Physics

Physics Investigation
Advanced Higher

6772

Spring 2000

HIGHER STILL

Physics

Physics Investigation
Advanced Higher

Support Materials

Physics Investigation (AH)

CONTENTS

1. GENERAL INTRODUCTION

Purpose of the guide

The purpose of this staff guide is provide some information and examples to illustrate the standard expected for the attainment of the Physics Investigation unit. In addition exemplars and comments are provided on the report of the investigation, which is part of the Advanced Higher course assessment.

The length of the Physics Investigation unit is 20 hours. Hence it is likely that the staff member, from the centre supervising the student, will ensure that there is an early focus and clear direction. Although it is expected that the student will be involved in some initial reading and research, this aspect cannot be allowed to absorb too much time. Some early discussion with the student is essential.

After completion of the unit, which involves maintaining the day book and completing the experimental work and analysis, the report for the course assessment is likely take a further 5 - 10 hours.

The following table provides a brief summary of a suitable time allocation required throughout this unit. It must be remembered that investigations, however, can vary widely in their scope.

Skill/activity		*Time*	*Comments*
Background reading initial discussions getting underway maintain the day book planning and organising	 O 1 O 1	5 hours	Teacher input required to ensure a focus to the ideas. Structured Outline discussed early
setting up equipment actual practical work taking measurements analysing readings graphs uncertainties	O 2 O 2 O 2	15 hours	Emphasis on the actual practical work Regular entries Avoid equipment which needs to be specially made or assembled Encourage use of spreadsheets Consider accuracy of instruments used
completion of report procedures conclusions evaluations	 *course*	5 - 10 hours	This is the course assessment Content relevance more important than length

Safety

Due attention must be given to safety in the laboratory. It is assumed that centres are familiar with statutory requirements, and will ensure that safe working practices are observed. The initial induction for students should include information on safety in the laboratory. All necessary safety notices should be clearly displayed. It is the centre's responsibility to ensure that an appropriate risk assessment is carried out for any experiment undertaken. All exemplars in this handbook are for illustrative purposes only.

2. UNIT REQUIREMENTS

The tasks associated with this unit involve selecting a suitable topic, appropriate background reading, planning and organising the investigation, setting up the equipment, obtaining the readings and observations, and all analysis of the results, including all graphs and uncertainties analysis.

For assessment purposes the student must submit a completed day book together with details of all the readings, observations and analysis. The unit has two outcomes and the Teacher/Lecturer guide given on page 4 is provided to indicate what must be addressed to achieve a specific performance criterion.

Day book

Outcome 1 requires that a day book is maintained. This should contain the student's notes as they proceed. It is for use by the student and as such can be in the form of brief statements, phrases or sentences. There is no requirement for this material to be 'written up' or typed and such time wasting should be discouraged. The amount of detail recorded will vary considerably among individuals, this is a purely personal matter.

However the day book is a working document. It will contain all, or most of the information which will be required for the final report. In many cases a loose leaf format might be appropriate. Computer generated tables and graphs can then easily be included. All pages should be clearly numbered and dated.

The following outline indicates some possible entries which might appear in a day book. Comments are given in italics.

Exemplar entries

Date Discussion with (name of teacher/lecturer). A list of possible topics agreed.

Date Reading on topics, decided on topic XX or YY. References noted down. Discussion with (staff name) chose topic X. Apparatus for Y not available/would take too long/ etc [*full details not essential*]

Date Further reading, decided on exp. X_1 and X_2 for material Q. Spoke to (staff name) discussed equipment and operation of specific apparatus T and asked about some details in manual [*brief statements of any help received*]. Any references noted.

Date Rough sketch of apparatus with labels [*to use later in report*] other phrases or statements on procedure for future use, comments on selection of apparatus and any set-up issues [*can be brief, since for students use, but needed for report*]

Date Readings obtained for experiment. X_1, actual tables of readings/results

Date Experiment X_2, problems with ...discussed(staff name) /helped /adjusted/ ......

Date Readings for experiment X_2, actual pages containing tables of readings/results;

Date Graphs and uncertainties, actual pages of analysis

Date Rest of analysis finished, actual pages of analysis included.

It is possible that the student may consider conclusions and evaluations and make some notes, although this is not a unit requirement.

Comments on unit attainment

The Physics Investigation Teacher/Lecturer guide is designed to assist staff assessing this unit.

Outcome 1

The day book must be maintained. There must be evidence of regular entries. Any help given should be briefly recorded. The entries must be legible but the presentation is not assessed. Adequate notes regarding the experimental design and methods used are expected. In some cases a labelled diagram is sufficient, or a photocopy modified if necessary.

Outcome 2

PC a) It is the responsibility of the staff to ensure that the student can work individually, e.g. the provision of a suitable working area and of individual equipment.

PC b) The use of a spreadsheet package is to be encouraged but it is not mandatory. However the use of a dedicated analysis package is not appropriate.

PC c) As above, graphs (charts) can be generated from a spreadsheet, if this facility is available, but the student must be involved in the analysis.
Any final calculated results should be stated clearly.

PC d) A record of calibration uncertainties is required for all instruments, if available.
Uncertainties in scale readings is expected for all instruments.
For repeated readings, the approximate random uncertainty in the mean should be stated.
Uncertainties estimated from a straight line graph are expected where appropriate. Error bars should be plotted, if appropriate.
After due consideration of any negligible uncertainties, the combination of uncertainties should be stated. The uncertainty in any final value should be stated.

The analysis should be in a clear format, but any details of presentation are not necessary for unit attainment. For example, a spreadsheet might generate a graph with the 'last' point on the extreme edge of the graph. For the course report it is likely that the student would alter the axis scales. However for unit attainment this is not required. For the unit, there must be evidence that the experimental work has been completed.

Similarly, if the width of a beam is measured in three places and the mean obtained, this could be adequate for unit attainment. However full marks may not be awarded in this section, for the course, where a minimum of five repeated readings is desirable for the determination of the approximate random uncertainty in the mean.

Physics Investigation (AH): Teacher/Lecturer guide

For both Outcomes, all the performance criteria given in the left-hand column must be achieved in order to attain the outcome. The right-hand column gives suggested items which might aid the professional judgement of the assessor.

Outcome 1

PERFORMANCE CRITERIA	SUGGESTED ITEMS TO AID PROFESSIONAL JUDGEMENT
a. A day book is maintained in a regular manner.	The entries in the daybook can be brief and need not be structured paragraphs. Regular notes should be entered in the daybook. Notes/comments on ideas rejected should be entered. Contributions made by other individuals should be entered.
b. Experimental and observational techniques and apparatus are appropriate for the investigation.	Notes/comments on planning and design should be entered. Notes/comments on selection of method used should be entered.

Outcome 2

PERFORMANCE CRITERIA	SUGGESTED ITEMS TO AID PROFESSIONAL JUDGEMENT
a. The collection of the experimental information is carried out with due accuracy.	The collection of the information is the individual work of the student. The information is collected with due accuracy.
b. Relevant measurements and observations are recorded in an appropriate format.	Readings or observations recorded in a clear table which must include: • correct headings • appropriate units • correctly entered readings/observations.
c. Recorded experimental information is analysed and presented in an appropriate format.	Readings should be analysed and presented in tabular or graphical form as appropriate: For a tabular presentation this may be an extension of the table used for performance criterion b. above, e.g. the calculation of the inverse or square of a variable, and must include: • a table with suitable headings and units • a table with ascending or descending independent variable • a table showing appropriate computations. For a graphical presentation this must include: • a graph with independent and dependent variables plotted on appropriate axes • a graph with suitable scales and axes labelled with quantites and units • a graph with data correctly plotted, with error bars, and with a line or a curve of best fit.
d. Uncertainties are treated appropriately.	Depending on the activity the following should be included as appropriate: • calibration uncertainties, readings uncertainties and random uncertainties • a combination of individual uncertainties • an uncertainty in the numerical value of a measured quantity • uncertainties estimated from a straight line graph.

3. COURSE REQUIREMENTS

The course assessment at Advanced Higher consists of a question paper worth 80% of the total marks and a report on the investigation worth 20% of the total marks. The question paper has a total of 100 marks and 25 marks are allocated for the investigation report.

Assessment details

The mark allocation for the *Management of resources* for each investigation will require to be recorded on the form accompanying the investigation reports.

The report will be externally assessed against the evidence described in the following marking scheme under the headings (a) to (e). A visit from an external assessor will take place to interview each candidate. The purpose of this oral is twofold; first, to provide the candidate with the opportunity to clarify to the assessor aspects of their investigation. This may lead to readjustment of the marks awarded under the headings (a) to (e). Secondly the oral will provide the candidate with the opportunity to discuss coherently how the investigation was conducted and to show knowledge and understanding of the physics involved.

For the oral examination:

- the candidate must bring their day book
- the day book may be referred to
- the duration of the oral will be about 20 minutes.

Marking scheme for the investigation report

ASSESSMENT CATEGORY	MARKS
(a) Background information A title and contents page. A brief summary stating the purpose and overall findings of the investigation. An introduction including the physics involved.	2
(b) Description of procedures Labelled diagrams or descriptions of apparatus/instruments in words. Clear descriptions of how the: independent and dependent variables were measured independent variables were altered Range of procedures used.	4
(c) Readings/results/analysis Tables of results with headings, suitable range of independent variables. Quality and reproducibility of results. Uncertainties in individual readings and final result. Graphs: labelled axes, error bars, best fit line as appropriate.	5
(d) Conclusions/evaluation Clear statements consistent with processed data. Evaluation to include: limitations of equipment, reliability of the methods and sources of error, comparison of methods used/results obtained with accepted values.	4
(e) Presentation The length of the text should not exceed 2000 words, excluding tables, figures, graphs, etc. The structure and details of the report should be sufficient to allow the investigation to be repeated. The investigation report is clear and concise. Sufficient clear illustrations are provided e.g. diagrams, figures, graphs. References and acknowledgements: sufficient quantity and relevant.	3
(f) Application of knowledge and understanding (during the oral) Defines terms accurately. Explains ideas clearly. Describes how experimental readings/results were obtained. Discusses conclusions and evaluation.	4
(g) Management of resources (allocated by the centre) Investigation is carried out in a self reliant manner. Appropriate and safe practices are adopted. Investigation is well managed.	3
Total marks	**25**

Further comments on the marking of the report

Topics for investigation do not require prior approval from SQA. Candidates have a great deal of freedom in selecting topics for their investigation and, in particular, are not restricted to the content of the Mechanics, Electrical Phenomena and Wave Phenomena units. Staff and student should note that the Physics content of the investigations must be at a level appropriate to the Advanced Higher course. Trivial investigations are not acceptable.

Due to the open way in which the investigation has been specified, the marking scheme for the investigation report allows for wide variation in the sunject matter, length and presentation of reports. The criteria specified in the marking scheme are designed to ensure consistency across the country.

Some of the criteria are clear and unambiguous, for example, "Clear descriptions of how the independent and dependent variables were measured". Others are less clear-cut, for example, "Quality and reproducibility of results. It is possible therefore that SQA assessors will be provided with additional guidance on the marking of the report. If additional guidance is produced, it is likely that this will be discussed by the assessors and adapted in the light of experience.

Within the investigation there is likely to be more than one actual 'experiment'. In the time available the student might carry out perhaps two to four separate, but related, experiments. In the exemplars in this pack, the Young's modulus involves two experiments, the MOS – transistor and the Fluid Flow involve three experiments. It would not be practicable to prescribe the number of experiments or the total number of readings. It is important to remember that only 20 hours is available for the planning, organising and carrying out of the practical work. There is no intention to encourage additional time to be spent in the expectation that a higher mark will be obtained. However a report which suggests a minimal effort will be rewarded accordingly.

Marks may be adjusted after completion of the oral examination. The oral will be used to give candidates the opportunity to clarify any aspects of the report which the assessor may wish to query. Any readjustment of marks awarded under the headings (a) to (e) may involve an increase or a decrease. This adjustment is in addition to the four marks allocated to the oral under heading (f).

The use of {½ }marks allows for quality and completeness to be taken into account. Information provided in one section of a report relating to another section will receive credit. Some comments are given below for each of the categories.

(a) Background information

It is suggested that {1} mark is available for each of the summary and introduction. A {½ } mark will be deducted in the unlikely event of no title and contents page.

(b) Description of the procedures

There are four marks available under this heading. A possible breakdown is:

{1} mark for the labelled diagrams/descriptions of apparatus across the various experiments

{2} marks for the clear description of the how the variables were measured, and the independent variables altered across the various experiments

{1} mark for the range and suitability of the experimental procedures.

(c) Readings/results/analysis

The following allocation of the five marks has been suggested.

{1} mark for the readings, to include the range of the independent variables, repeated readings.

{1} mark for the quality and reproducibility of the results.

{2} marks for the uncertainties, to include calibration uncertainties for all instruments where possible, reading uncertainties, random uncertainties, combination of uncertainties and comments on any small uncertainties neglected, uncertainties in gradients and intercepts of graphs if appropriate.

{1} mark for the graphs, to include best fit straight lines or curves, error bars if appropriate, and completeness and suitability of graphs plotted.

(d) Conclusions/evaluation

There may be overlap between these two headings.

{1} mark for the clarity and completeness of the conclusion.

{3} marks for the evaluation, to include any limitations of equipment, reliability of method and/or comparison of the methods, comparison of results with accepted values, and sources of errors or highlighting positive features.

(e) Presentation

The overall quality of the report is reflected in the first two marks.

{1} mark for the clarity and conciseness of the report.

{1} mark for the illustrations, sufficient and relevant.

{1} mark for sufficient and relevant references.

A {½ } mark will be deducted if the acknowledgements list is omitted.

(f) Oral

A possible division of the four marks is given below but there may well be overlap depending on the individual investigation.

{2} marks for defining terms accurately and explaining ideas clearly.

{2} marks for describing how experimental readings and results were obtained and discussing conclusions and evaluations.

The student is advised to keep a copy of the report to ensure adequate preparation for the oral.

(g) Management of resources (allocated by the centre)

The award of the marks in this category should reflect the overall approach demonstrated by the student. The marks should be allocated as follows:

{1} mark for carrying out the investigation in a self reliant manner

{1} mark for adopting appropriate and safe practices

{1} mark for an investigation which is well managed.

