by latching.

The future

In 1994 a report was released by the Government stating that it had decided not to fund any further work on wave energy[5]. Two years previous a review of wave energy commissioned by the Department of Trade and Industry was completed by ETSU[2]. This review suggested that wave energy exploitation in the UK was unlikely to be economically competitive in the short term. However at the international conference of wave energy in Portugal in 1995 the message from the European Commission was "Wave energy will overtake wind energy round the year 2010" which sounds far more promising. Whether this holds true or not is largely down to the funding put forward by Government bodies around the world (if not our own) to support wave energy projects. Wave energy may not make an impact now, but in years to come when our fossil fuel resources are close to extinction, then wave energy could prove the most significant energy resource . available.

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Edwards, R. (1998), The Big Break, New Scientist, 160(2154), 30-34.

Personal communications with Taylor, J. (1999), email at jamie.taylor@ed.ac.uk.

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An appropriate range and variety of sources of information – well-structured bibliography. fully documented.

9 Coursework forms

OCR is producing a Coursework Administration Pack for each specification containing coursework. This pack will contain copies of all relevant forms and instructions for completion.

10 Contacts

Subject Officer for A Level Physics (specification-specific queries only)

OCR
1 Hills Road
Cambridge
CB1 2EU

Training and Customer Support (INSET enquiries)

OCR
Mill Wharf
Mill Street
Birmingham
B6 4BU

Tel: 0121 628 2950
Fax: 0121 628 2940
Email: tcs@ocr.org.uk

OCR Information Bureau (General Assessment)

Tel: 01223 553998
Email: helpdesk@ocr.org.uk
Website: www.ocr.org.uk

Advancing Physics Project Support

The *Advancing Physics* project will provide support for teachers through:

- INSET for teachers who plan to take up the course – covering new teaching material as well as new teaching approaches.
- A network of user groups so that teachers of the course can meet with colleagues using the materials in other schools and colleges.
- The Advancing Physics newsletter – helping teachers keep in touch with the publishers; the examination board, OCR; and the Project team at the Institute of Physics.
- The Advancing Physics website – providing an opportunity for teachers to keep up to date with new contexts for the physics in the course; to share ideas and to link to the wider physics community. http://post16.iop.org/advphys/

The *Advancing Physics* Project can be contacted at : Project Administrator, *Advancing Physics*, Institute of Physics, 76 Portland Place, London W1N 3DH, or by email 16-19project@iop.org

11 Support Materials for the Course

Advancing Physics – Published Resources

The course is supported by a full range of resources, both in print and in electronic form, published by Institute of Physics Publishing and endorsed by OCR.

Advancing Physics Student's book (one each for AS and A2) 256 pages in full colour provides good physics reading for students as well as a grounding in the essential physics of the course.

Advancing Physics Student's CD-ROM (one each for AS and A2) containing the Course Guide, Resource Finder and Physics A-Z. Each CD-ROM includes a study guide to support the student throughout the course. Whilst much of the Study Guide can be printed off as hard copy, the interactive nature of the medium enhances its use as a learning tool. The CD-ROM includes modelling software to enable students and teachers to try out physics models developed for the course as well as building their own models. The Study Guide provides many opportunities for self-study.

Advancing Physics Teacher's Handbook (one each for AS and A2) which guides the teacher through the course; helps with organising the teaching and learning; and gives guidance on the management of coursework.

Advancing Physics Teacher's CD-ROM (one each for AS and A2) which holds all the Student CD-ROM and the text of the Teacher's Handbook. It also provides more detailed support for teaching the course, including background physics; materials for classroom activities – including photocopiable material for OHTs, worksheets, and tests; and listings of apparatus requirements. All the materials can be printed and customised to suit the particular circumstances of the school or college. Other resources for the teacher will include a bank of questions, with answers; data for use with software programs, tools and simulations.

All AS support materials are now available.

All A2 support materials will be published in Summer 2001.

For further information about published resources contact:

Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE UK

Tel: +44 (0)117 930 1148 (Direct) Fax: +44 (0)117 929 4318

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