4. LIST OF SUGGESTED TOPICS

The investigation selected should be at an appropriate standard. The candidate can discuss the selection of possible topics with a member of staff to ensure that time is not wasted on research into topics which are unsuitable, either because of their level of demand or the lack of appropriate apparatus within the centre.

Suggested topics for the Physics Investigation unit

The topic chosen for the investigation is not prescribed. Any topic can be chosen providing it enables the performance criteria for the unit to be achieved and the report on the topic is suitable for the course assessment, if this is required. However the topic chosen must be at a standard commensurate with the demands of Advanced Higher Physics.

The topic can involve Physics which is covered in the Advanced Higher course or can involve Physics outwith this course content. The following list provides some suggestions.

Investigation topics: some common topics

Measurement of 'g': different methods
Simple harmonic motion: investigation of damping
Factors affecting inductance: number of turns, length and width
Factors affecting capacitance: separation and area of plates, dielectric
Electronic characteristics, e.g. using the school's chip
Electrical resonance
Refractive index of liquids: different methods
Refractive index of gases
Surface tension: different methods
Young's modulus: different methods
Viscosity: different methods

Other topics are listed below

Strength of materials; strength of wires; hardness of materials/adhesives; friction; fluid flow/Bernoulli principle; aerodynamics/airfoil lift; thermometry; thermal conductivity; thermal expansion/coefficients of expansion; resonance(mechanical, sound or electrical); musical instruments; lens aberrations; speed of sound; capacitance, permittivity; resistance and temperature; resistivity; Hall effect; motors; magnetic field around solenoid; a.c.(series and parallel circuits, phase); wind turbines; properties of the electron; radon levels; Plank's constant;
any other suitable topic of interest to the student.

5. EXEMPLAR: YOUNG'S MODULUS

The following pages contain an exemplar report involving two experimental methods for the determination of Young's modulus for steel. Full details of the readings and analysis for the second experiment are not included but notes are provided on the standard of the work involved.

In order to achieve the unit, the investigation must meet the stated performance criteria. This involves the day book, details of which are not provided. However Outcome 2 of the unit involves the readings, analysis and uncertainties. This material is required for both the unit and the course report.

Apart from the graph, page 6 (draft only), the exemplar only contains the material for the course report. Comments are provided which refer to both the unit and the course.

A title page contained the following statement.

Young's modulus for mild steel

The contents page was as follows.

CONTENTS

Summary

"Determination of Young's Modulus for Mild Steel"

The intention of this investigation is to confirm the theoretical value of Young's modulus of Elasticity for mild steel by means of different experiments.

The first was a straight forward but effective experiment which involved loading a beam of the metal and recording the sag caused.

Experiment two was slightly different as the period of vibration for a loaded cantilever of the appropriate metal was investigated and used to find the value for Young's modulus.

This page is not required for the unit.
If the summary is omitted for the course report, marks will be lost.
This summary does not really provide 'overall findings of the investigation'. An additional brief sentence would be desirable.
However a lengthy summary is not required. Initially a mark might be awarded and confirmed or reduced after the oral.

Introduction

Young's Modulus of a solid

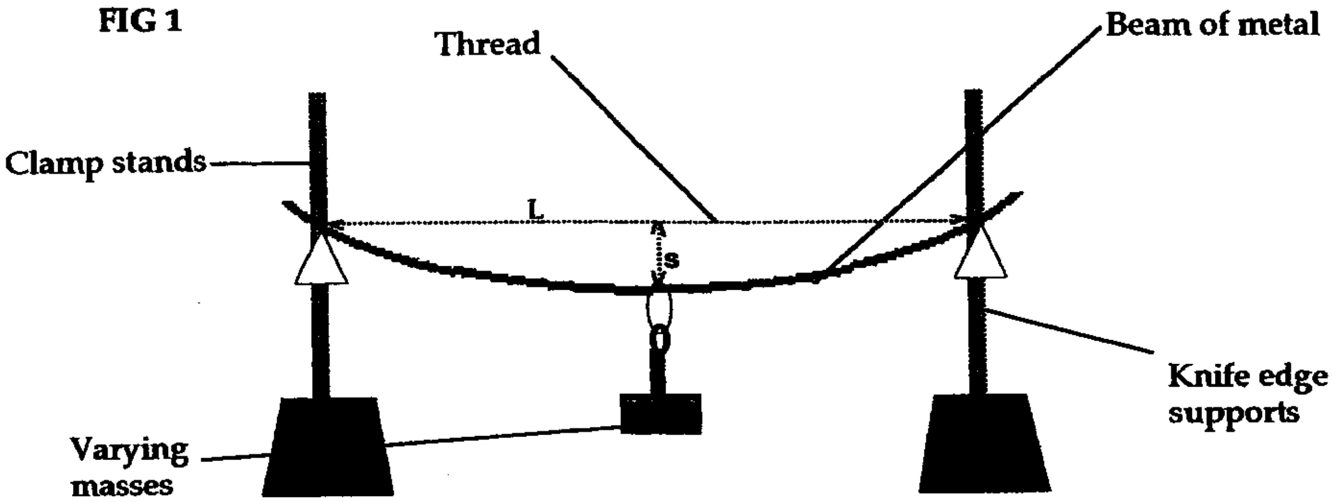
When a solid is subjected to forces it will often undergo changes in its shape. If the body recovers it original shape it is said to be elastic. Materials with this ability have an elastic constant, which is called Young's Modulus.

This page is not required for the unit. The day book may contain some notes.
Although full details of the theory are not required, this explanation is too brief. It is unlikely that any marks would be awarded for this introduction.

Experiment 1

The Apparatus was set up as shown in Fig 1.

FIG 1



The beam was placed on the supports roughly 80 cm apart. Masses were placed on the scale pan and the corresponding depressions (distance between thread and beam) were measured with a metal rule. After loading another set of readings was taken as the masses were gradually removed from the pan. Distance L was measured with a plastic metre stick and the thickness (d) and breadth (b) were measured with a micrometer.

This page is part of the course report only.
The day book could contain a rough sketch of the apparatus and some brief notes.

Results for Experiment 1 for mild steel

Load /g	Depression measurement / mm			Mean Sag/mm
	1st	2nd	3rd	
200	6	5	5	5.3
300	5	7	6	6.0
400	8	8	8	8.0
500	10	9	9	9.3
600	10	10	10	10.3
700	11	12	12	11.6
800	13	14	13	13.3
900	13	15	14	14.0
1000	15	16	16	15.7
1100	18	17	18	17.7
1200	19	18	18	18.3
1300	20	19	20	19.7

Uncertainties

Calibration uncertainty in plastic rule - 0.1 mm
Reading uncertainty rule - 0.5 mm
Random uncertainty = (largest reading - smallest reading)/no. of readings

Calibration uncertainty can be ignored as it is less than a third of the Reading uncertainty

Example of uncertainties calculated

Random uncertainty = (largest - smallest)/no. of readings
= (6-5)/3 = ± 0.33

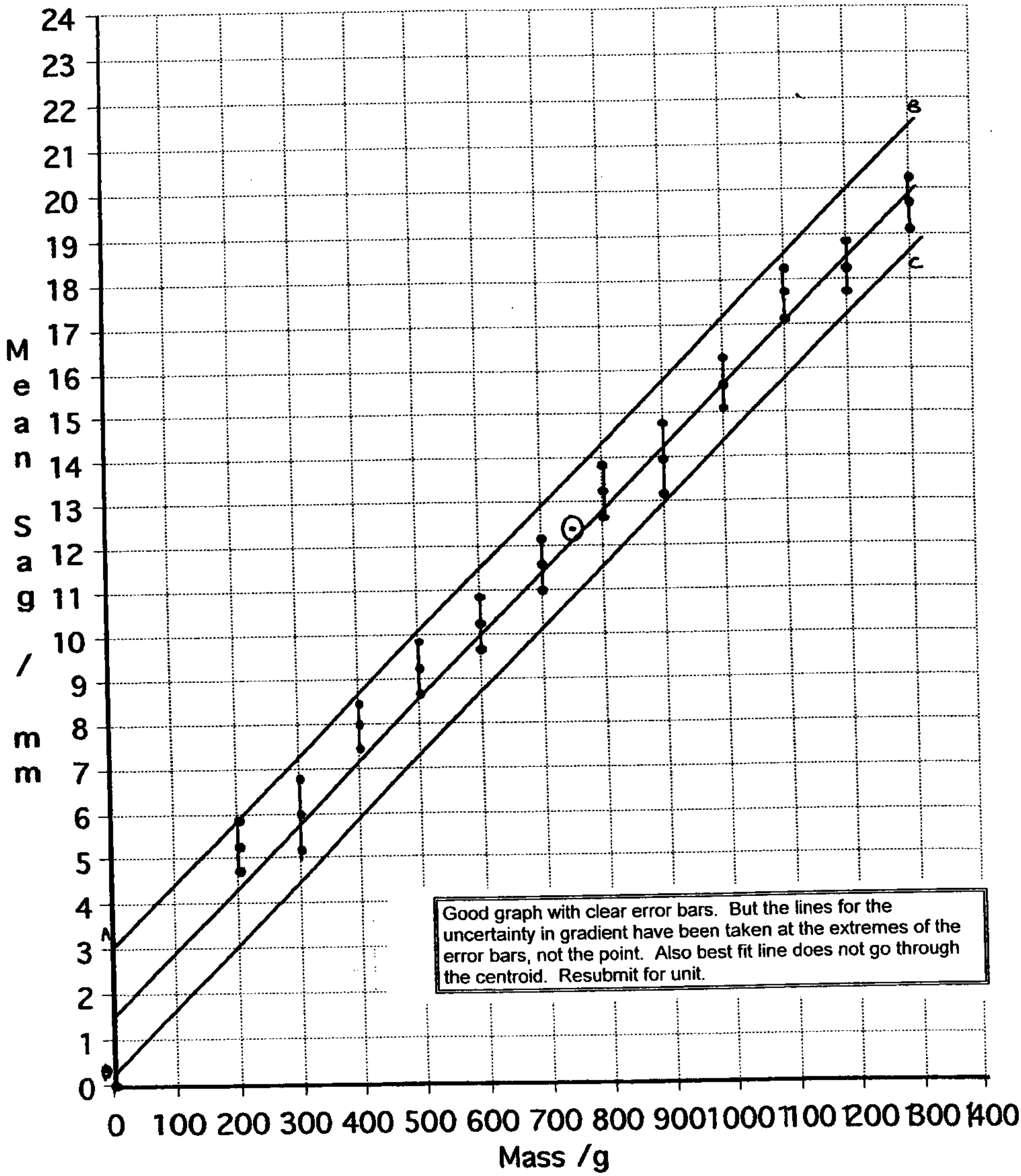
therefore total uncertainty = $\sqrt{0.33^2 + 0.5^2}$ = ± 0.6

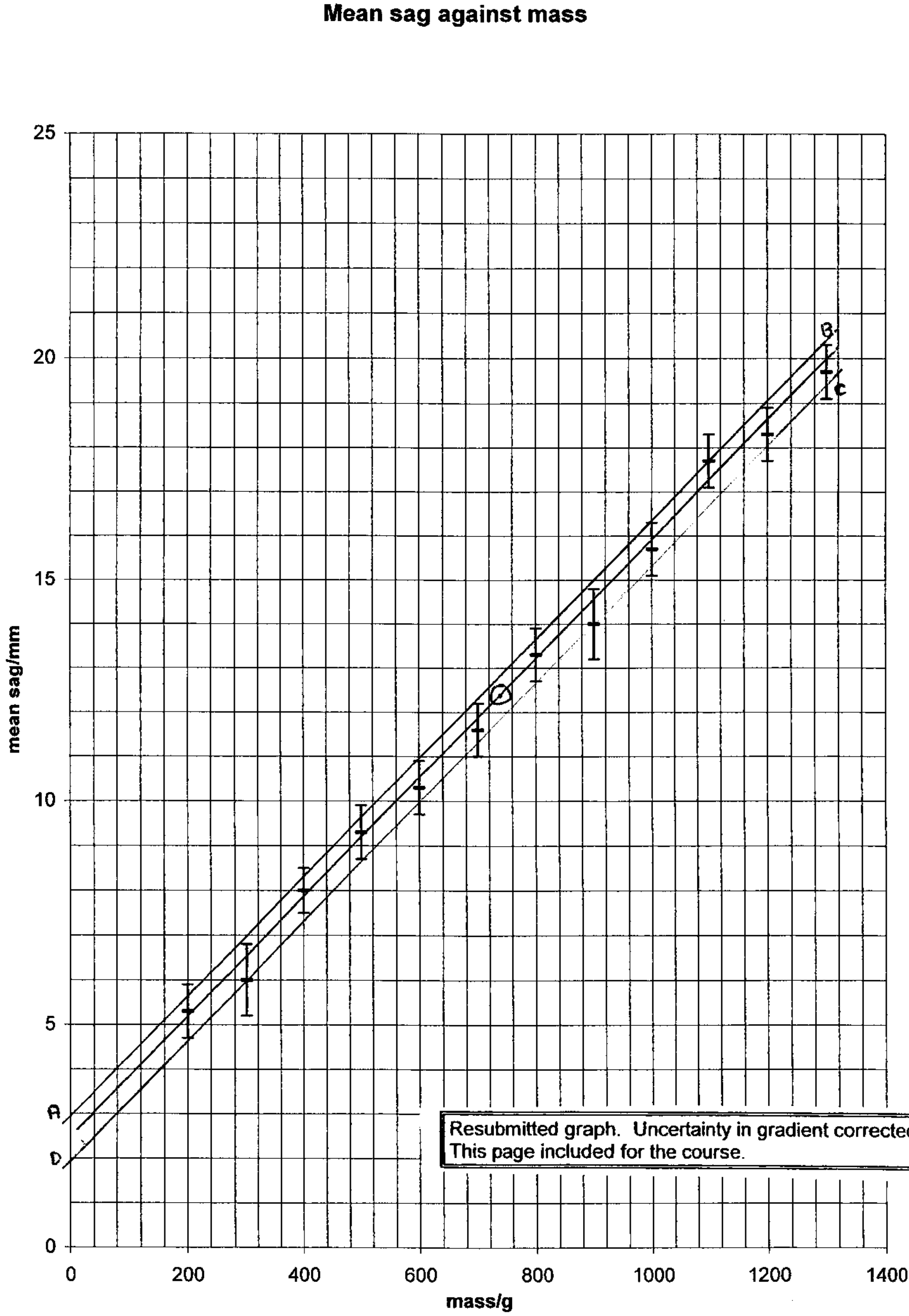
Load uncertainties are negligible.
(The mean values and uncertainties have been taken to one decimal place at this stage.)

LOAD / g	Mean Sag/mm
200	5.3 ± 0.6
300	6.0 ± 0.8
400	8.0 ± 0.5
500	9.3 ± 0.6
600	10.3 ± 0.6
700	11.6 ± 0.6
800	13.3 ± 0.6
900	14.0 ± 0.8
1000	15.7 ± 0.6
1100	17.7 ± 0.6
1200	18.3 ± 0.6
1300	19.7 ± 0.6

Table of readings is suitable for both unit and course. Three repeated readings is suitable for this experiment.
All uncertainties have been recorded. Combination of uncertainties clear. Good for both unit and course.

Graph of Mass against Mean Sag for Mild steel





Resubmitted graph. Uncertainty in gradient corrected.
This page included for the course.

Mild Steel calculations

Gradient of graph was determined by using the SLOPE function for the mean sag and mass data.
Gradient = 0.01335 m kg^{-1}

Uncertainty in gradient
This was calculated using the points A, B, C and D.
A (0, 3.0)
C (1300, 19.3) Gradient AC = 0.0125

B (1300, 20.4)
D (0, 2.0) Gradient BD = 0.0142

$$\text{uncertainty in gradient} = \frac{\text{gradient BD} - \text{gradientAC}}{2\sqrt{n-2}} = 0.00027 \text{ m kg}^{-1}$$

Mean sag / mass = s / M = 0.0134 ± 0.0003 = 0.0134 ± 2% (to three sig figs)

so M / s = 74.6 ± 2% kg m^{-1}

Good analysis for both unit and course requirements.

Values for the beam

Values for L measured: 79.9 80.8 80.3 80.5 80.3 80.7 cm
Mean value of L = 80.5 cm

$$\text{Random uncertainty in the mean} = \frac{\text{biggest reading - smallest reading}}{\text{no. of readings}} = \pm 0.2 \text{ cm}$$

Reading uncertainty = half a scale division = ± 0.5 mm
Calibration uncertainty = ± 0.1 mm
(These two can both be ignored as they are less than a third of the random uncertainty)

So L = 80.5 ± 0.2 cm = 0.805 ± 0.25% m

Values for breadth: 1.605 1.609 1.608 1.605 1.604 1.602 cm
Mean value of b = 1.606 cm
Random uncertainty in the mean = ± 0.0012 cm

Reading uncertainty = half a scale division = ± 0.0005 cm
Calibration uncertainty = ± 0.0002 cm (This can be ignored as it is less than a third of the random uncertainty)

Total uncertainty = $\sqrt{0.0005^2 \pm 0.0012^2} = \pm 0.0013$

So b = 1.606 ± 0.001 cm = 0.01606 ± 0.062% m

Values for thickness: 0.317 0.315 0.321 0.312 0.318 0.314 cm
Mean value of d = 0.316 cm
Random uncertainty in the mean = ± 0.002 cm

Reading uncertainty = half a scale division = ± 0.0005 cm
Calibration uncertainty = ± 0.0002 cm (Both these can be ignored, both are less than a third of the random uncertainty)

Total uncertainty = ± 0.002 cm

So d = 0.316 ± 0.002 = 0.316 ± 0.63% cm

$d^3 = 0.316^3 \pm 1.9\,\%\ \text{cm}^3$ (uncertainty = 0.63 x 3 giving 1.9 %)

$d^3 = 0.00316^3 \pm 1.9\,\%\ \text{m}^3$

> If only three readings for L, b and d had been taken, this would be adequate for the unit but marks would be lost for the course. The analysis is clear for both unit and course.

Values for the beam

Values for L measured: 79.9 80.8 80.3 80.5 80.3 80.7 cm
Mean value of L = 80.5 cm

$$\text{Random uncertainty in the mean} = \frac{\text{biggest reading - smallest reading}}{\text{no. of readings}} = \pm 0.2 \text{ cm}$$

Reading uncertainty = half a scale division = ± 0.5 mm
Calibration uncertainty = ± 0.1 mm
(These two can both be ignored as they are less than a third of the random uncertainty)

So L = 80.5 ± 0.2 cm = 0.805 ± 0.25% m

Values for breadth: 1.605 1.609 1.608 1.605 1.604 1.602 cm
Mean value of b = 1.606 cm
Random uncertainty in the mean = ± 0.0012 cm

Reading uncertainty = half a scale division = ± 0.0005 cm
Calibration uncertainty = ± 0.0002 cm (This can be ignored as it is less than a third of the random uncertainty)

Total uncertainty = $\sqrt{0.0005^2 \pm 0.0012^2} = \pm 0.0013$

So b = 1.606 ± 0.001 cm = 0.01606 ± 0.062% m

Values for thickness: 0.317 0.315 0.321 0.312 0.318 0.314 cm
Mean value of d = 0.316 cm
Random uncertainty in the mean = ± 0.002 cm

Reading uncertainty = half a scale division = ± 0.0005 cm
Calibration uncertainty = ± 0.0002 cm (Both these can be ignored, both are less than a third of the random uncertainty)

Total uncertainty = ± 0.002 cm

So d = 0.316 ± 0.002 = 0.316 ± 0.63% cm

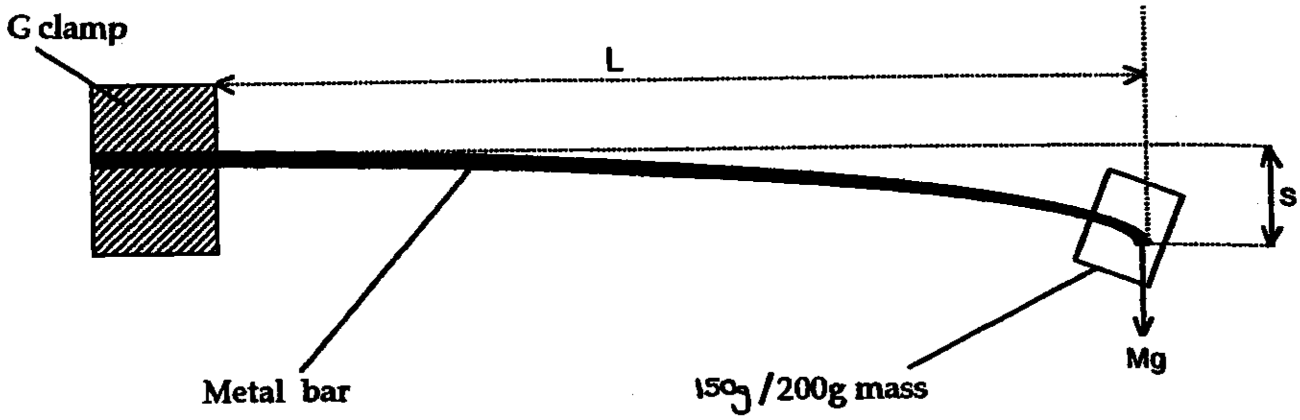
$d^3 = 0.316^3 \pm 1.9\%\ \text{cm}^3$ (uncertainty = 0.63 x 3 giving 1.9 %)

$d^3 = 0.00316^3 \pm 1.9\%\ \text{m}^3$

> If only three readings for L, b and d had been taken, this would be adequate for the unit but marks would be lost for the course. The analysis is clear for both unit and course.

Experiment 2

The apparatus was set up as shown in Fig 2



Using a G clamp the loaded beam was clamped tightly to a bench with length L projecting out. The bar was made to vibrate and the time for 20 vibrations was recorded with a digital stop watch. The procedure was repeated with varying lengths L which were measured carefully with a plastic metre stick.
The width (b) and depth (d) of the bar were measured with a micrometer.

This page is part of the course report only.
The day book could contain a rough sketch of the apparatus and some brief notes.

Readings, graphs and calculations for Experiment 2 are not included. It may be assumed that these were of a similar standard to that of the corrected version for Experiment 1.

Page 11: readings of time for 20 vibrations (repeated three times)
uncertainties in T^2 and L^3 tabulated (using a spreadsheet)

Page 12: Graph

Page 13: Determination of uncertainty in gradient of graph (similar to page 7)
Values for beam calculations (similar to page 8)

Page 14: Calculation of Young's Modulus using the equation

$$\frac{16\pi^2 M}{bd^3} \cdot \frac{L^3}{T^2}$$

comments made when certain uncertainties were ignored due to their size.

Pages 15 and 16 follow.

Conclusion

	Mild Steel
Theoretical value	2.1×10^{11} N m^{-2}
Experiment 1	$1.86 \times 10^{11} \pm 0.04 \times 10^{11}$ N m^{-2}
Experiment 2	$1.40 \times 10^{11} \pm 0.11 \times 10^{11}$ N m^{-2}

As can be seen from the above table the experimental results compare favourably with the accepted theoretical values.

In particular Experiment 1 appears to have been particularly successful.

Experiment 2 shows less accurate results. The main cause for this was due to the requirement of the experiment to measure the period of vibration using a stop watch. This means that human reaction time affected the results, particularly when the length decreased as the period was small and more difficult to record.

This page is not required for the unit. The day book may contain some notes.
This section should contain Conclusions and Evaluation.
The conclusion is minimal and the evaluation inadequate, very few marks would be awarded.

References

The theoretical proof for Experiment 1 can be found on page 43 of

A Laboratory Manual of Physics
Edward Arnold Ltd 1967
by Tyler F.

The theoretical proof for Experiment 2 can also be found in the above book on page 45

Introduction written with help from
Advanced Level Physics
Heinemann Educational Books 1978
ISBN 0 435 68610 0
by Nelkon and Parker

Acknowledgements

These have not been reproduced, but a clear list of names was given.

The references are rather minimal. The Introduction does not reflect the information provided by the second reference.

General comments on Young's modulus Investigation Report

This report on Young's modulus has comments relating to both the unit and the course.

For the course the report is externally marked using the marking scheme, shown on page 6. The marking scheme for the report has seven 'headings' (a) to (g) and each will be considered in turn with reference to this exemplar.

(a) Introduction

Two marks are available. The title and contents page and pages 1 and 2 are relevant. The explanation of Young's modulus is too brief and full marks will not be awarded. The assessor may bear this in mind for the oral, and marks may be slightly adjusted.

(b) Description of the procedures

Both descriptions are brief but very pertinent. In experiment 1 there is no statement of how the mass was measured. There is an implication that standard masses were used. It is worth noting that a clear concise description is required, not a lengthy rambling account. However it might be considered that these descriptions are just too brief. These points might require to be clarified during the oral and marks adjusted accordingly.

(c) Readings/analysis/results

Most of this section is a unit requirement to some extent. The readings and analysis are clearly laid out.

(d) Conclusion/evaluations

The conclusions on Young's page 15 are rather minimal. In particular no attempt is made to explain why the accepted value does not lie in the uncertainty range of the measured value. There is some evaluation of experiment 2 but none for experiment 1. Marks would be lost in this section.

(e) Presentation

The report is clear and concise with sufficient illustrations and graphs. The references are rather slim. Although most marks would be gained in this section it is unlikely that full marks would be awarded.

(f) Oral

The oral may include specific questions on the physics involved as well as general discussions on the investigation. During the oral the candidate has an opportunity to improve on the marks awarded under the headings (a) to (e). For example, the candidate may clarify that standard masses were used. Marks for this section might then be adjusted.

(g) Management of resources

This is awarded by the centre.

6 EXEMPLAR: CHARACTERISTICS OF MOS-TRANSISTOR

The following pages contain an exemplar report involving characteristics of MOS-transistors.

In order to achieve the unit, the investigation must meet the stated performance criteria. This involves the day book, details of which are not provided. However Outcome 2 of the unit involves the readings, analysis and uncertainties. This material is required for both the unit and the course report. Although for the course the presentation might be improved.

This exemplar only contains material for the course report. Comments are provided, on the report pages, which refer to both the unit and the course.

Title page contained the following statement.

Characteristics of MOS-transistor

Contents page was as follows.

Contents	**Page**

Summary

The aim of the project is to investigate some of the characteristics of the Motorola MOS-transistor chip from the 'Motorola Schools Chip Package'. On the I.C. are four n-type transistors and four p-type MOS-transistors of varying Gate Widths.

The MOS-transistor comprises of a sandwich of Metal, silicon diOxide and Silicon hence the name MOS. The top metal contact is called the Gate and the two contacts in the silicon are called the Source and Drain (see Appendix I). When a voltage is applied to the Gate a conductive channel forms between the Source and the Drain contacts allowing current to flow between the Source and Drain. The bigger the voltage the bigger the channel meaning a larger current is able to flow.

With this Integrated Circuit several characteristics of the MOS-transistor are investigated. Firstly the relationship between Gate Voltage and Drain Current for an n-type MOS-transistor is investigated. Some results are plotted on a graph giving a growth curve with an asymptote when the Gate Voltage = 4.54V. Now the relationship between Gate Voltage and Source Current for a p-type MOS-transistor is investigated. The results are plotted on another graph this time giving a decay curve with an asymptote when the Gate Voltage = 0.270V. The ON and Off Resistance of an n-type and a p-type MOS-transistor is investigated and the results show that the OFF Resistance is much higher than the ON Resistance.

This page is not part of the unit requirements.
The summary is required for the course. A clear summary

Introduction

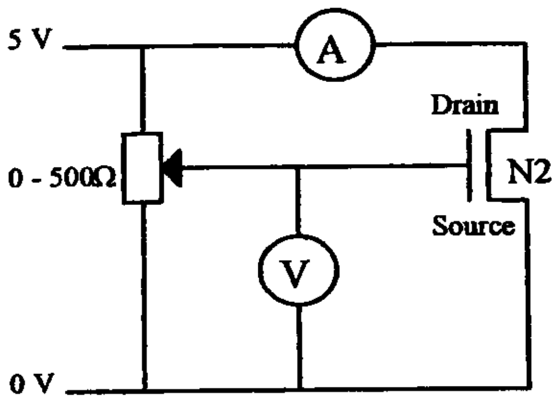
There are two main types of transistors, Bipolar and MOS. MOS technology account for 90% of the world market for semiconductors, in particular, almost all memories and microprocessors. It is easier to understand how a MOS-transistor works in comparison to the complexity of its Bipolar counterpart because it comprises of a basic sandwich of Metal, silicon diOxide and Silicon hence the name MOS. The top metal contact is called the Gate and the two contacts in the silicon are called the Source and Drain (see Appendix I). When a voltage is applied to the Gate a conductive channel forms between the Source and the Drain contacts allowing current to flow between the Source and Drain. The bigger the voltage the bigger the channel meaning a larger current is able to flow. There are two types of MOS transistor the n-type and the p-type. The n-type is ON when the Gate Voltage = 5V and the p-type is ON when the Gate Voltage = 0V. Both types can be operated by a positive or a negative Gate Voltage making them extremely versatile for use in all sorts of applications.

This page is not part of the unit requirements. The introduction is required for the course. A clear concise introduction.

The Relationship Between Gate Voltage and Drain Current for an n-type Transistor

Firstly It was decided to investigate the effect that varying the Gate Voltage would have on the Drain Current of the transistor. In order to vary the Gate Voltage satisfactorily and measure the Drain Current the circuit was set up as shown below in **Circuit Diagram 1**. With this circuit results were taken for a range of Gate Voltages from 0 to 5V. The results were recorded in **Table 1** and then plotted on **Graph 1** on the next page.

Circuit Diagram 1

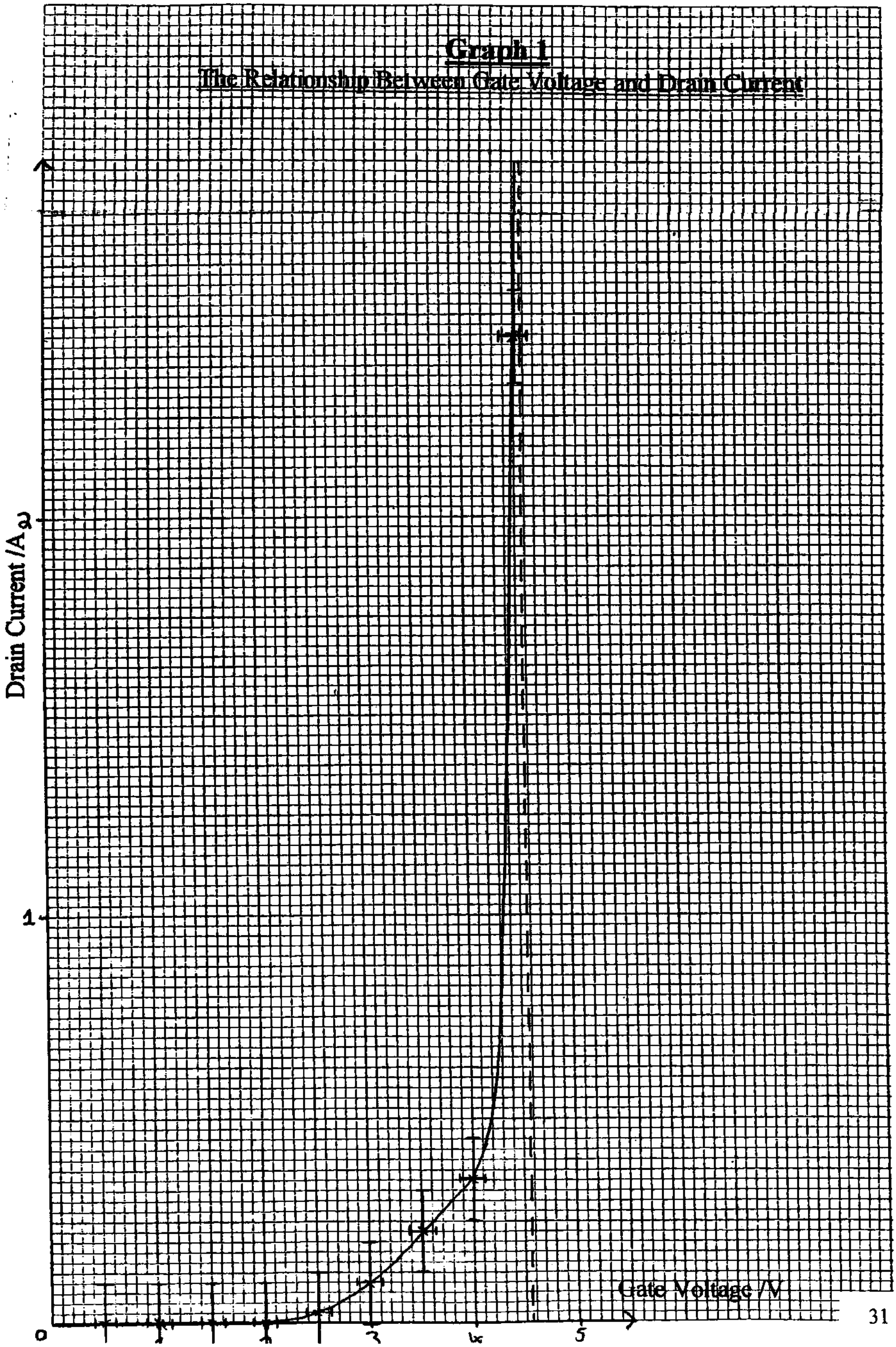


Procedure lacks detail and clarity. The words 'results were taken' is too vague. Were readings repeated? Marks would be lost for the course.
The procedure is not required for the unit, but the daybook is likely to contain appropriate notes

Table 1

Gate Voltage (v)	Uncertainty	Drain Current (A)	Uncertainty
0.5	± 0.10	0	± 0.10
1	± 0.11	0	± 0.10
1.5	± 0.11	0	± 0.10
2	± 0.11	0	± 0.10
2.5	± 0.11	0.02	± 0.10
3	± 0.11	0.10	± 0.10
3.5	± 0.12	0.22	± 0.10
4	± 0.12	0.35	± 0.10
4.5	± 0.12	2.45	± 0.11
4.54	± 0.12	∞	Not applicable

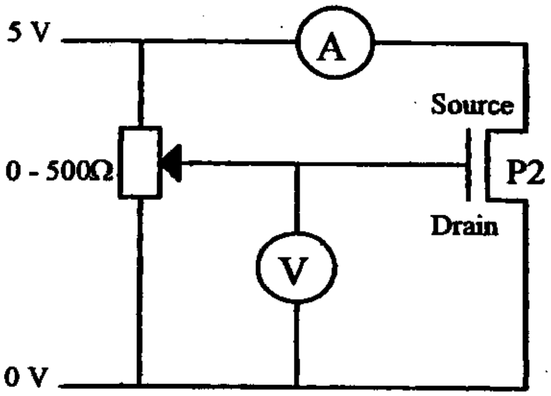
Mention that Gate Voltages should all be given to 2 significant figures. A reference to page 10 for the uncertainties is required. Adequate for unit. Table 1 and Graph 1 are required for the unit and course.


Graph 1
The Relationship Between Gate Voltage and Drain Current
Drain Current /A
Gate Voltage /V
0
1
2
3
4
5

The Relationship Between Gate Voltage and Source Current for a p-type Transistor

After investigating the effect that varying the Gate Voltage had on the Drain Current for an n-type transistor, the same effect was investigated for a p-type transistor. The circuit as shown in **Circuit Diagram 2** was set up, several results were taken for a range of Gate Voltages between 0 and 4V. The results were recorded in **Table 2** and then plotted them on **Graph 2** over the page.

Circuit Diagram 2

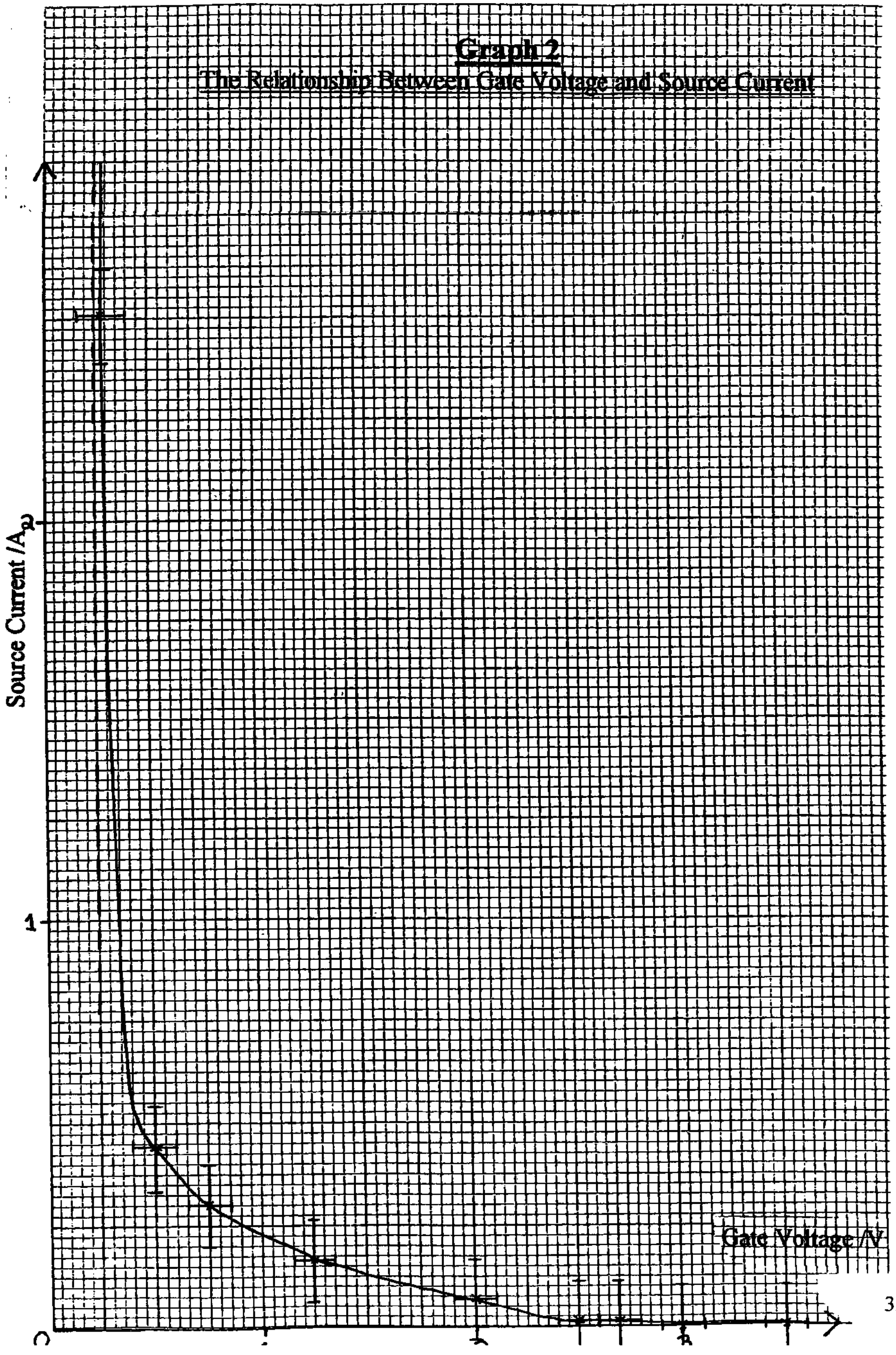


Procedure lacks detail and clarity as mentioned on page 4. If clear details had been given on page 4 then this might be adequate. Marks would be lost for the course. Some comment is required here, or elsewhere, why the gate voltage is now taken between the gate and drain.
The procedure is not required for the unit, but the daybook is likely to contain appropriate notes

Table 2

Gate Voltage (v)	Uncertainty	Source Current (A)	Uncertainty
0.270	± 0.10	∞	Not applicable
0.272	± 0.10	2.59	± 0.11
0.5	± 0.10	0.44	± 0.10
1	± 0.11	0.30	± 0.10
1.5	± 0.11	0.17	± 0.10
2	± 0.11	0.07	± 0.10
2.5	± 0.11	0.01	± 0.10
2.7	± 0.11	0.01	± 0.10
3	± 0.12	0	± 0.10
3.5	± 0.12	0	± 0.10

Mention that Gate Voltages should all be given to 2 or 3 significant figures. A reference to page 10 for the uncertainties is required. Adequate for unit. Table 2 and Graph 2 are required for the unit and course.


Graph 2
The Relationship Between Gate Voltage and Source Current
Source Current /A
Gate Voltage /V
2
1
0
3

Transistor ON/OFF Resistance

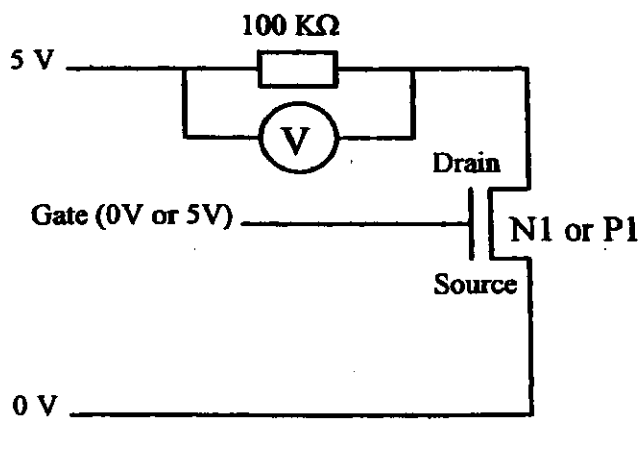
Next It was decided to investigate the transistor on and off resistance. This posed rather difficult as the resistance of the multimeter being used as an ohmmeter would affect the reading of a very high resistance as is the case when a transistor is off. An alternative method was found using the multimeter as a voltmeter and calculating the resistance of the transistor using the method shown below. The final circuit is below shown in **Circuit Diagram 3** and the results were recorded in **Table 3** over the page.

Transistor Resistance Calculation

$$V_{transistor} = V_{supply} - V_{resistor}$$
$$I_{resistor} = V_{resistor} \div R_{resistor}$$
$$I_{transistor} = I_{resistor}$$
$$R_{transistor} = V_{transistor} \div I_{transistor}$$

$$\Rightarrow \mathbf{R_{transistor} = [(V_{supply} - V_{resistor}) \times R_{resistor}] \div V_{resistor}}$$

Circuit Diagram 3



The procedure gives a good outline of the problems but does not clearly state what measurements were taken.
This page is not required for the unit, but the daybook is likely to contain notes.

Table 3

Transistor	Gate Voltage (V)	Uncertainty	Voltage in Resistor (V)	Uncertainty	Transistor Resistance (Ω)	Uncertainty
N1	0 (off)	± 0.10	0.01×10^{-3}	± 0.00	50.0×10^{9}	$\pm 50.4 \times 10^{9}$
N1	5 (on)	± 0.13	2.26	± 0.11	121.2×10^{3}	$\pm 1.1 \times 10^{3}$
P1	5 (off)	± 0.13	0.02×10^{-3}	± 0.00	25.0×10^{9}	$\pm 12.7 \times 10^{9}$
P1	0 (on)	± 0.10	2.78	± 0.11	79.9×10^{3}	$\pm 8.0 \times 10^{3}$

A note of the resistance of the resistor, (100 kΩ?) with its uncertainty should be given. Mention that voltage is 'across' a component not 'in' a component. Not a case for unit resubmission. Attention to significant figures is required in the final two columns.
Table 3 is required for both the unit and course.

Uncertainty Calculations

The uncertainties in the tables were calculated as follows:

Calculating the uncertainty for a reading of 2.5 V

Uncertainty in calibration of digital multimeters = ±0.5% of reading + 1 digit

Uncertainty = 2.5 x 0.5 ÷ 100
= 0.0125 + 1 in least significant digit
= 0.0125 + 0.1
= 0.1125

Uncertainty = ± 0.1125 V
= ± 0.11 V to 2 d.p.

Calculating uncertainty in Resistance calculation where R = 121.2 x 10^3

Uncertainty = $\sqrt{[(0.125^2) + (0.1113^2)]}$
= 0.16737
= 6.1%

Total uncertainty = $\sqrt{[(6.1^2) + (4.9^2) + (5^2)]}$
= 9.3%
= ± 1.1 x 10^3

This is an example of illustrating the uncertainty calculations, without undue repetition. However more explanation is required. The analysis is difficult to follow. A reference to the corresponding page for the readings would be helpful. For the resistance calculation a comment on the 0.125 and 0.1113 and a statement of the source of 4.9% and 5% is needed. The lack of units for resistance is unacceptable. The number of significant figures given is inappropriate, for example 2.5 V yet ± 0.11 V.
Marks would be lost for the course.

This might just be acceptable for unit requirements, since the day book may contain additional rough notes.

Conclusions

Gate Voltage and Drain Current for an n-type Transistor

From **Graph 1** it can be seen that the transistor switches on at 2.5V. The current then increases steadily until the Gate Voltage reaches 4.5V where the current increases exponentially from 0.35A to 2.45A and then 4.54V the current becomes infinitely high. This is caused as the channel between the Source and the Drain becomes broader (see Appendix I) allowing more current to flow. The transistor becomes saturated at 4.54V meaning that the current flowing between the Source and Drain becomes infinitely high.

Gate Voltage and Source Current for a p-type Transistor

From **Graph 2** it can be seen that a p-type transistor behaves in the opposite way from an n-type transistor. It switches on at 2.7V and the current increases steadily as the Gate Voltage decreases. At 0.272V the current increases exponentially from 0.44A to 2.59A and then to infinite when the Gate Voltage drops to 0.270V. This means that the transistor is saturated at 0.270V and that the current between the Source and Drain becomes infinitely high.

Transistor ON/OFF Resistance

The results show that when a MOS-transistor is OFF its Resistance is very high, as was to be expected because no channel is formed between the Source and the Drain contacts preventing current from flowing. The results also show that an n-type MOS-transistors ON when the Gate Voltage is 5V whereas a p-type is ON when the Gate Voltage is 0V proving again that an n-type MOS-transistor is the opposite from a p-type MOS-transistor.

> Conclusions required for the course only, although the daybook may contain some notes. The use of the word 'exponentially' requires comment. This might be questioned in the oral.
>
> An evaluation is required. Marks would be lost for the course.

Acknowledgements

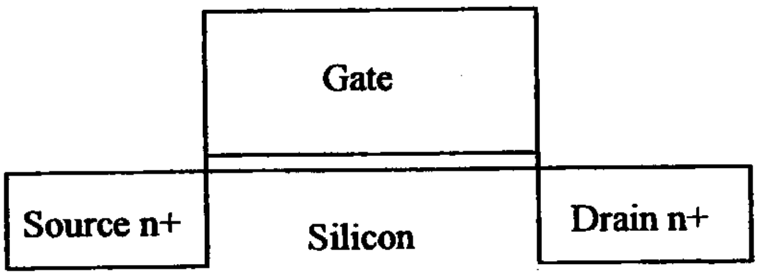
I am grateful to the following who provided help and encouragement during this investigation.

XX	Principal teacher of Physics ZZ High School
YY	Physics teacher ZZ High School
TT	Technician at ZZ High School

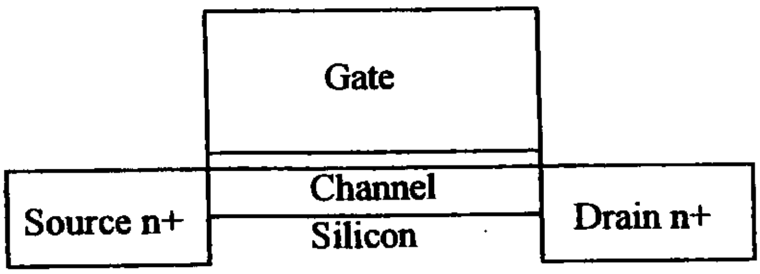
A clear section on references is required. This could refer to the Appendix. Marks would be lost for the course.

Appendix I

Transistor off



Transistor on



Schools Chip	Text
MOS Transistors	MOS Transistor Chip

Components List

N1 n-type transistor
50 × 100μm
P1 p-type transistor
100 × 100μm

N2 n-type transistor
100 × 100μm
P2 p-type transistor
200 × 100μm

N3 n-type transistor
200 × 100μm
P3 p-type transistor
400 × 100μm

N4 n-type transistor
400 × 100μm
P4 p-type transistor
800 × 100μm

> P1 and N2 seem similar yet they were not used in any comparison. This could be commented on in an evaluation.
>
> The origin of this extract should be included in the references.

General comments on Characteristics of MOS-transistor

This report on characteristics of MOS-transistor has comments relating to both the unit and the course.

For the course the report is externally marked using the marking scheme, shown on page 6. The marking scheme for the report has seven 'headings' (a) to (g) and each will be considered in turn with reference to this exemplar.

(a) Introduction

Two marks are available. The summary and introduction are of a reasonable length and detail.

(b) Description of the procedures

The descriptions on page 4 and 7 are too brief. A clear concise description is required, however these descriptions are inadequate. The report tends to give the impression that only minimal effort has been required. The discussions on page 8 are useful but clear statements of the measurements taken are required. Marks awarded in this section would be low. These aspects might be clarified during the oral and marks may be adjusted slightly.

(c) Readings/analysis/results

The comment on pages 4, 6, 9 and 10 illustrate aspects which would lose marks for the course. The apparent minimal extent of the experimental readings taken would be reflected in the marks awarded. Readings were not repeated and no comment on this is made. The apparent disregard for significant figures is of concern, for example a gate voltage of 1 V with an uncertainty of 0.11 (V?) with no explanation is poor.

(d) Conclusion/evaluations

The conclusions on page 11 are reasonably clear. There is no evaluation of the experiments. No comment has been made on any of the calculated uncertainties. Are these of any importance? Marks would be lost in this section.

(e) Presentation

The report is clear and concise with adequate illustrations and graphs. The references section has been omitted and marks would be lost.

(f) Oral

The oral may include specific questions on the physics involved and analysis of uncertainties as well as general discussions on the investigation. During the oral the candidate has an opportunity to improve on the marks awarded under the headings (a) to (e). For example, the statement that the 'same effect' is investigated for a p-type transistor in circuit 2 could be clarified by the student to the assessor. Similarly the candidate might justify the use of the word 'exponentially' in the conclusion. Some adjustment of marks may be possible.

(g) Management of resources

This is awarded by the centre.

7 EXEMPLAR: FLUID FLOW RATE IN CAPILLARY TUBES

The following pages contain an exemplar report involving fluid flow rate in capillary tubes.

In order to achieve the unit, the investigation must meet the stated performance criteria. This involves the day book, details of which are not provided. However Outcome 2 of the unit involves the readings, analysis and uncertainties. This material is required for both the unit and the course report.

This exemplar only contains material for the course report. Comments are provided which refer to both the unit and the course.

This example was taken from a CSYS project, where the word 'error' was used as opposed to 'uncertainty'. The AH documentation uses the word uncertainty, and it is likely that use of this word will become usual.

A title page was provided as follows.

Fluid Flow Rate in Capillary Tubes

Contents

[Note: Appendix B has NOT been reproduced here.
A good set of references was provided.
The acknowledgements section was good]

Note This report was written when the word 'error' was used instead of the word 'uncertainty' for numerical uncertainties.
In the AH course the word uncertainty is used in the documentation.

List Of Illustrations, Tables Of Results and Graphs

Illustrations

Tables

List Of Illustrations, Tables Of Results and Graphs (cont.)

Graphs – Appendix A

1. Introduction

In this project I will be investigating how certain factors affect the flow rate of water through glass capillary tubes. The factors to be investigated are the radius of the tube and the length of the tube.

These factors are related in Poiseuille's formula:

$$V = \frac{\pi p r^4}{8 \eta l}$$

Where V is the volume of liquid passing per second, p is the pressure difference, l is the length of the tube, r is the radius of the tube and η is the coefficient of viscosity. The pressure difference is equal to the pressure exerted by the water in the header tank from which the water is flowing, since atmospheric pressure acts on both ends of the tube. The situation in the length of capillary tube is shown below:

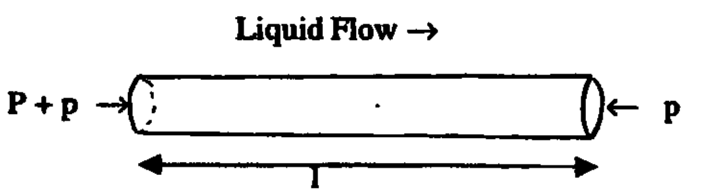


Figure 1

Where l is length of tube, P is pressure due to fluid head and p is atmospheric pressure. The pressure due to the head can be calculated using $P = \rho g h$ where ρ is the density of water, g is the gravitational field strength and h is the pressure head (the height difference between where the water is flowing from and the start of the capillary tube).

The coefficient of viscosity of a fluid is a measure of its resistance to motion. It is defined as the tangential force per unit area of fluid which resists the motion of one layer over another when the velocity gradient between the layers is unity, and is calculated by dividing the tangential stress by the velocity gradient. In this project I will also use Poiseuille's formula to calculate a value for the coefficient of viscosity of water from my experimental results. The theoretical value for this is 1.0×10^{-3}.

According to Poiseuille's formula the theoretical results for this investigation are that the flow rate will vary:

a) in direct proportion to the pressure difference, if radius and length are constant,
b) in direct proportion to the radius to the power of four, if pressure and length are constant, and
c) in inverse proportion to the length of the tube, if pressure and radius are constant.

The experiments carried out as part of this project will aim to demonstrate a) and b).

> This page is not part of the unit requirements. Notes may have been recorded in the daybook. This is a good introduction covering the relevant theory. A unit is required for the theoretical value of η.
> A separate summary has not been provided. The first paragraph and last sentence provide some information. The student could be advised to provide a separate summary to ensure marks are not lost for this section.

2. Apparatus

Complete Apparatus

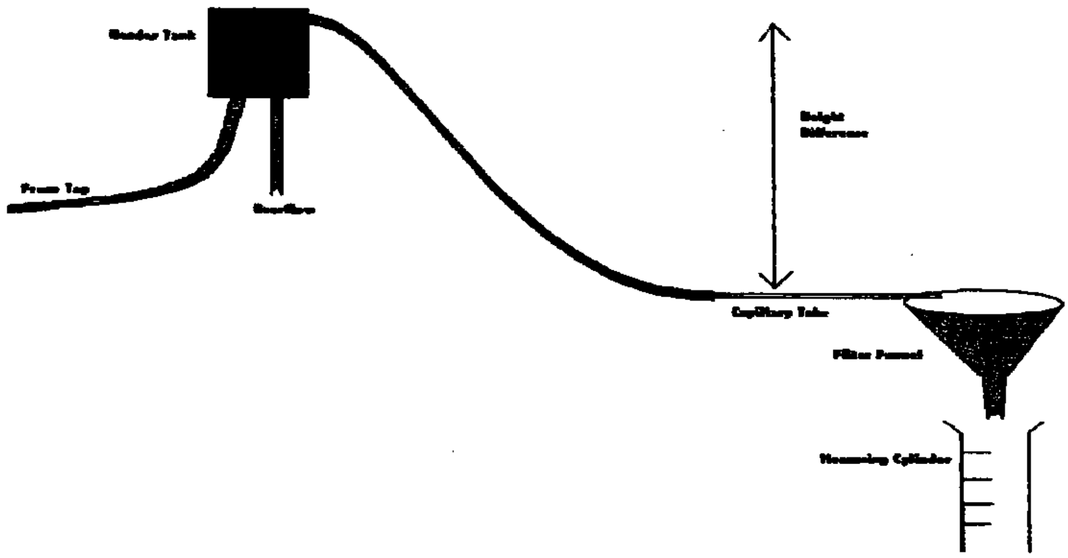


Figure 2

Header Tank

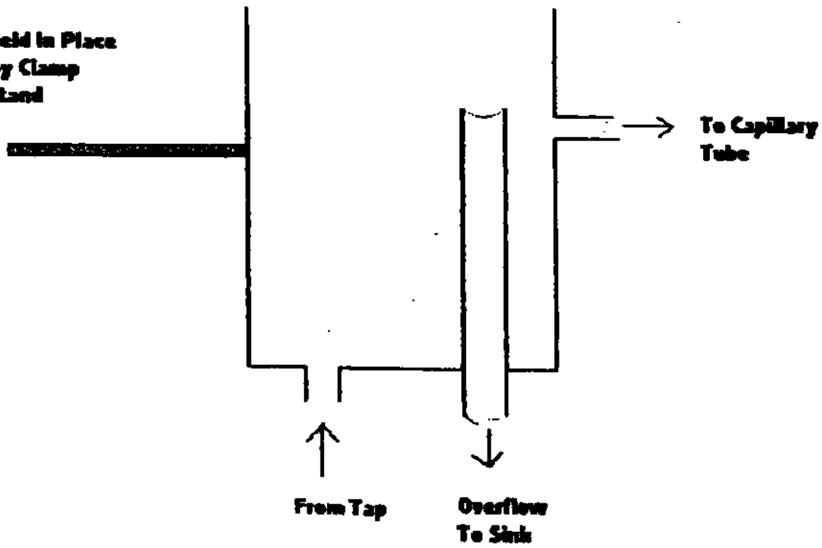


Figure 3

The main requirement of the equipment is to provide a steady flow of water to the capillary tubes during each experiment. A header tank, shown in Figure 3 above, is used to provide the supply of water. As long as the water entering the tank from the tap is not too powerful the level of water cannot rise above the top of the overflow pipe. This means that by adjusting the flow of water into the header tank, the level can be kept at the top of the overflow, and hence the pressure at the capillary tube due to the head of fluid will be constant.

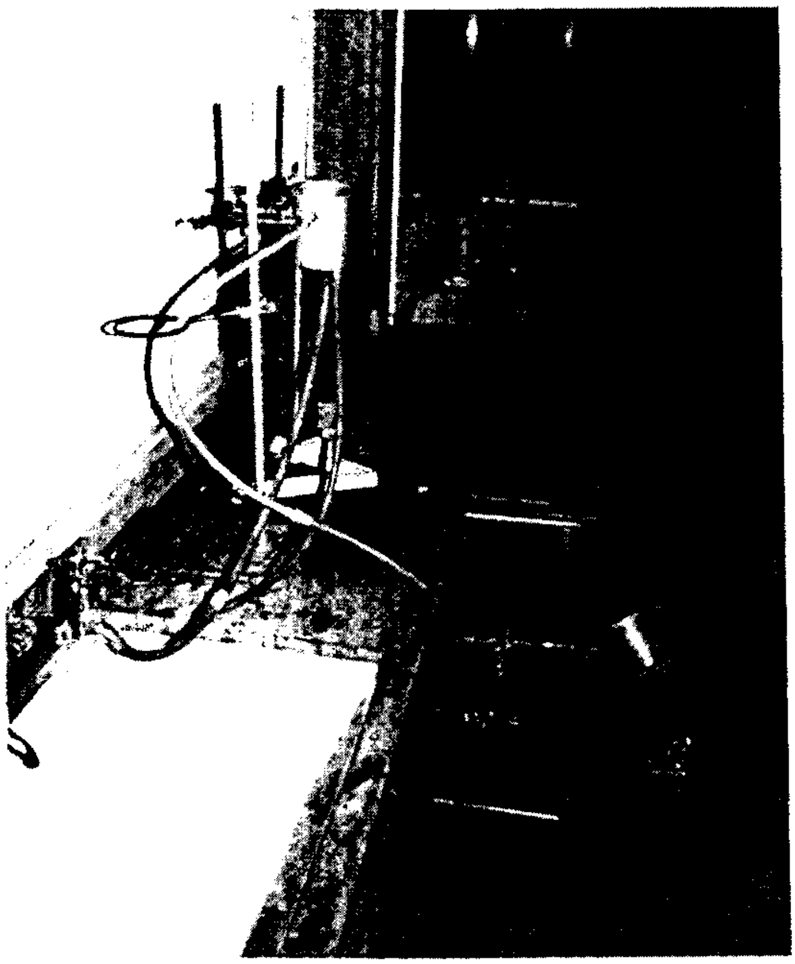


Figure 4

3. Method

Preparation - Measuring the Radius Of the Capillary Tubes

Glass capillary tubes of different radii were selected and a glass cutter was used to cut them to as equal lengths as possible so that the flow through these tubes could be compared in order to determine the effect on the flow rate of the radius if the tube. Three different lengths of the same radius tube were cut so that the effect of the length of the tube could be found.
The length of the tubes was then measured to the nearest millimetre using a steel ruler. A travelling microscope was used to measure the radii of the tubes by looking at the cross section of the tubes, recording the position of the microscope at either side of the bore to find the diameter and then halving this to find the radius.
A header tank was set up held in a constant position by clamp stands and connected to each capillary tube, also held in place by clamp stands, by rubber tubing. The vertical distance between the level in the header tank from which the water would flow through the rubber tubing and the start of the capillary tube was then measured using an accurate metre stick.

Experiment 1 - Effect Of Radius Of Tube On Flow Rate

The length of tube with the smallest radius was supported in a clamp stand so that it was perfectly horizontal and was connected to the header tank. The flow into the header tank was adjusted until the water was flowing through the tube with a steady flow. The flow from the tube was then switched from being collected in a large beaker to being collected in a measuring cylinder and at this point a timer was started. The flow from the tube was collected in the measuring cylinder for an accurately measured period of time after which it was switched back to flowing into a beaker. The volume of water in the measuring cylinder was recorded and divided by the time to find the flow rate, then the process was repeated five times with the same tube and an average of the results was taken. The whole process was then repeated with each of the other lengths of tube with the same length but different diameters.

Experiment 2 - Effect Of Length Of Tube On Flow Rate

The three tubes with the same radius and different lengths were taken and the one with the second smallest length was attached to the header tank. The flow rate of water through this tube was then measured in the same way as the first experiment. The flow rate through the longest of the tubes was then measured. No new measurements needed to be taken for the shortest of the three tubes since it had already been used in the previous experiment.

This page is not part of the unit requirements, but notes are likely to have been made in the daybook.
The procedure is required for the course.

This page is required for both the unit and course.
The unit for flow rate should be $cm^3 s^{-1}$ since 'sec' is not a standard abbreviation. Not a reason for unit resubmission. Good display of readings.

4. Results

Measuring the Radius Of the Capillary Tubes

Table 1

Tube	Initial Position Of Microscope	Final Position Of Microscope	Diameter Of Tube (cm)	Radius Of Tube (cm)
Smallest	7.452	7.363	0.089	0.0445
2nd Smallest	6.249	6.359	0.110	0.0550
3rd Smallest	6.359	6.564	0.205	0.1025
3rd Largest	7.210	7.452	0.242	0.1210
2nd Largest	7.691	7.210	0.481	0.2405
Largest	7.850	7.104	0.746	0.3730

Error on positions of microscope = ±0.0005 cm.
Error on diameter and on radius = ±0.001 cm.

Experiment 1 - Effect Of Radius Of Tubes On Fluid Flow

For all the tubes used here the header tank was 62.0 cm ± 0.5 cm above the start of the capillary tube and all the tubes were of length 11.80 cm ± 0.05 cm.

Table 2

Radius Of Tube (cm)	Time (seconds)	Volumes Of Water Collected (cm^3)	Average Volume Of Water Collected(cm^3)	Flow Rate (cm^3 per sec.)
0.0445	600	86.5 87 87 86 84 88.5 83 90.5 83 84	86	0.143
0.0550	600	212 218 204 207 221 223 211 215 204 206	212	0.3535
0.1025	60	256 268 252 264 262 254 254 252 250 255	256	4.2783
0.1210	60	499 500 498 502 499 496 495 498 498 499	498	8.3067
0.2405	15	467 468 465 470 463 462 463 470 469 465	466	31.08
0.3730	10	351 353 349 347 346 345 353 354 343 349	349	34.9

Time is the length of time over which fluid is collected.
Error on time = ±0.2 seconds.
Reading error on volume collected for the smallest tube (different since a smaller measuring cylinder could be used) = ±0.5 cm^3

Uncertainty on readings from 0.0445 cm radius tube = ± (90.5-83) / 10
= ± 0.75 cm^3

Total error on average volume from 0.0445 cm tube = $\pm\sqrt{(0.75^2 + 0.5^2)}$
= ± 0.8125 cm^3
Rounded up to the nearest 0.1 cm^3 = ±0.9 cm^3
Fractional error in time = 0.2 / 600 = 0.0003 This error is small enough to be negligible, and hence the value of the fractional error for the flow rate will be the same as that of the fractional error for the volume.
Fractional error = 0.9 / 86 = 0.0105
In terms of flow rate this error = 0.0105 x 0.143 = ± 0.00150 cm^3 per second.
Rounding up, error = ± 0.002 cm^3 per second.
Flow rate for 0.0445 cm radius tube = 0.143 ± 0.002 cm^3 per second.

Reading error on volume collected from five larger tubes = ± 1 cm^3

Uncertainty on readings from 0.055 cm radius tube = ± (223-204) / 10
= ± 1.9 cm^3
Total error on average volume from 0.055 cm tube = $\pm\sqrt{(1.9^2 + 1^2)}$
= ± 2.15 cm^3
Rounded up to nearest 0.1 cm^3 = ± 2.2 cm^3
Fractional error on time = 0.2 / 600 = 0.000333
This error is small enough to be negligible and hence the value of the fractional error for the flow rate will be the same as the fractional error for the volume.
Fractional error = 2.2 / 212. = 0.0104
In terms of flow rate error = 0.0104 x 0.3535 = ± 0.0037 cm^3 per second.
Rounding up, error = ± 0.004 cm^3 per second.
Flow rate for 0.0550 cm radius tube = 0.354 ± 0.004 cm^3 per second.

Uncertainty on readings from 0.1025 cm radius tube = ± (268-250) / 10
= ± 1.8 cm^3
Total error on average volume for 0.1025 cm tube = $\pm\sqrt{(1.8^2 + 1^2)}$
= ±2.06 cm^3
Rounded up to nearest 0.1 = ± 2.1 cm^3
Fractional error on time = 0.2 / 60 = 0.0033
Fractional error on volume = 2.1 / 256 = 0.0082
Fractional error for the flow rate = $\sqrt{(0.0033^2 + 0.0082^2)}$ = 0.0088
In terms of flow rate error = 0.0088 x 4.2783 = ± 0.038 cm^3 per second
Rounding up, error = ± 0.04 cm^3 per second.
Flow rate for 0.1025 cm radius tube = 4.28 ± 0.04 cm^3 per second.

Uncertainty on readings from 0.1210 cm radius tube = ± (502-495) / 10
= ± 0.7 cm^3
Total error on average volume from 0.1210 cm tube = ± $\sqrt{(0.7^2 + 1^2)}$
= ± 1.2207 cm^3
Rounded up to nearest 0.1 cm^3 = ± 1.3 cm^3
Fractional error on time = 0.2 / 60 = 0.0033
Fractional error on volume = 1.3 / 498 = 0.0026
Fractional error for the flow rate = $\sqrt{(0.0033^2 + 0.0026^2)}$ = 0.0042
In terms of flow rate error = 0.0042 x 8.3067 = 0.035 cm^3 per second
Rounding up, error = ± 0.04 cm^3 per second.
Flow rate for 0.1210 cm radius tube = 8.31 ± 0.04 cm^3 per second.

Uncertainty on readings from 0.2405 cm radius tube = ± (470 -462) / 10
= ± 0.8 cm^3
Total error on average volume from 0.2405 cm tube = ± $(0.8^2 + 1^2)$
= ± 1.28 cm^3
Rounded up to nearest 0.1 cm^3 = ± 1.3 cm^3
Fractional error on time = 0.2 / 15 = 0.013
Fractional error on volume = 1.3 / 466 = 0.0028
Fractional error for flow rate = $\sqrt{(0.013^2 + 0.0028^2)}$ = 0.0133
Error in terms of flow rate = 31.08 x 0.0133 = ± 0.413 cm^3 per second.
Rounding up, error = ± 0.5 cm^3 per second.
Flow rate for 0.2405 cm radius tube = 31.1 ± 0.5 cm^3 per second.

Uncertainty on readings from 0.3730 cm radius tube = ± (354-343) / 10
= ± 1.1 cm^3
Total error on average volume from 0.3730 cm tube = ± $(1.1^2 + 1^2)$
= ± 1.487 cm^3
Rounded up to nearest 0.1 cm^3 = ± 1.5cm^3
Fractional error on time = 0.2 / 10 = 0.02
Fractional error on volume = 1.5 / 349 = 0.0043
Fractional error on flow rate = $\sqrt{(0.02^2 + 0.0043^2)}$ = 0.0205
Error in terms of flow rate = 0.0205 x 34.9 = ± 0.8725 cm^3 per second.
Rounding up, error = ± 0.9 cm^3 per second.
Flow rate for 0.3730 cm radius tube = 34.9 ± 0.9 cm^3 per second.

<u>Table 3</u>

Radius Of Tube (cm)	$Radius^4$	Flow Rate	Flow rate / $Radius^4$
0.0445	0.00000392	0.143	36480
0.0550	0.00000915	0.354	38689
0.1025	0.000110	4.28	38909
0.1210	0.000214	8.31	38832
0.2405	0.00335	31.1	9284
0.3730	0.0194	34.9	1799

Experiment 2 - Effect Of Length Of Tubes On Fluid Flow

Table 4

Length Of Tube (cm)	Time (sec.)	Volumes Recorded (cm^3)	Average Volume Collected (cm^3)	Flow Rate (cm^3 per sec.)
11.80	60	499 500 498 502 499 500 498 501 494 501	499.2	8.32
17.55	60	331 336 338 329 328 327 339 329 336 334	332.7	5.545
21.56	60	269 275 268 272 274 265 274 274 268 267	270.6	4.51

Error in all time readings = ± 0.2 seconds.
Error in all lengths = ± 0.05 cm.
Reading error on the volume collected for all three lengths of tube = ± 1 cm^3.
From calculations above, **flow rate for tube of length 11.8 cm = 8.31 ± 0.04 cm^3 per second.**

Uncertainty on readings from tube of length 17.55 cm = ±(339-327) / 10
= ± 1.2 cm^3
Total error on average volume from 17.55 cm tube = ± $\sqrt{(1.2^2 + 1^2)}$
= ± 1.562 cm^3
Rounded up to nearest 0.1 cm^3 = ± 1.6 cm^3
Fractional error in time = 0.2 / 60 = 0.0033
Fractional error in volume = 1.6 / 332.7 = 0.0048
Fractional error in flow rate = $\sqrt{(0.0033^2 + 0.0048^2)}$ = 0.0063
Error in terms of flow rate = ± 0.0063 x 5.545 = ± 0.035 cm^3 per second.
Rounding up, error = ± 0.04 cm^3 per second.
Flow rate for tube of length 17.55 cm = 5.55 ± 0.04 cm^3 per second.

Uncertainty on readings from tube of length 21.56 cm = ± (275-265) / 10
= ± 1 cm^3
Total error on average volume from 21.56 cm tube = ±$\sqrt{(1^2 + 1^2)}$ = ± 1.414 cm^3
Rounded up to nearest 0.1 cm^3 = ± 1.5 cm^3
Fractional error in time = 0.0033 (as above)
Fractional error in volume = 1.5 / 270.6 = 0.0055
Fractional error in flow rate = $\sqrt{(0.0033^2 + 0.0055^2)}$ = 0.0064
Error in terms of fluid flow = ± 0.0064 x 4.51 = 0.0289 cm^3 per second.
Rounding up, error = ± 0.03 cm^3 per second.
Flow rate for tube of length 21.56 cm = 4.51 ± 0.03 cm^3 per second

Comments on the analysis on pages 9 and 10 are given below.

The uncertainties are required for both the unit and the course. The analysis here is satisfactory.

Although the report consistently and clearly states that the 'total error on average volume' is rounded **up** to the nearest 0.1 cm^3, this is not usual practice. A figure of 0.8125 would be expected to be rounded to 0.8 not 0.9. This point might be discussed during the oral examination.

However there is no need to repeat the details. A full analysis could have been given for the first tube size only. There is a great advantage in using a spreadsheet to calculate the information. This avoids time spent in typing out the analysis. An example is given below using these results.

Experiment 1

Reading error on time = ± 0.2 s
Reading error on volume for smallest tube = ± 0.5 cm^3
Reading error on volume for five largest tubes = ± 1 cm^3

Radius of tube used /cm	random error in volume /cm^3	total error on average volume /cm^3	fractional error in volume	fractional error in time	comment	total fractional error	absolute error in flow rate /(cm^3/s)	flow rate /(cm^3/s)
0.0445	0.75	0.9	0.0105	0.0003	neglect 0.0003	0.0105	0.002	0.143
0.0550	1.9	2.2	0.0104	0.00033	neglect 0.00033	0.0104	0.004	0.354
0.1025	1.8	2.1	0.0082	0.0033	combine errors	0.0088	0.04	4.28
0.1210	0.7	1.3	0.0026	0.0033	combine errors	0.0042	0.04	8.31
0.2405	0.8	1.3	0.0028	0.013	combine errors	0.0133	0.5	31.1
0.3730	1.1	1.5	0.0043	0.02	combine errors	0.8725	0.9	34.9

5. Evaluation

Throughout this project the errors involved have come mainly from the reading errors involved in the equipment that was used rather than from uncertainties, since the results obtained were fairly consistent. In measuring the tubes the error was very small due to the accuracy of the vernier scale on the travelling microscope. Accuracy in timing was reasonably good since all that was involved was moving the measuring cylinder and replacing it with another container after the designated time. The major reading errors involved in the project were due to the relative inaccuracy of the measuring cylinder used and of the metre stick used to measure the height of the header tank in order to determine the pressure change. Use of more accurate equipment would improve the reading errors in both situations but the errors that did arise had little bearing on the results recorded in the project. Another potential source of error is the possibility of the height, and hence pressure differences, not being kept perfectly constant throughout Experiments 1 and 2 (the effect of the length of tube and the effect of the radius of tube). The fact that the friction in the rubber tubing may have slowed the flow of the water down is unimportant since the length of rubber tubing was kept constant for all the readings taken in the three experiments and hence the effect was constant for all cases. In general the only way in which the accuracy of this experiment could have been improved would be through the use of more sophisticated and more accurate measuring equipment.

> This page provides a good evaluation, with due consideration of the apparatus.
>
> The following page has a good conclusion.

> In the Introduction on page 4, it is mentioned that a value for the viscosity will be calculated. This has not been done.
> Nor is there any record of the height of the pressure head being measured as mentioned on page 7. It may be that there was insufficient time. However some note in the report would be expected.
> This point is likely to be introduced in the oral by the external assessor.

6. Conclusions

The results of the experiments were plotted on a number of graphs which are included in Appendix A.

Effect Of Radius Of Tube On Flow Rate

The results from Experiment 1 were plotted on Graphs 1 and 2.
Graph 1 shows flow rate plotted against the radius of tube.
Graph 2 shows flow rate plotted against the radius of tube to the power of four. The results for the two largest radius tubes have not been plotted on Graph 2 because of the scale of the y-axis.

Graph 2 shows that when the smaller radii taken to the power of four are plotted against the flow rate a straight line can be drawn through the origin. This shows that the flow rate (v) is directly proportional to radius of the tube to the power of four (r^4) when the fluid pressure and length are constant.
From the results shown in Table 2 it can be seen that if it were possible to plot the larger radii to the power of four on the same axis as the smaller ones then the line would flatten out rather than retaining a constant gradient. This can be accounted for by assuming that at this stage the flow is becoming turbulent. Turbulence is when the liquid becomes churned up and the streamlines stop being parallel and straight, as they are in constant flow. Reynold's number is used in defining the point at which flow becomes turbulent. When the value of Reynold's number is greater than a certain figure the flow becomes turbulent, and this number is defined by the following equation:

$$Re = \frac{v\,l\,\rho}{\eta}$$

Where Re is Reynold's number, v is the velocity of fluid, ρ is the density of the fluid and η is the coefficient of viscosity. This shows that, since Reynold's number is directly proportional to velocity of the fluid, when the velocity of the fluid reaches a certain value it will become turbulent and hence when the flow rate of the fluid in the capillary tubes reaches a certain value turbulence starts. This accounts for the decreasing gradient of the graph since turbulence disrupts and reduces the flow of the fluid after a point when the radius, and hence the velocity, becomes great enough to introduce turbulent flow.

Effect Of Length Of Tube On Flow Rate

The results from Experiment 2 were plotted on Graphs 3 and 4.
Graph 3 shows flow rate plotted against the length of tube.
Graph 4 shows flow rate plotted against the reciprocal of the length of tube.

Graph 4 clearly illustrates that when the flow rate is plotted against the reciprocal of the length of the tube a straight line is formed which passes through the origin. This indicates that the fluid flow (v) is inversely proportional to the length of tube (l), when the fluid pressure and radius are constant, which is consistent with Poiseuille's formula.

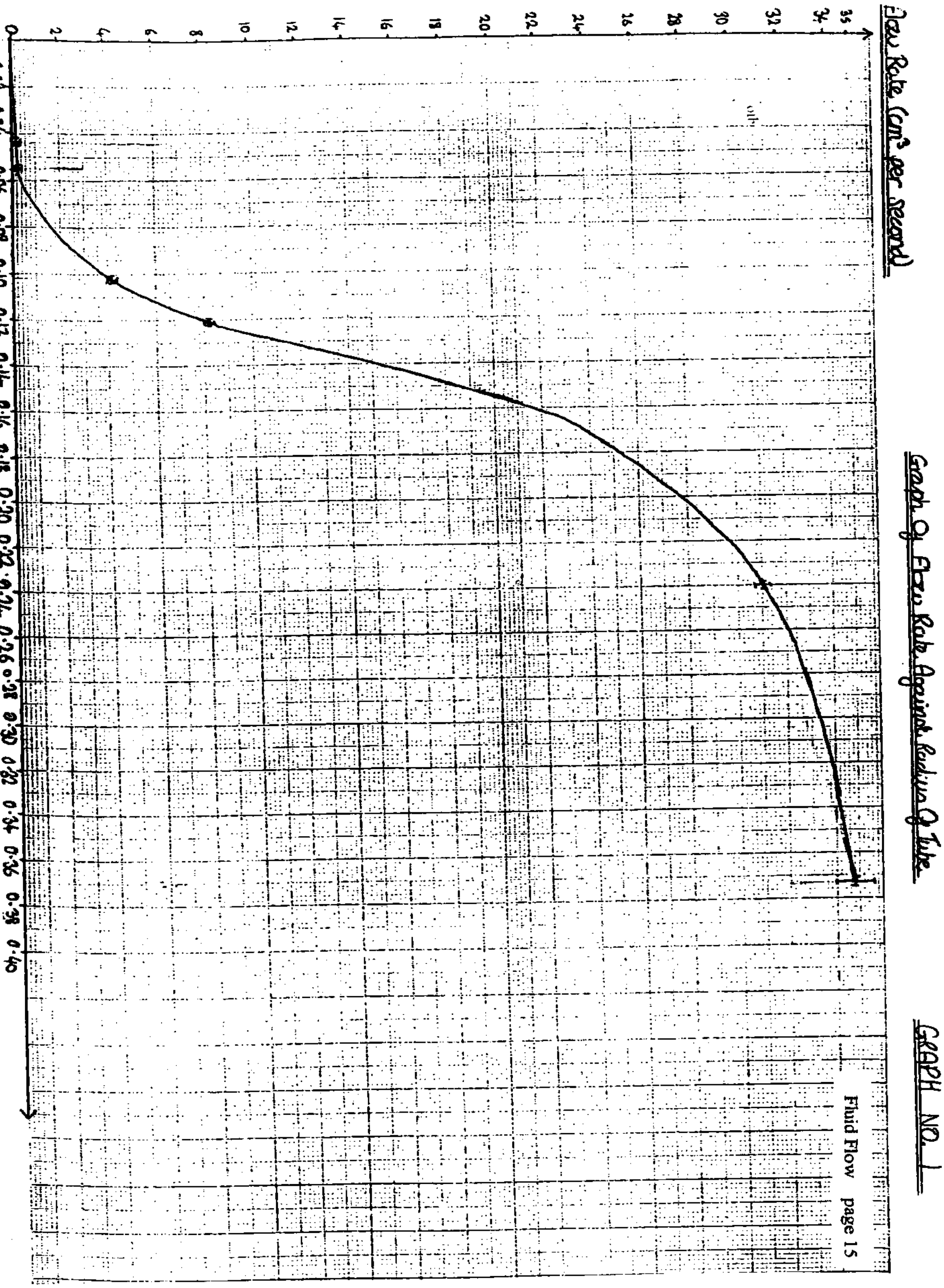
APPENDIX A - Graphs

Graph 1: Graph of the flow rate against the radius of tube.

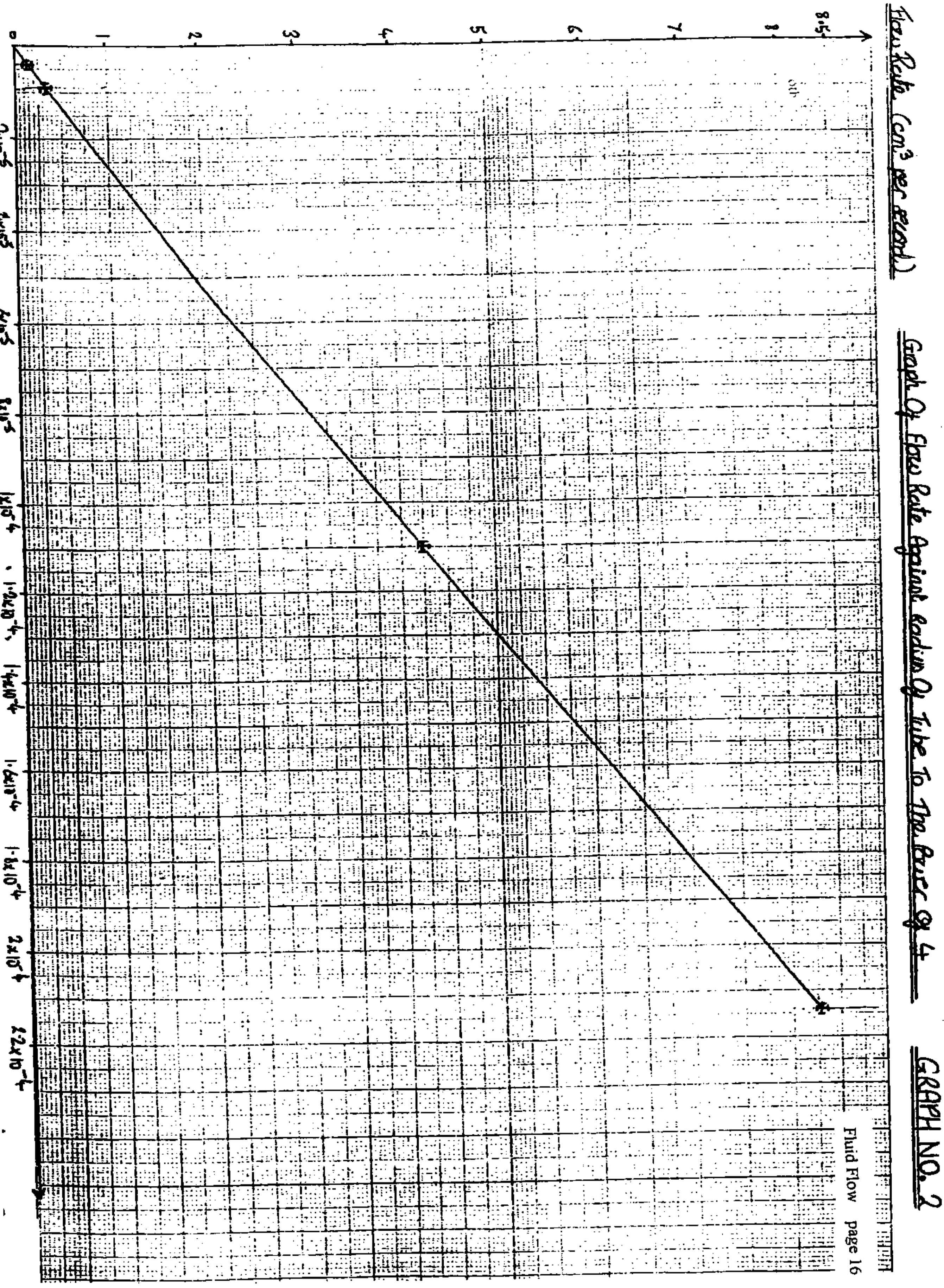
Graph 2: Graph of the flow rate against the radius to the power of four for the four tubes with the smallest radii.

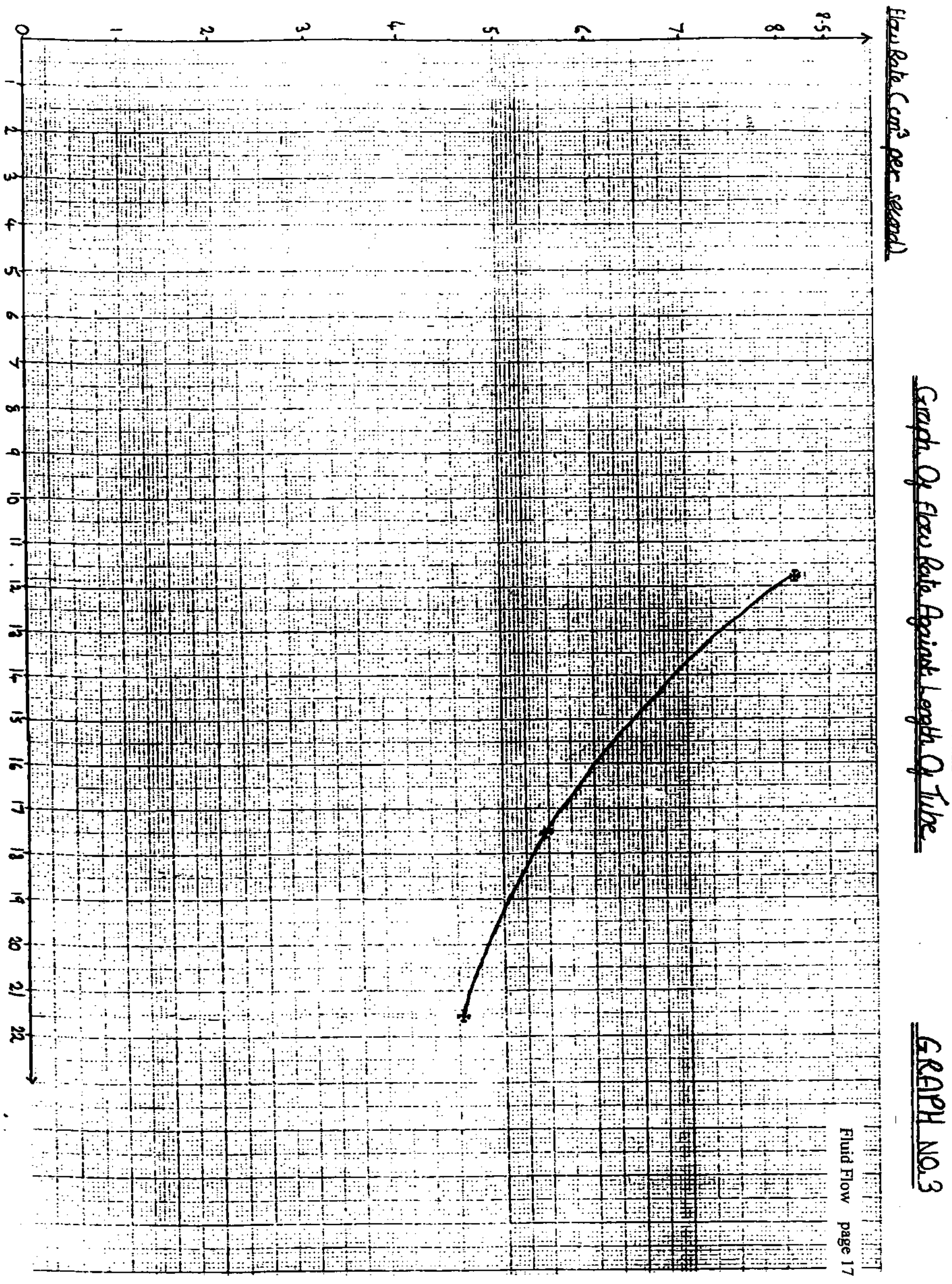
Graph 3: Graph of the flow rate against the length of tube.

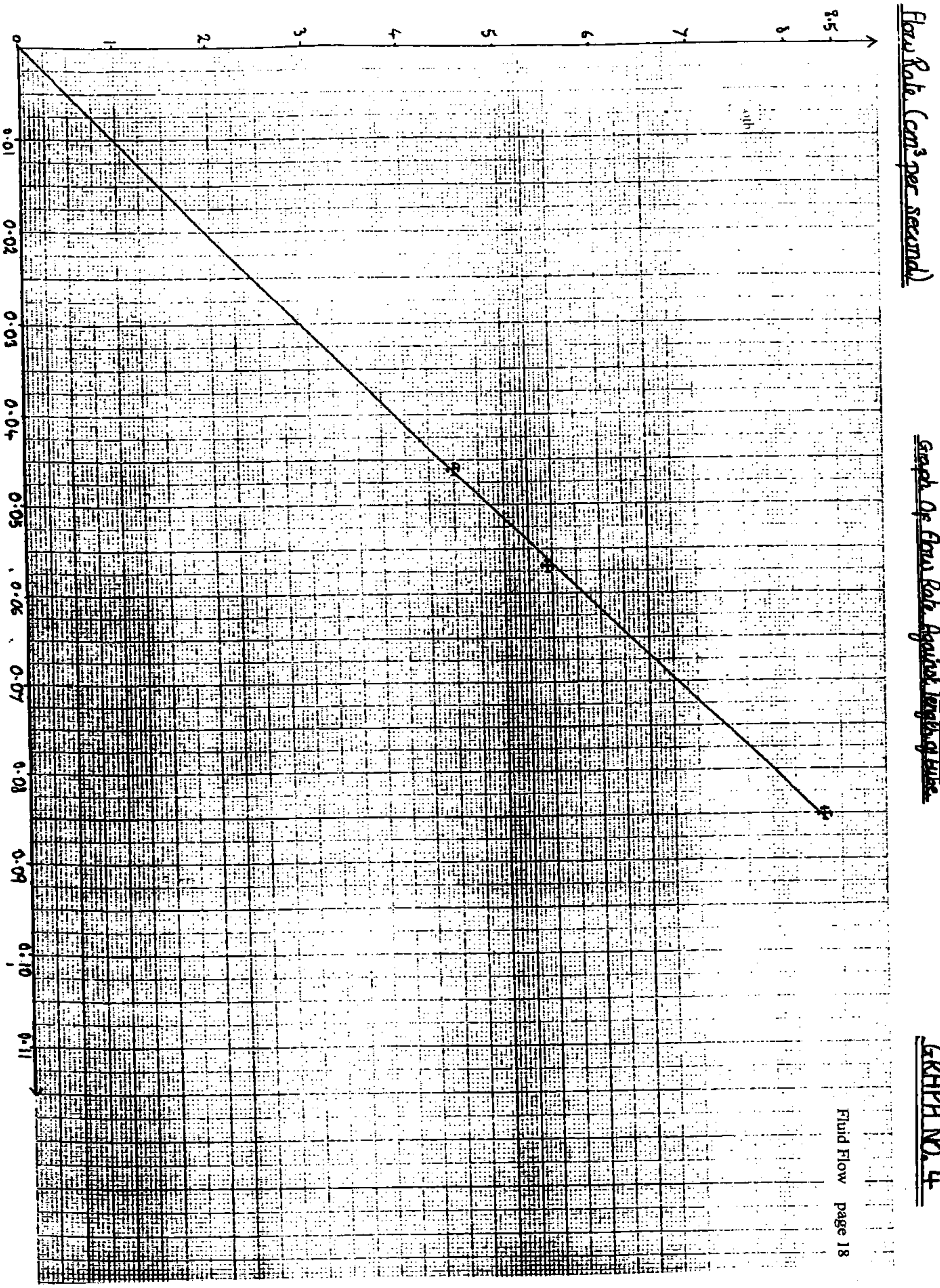
Graph 4: Graph of the flow rate against the reciprocal of the length of tube.



Fluid Flow page 15


GRAPH NO. 2
Graph Of Flow Rate Against Radius Of Tube To The Power Of 4
Flow Rate (cm³ per second)
Fluid Flow page 16
8.5
8
7
6
5
4
3
2
1
0
2x10⁻⁵
4x10⁻⁵
6x10⁻⁵
8x10⁻⁵
1x10⁻⁴
1.2x10⁻⁴
1.4x10⁻⁴
1.6x10⁻⁴
1.8x10⁻⁴
2x10⁻⁴
2.2x10⁻⁴


GRAPH NO.3
Graph Of Flow Rate Against Length Of Tube
Flow Rate (cm³ per second)
0
1
2
3
4
5
6
7
8
8.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Fluid Flow page 17


GRAPH NO. 4
Graph Of Flow Rate Against 1/length of tube
Flow Rate (cm³ per second)
0
1
2
3
4
5
6
7
8
8.5
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
Fluid Flow page 18

General comments on Fluid Flow Rate in Capillary Tubes

This report on fluid flow rate in capillary tubes has comments relating to both the unit and the course.

For the course the report is externally marked using the marking scheme, shown on page 6. The marking scheme for the report has seven 'headings' (a) to (g) and each will be considered in turn with reference to this exemplar.

(a) Introduction

Two marks are available. The title and contents page and pages 1 and 2 are relevant. The introduction is good but a separate summary would be desirable.

(b) Description of the procedures

The descriptions on pages 5 to 7 show an attention to detail and an interest in the investigation.

(c) Readings/analysis/results

Most of this section is a unit requirement to some extent. Comments are given after page 11. The report indicates that a sufficient amount of experimental work has been undertaken. The repetition of detail of the uncertainty analysis is not necessary and a spreadsheet can be used. Only three tube lengths were used, giving a graph with three points, which is hardly adequate for making a confident conclusion of proportionality between the variables. This issue is likely to be raised during the oral.

(d) Conclusion/evaluations

The evaluations and conclusions on pages 12 and 13 are clear. The use of only three tube lengths could have been mentioned in the evaluation. The omission of a calculation for viscosity, or a comment, is surprising in such a report. This aspect would be clarified in the oral.

(e) Presentation

The report is clear and concise with sufficient illustrations and graphs. The references section has not been reproduced, but it may be assumed that this was good.

(f) Oral

The oral may include specific questions on the physics involved and analysis of uncertainties as well as general discussions on the investigation. During the oral the candidate has an opportunity to improve on the marks awarded under the headings (a) to (e). For example, there may have only been time for three tube lengths and the candidate may well be aware that five points are normally required for such a graph.

(g) Management of resources

This is awarded by the centre.

8 GENERAL COMMENTS ON REPORTS

Investigations will vary widely in their subject matter and method of approach. It is not necessarily the level of difficulty of the underlying physics which makes for a more 'difficult' investigation. Sometimes the adjustment and improvement of seemingly simple apparatus can be a very valuable exercise. Alternatively the use of different methods to measure a quantity of interest can make for a worthwhile investigation.

The MOS-transistor investigation involves three 'experiments' and the Young's modulus investigation has only two 'experiments'. However it has been commented that the MOS-transistor report seems rather thin in comparison to the other two exemplars. The total number of experiments is not necessarily a guide to the quality of the investigation.

Significant figures

A comment on significant figures is appropriate. At this level it is expected that attention is given to this in detail. If a reading is 3.0 V then to record 3 V is not acceptable. In some spreadsheets the '0' might be omitted unless the 'number format' has been correctly chosen. Students should ensure that the display is correct. Although it is acceptable for uncertainties to be given to a number of significant figures for interim calculations, final uncertainties are usually given to one significant figure. The Fluid Flow exemplar shows this correctly. Assessors have commented that sometimes a final value is incorrectly stated, for example $Z = 8.9 \pm 0.32$ N or $Z = 8.87 \pm 0.3$ N. Neither of which are correct and marks would be lost. The correct statement is $Z = 8.9 \pm 0.3$ N.

Significance of the oral

The purpose of the oral is two fold. There are four marks available for the oral under heading (f). The marks awarded will depend on the candidates' responses during the oral examination.

In addition, there may be some adjustment of the marks under headings (a) to (e), after clarification of specific points by the candidate. The report will be marked on the evidence contained within that report. However there may be areas where the assessor is slightly unsure about how much is implied as opposed to omitted. It is in these areas that the marks can be adjusted after clarification at the oral examination.

Report structure

It may be useful for students to use the suggested headings in order to ensure that sections are not omitted. However this structure is not mandatory. Details provided in one section of the report may well satisfy requirements under another heading and credit would be given. This may be particularly relevant in the conclusion/evaluation area where there may be overlap.

There is a requirement that the report should be clearly presented, heading (e). Hence alternative overall report structures should be considered carefully.

9 ADVICE TO STUDENTS

The two tables below provide summary advice to students for the unit and for the course.

Summary: Advice to students on the unit requirements

Item	Advice to student
Choosing your investigation	• you must work individually • the investigation must be at a suitable level of demand • select a topic in which you are genuinely interested • avoid being over ambitious • discuss potential topics with your teacher.
Maintain a day book (much of this may be used in your course report)	• record brief notes/comments on a regular basis • date all entries • note ideas rejected • note any planning and design • note any help given by others • note any details of procedures • note sources of information and references • note your aim or aims
collect and analyse the information (this should be clear and complete but can be tidied for the course report)	• pay attention to safety codes and regulations • become familiar with any equipment or techniques • be prepared to modify your plan • record all readings in a clear table • note all observations • analyse results using a clear table, • use a spreadsheet if appropriate • produce suitable graphs • include error bars if appropriate • analyse uncertainties (you need not provide details for every calculation, tabulate where necessary)

Summary: Advice to students on the structure for the course report

- Title
- Contents page
- Page listing the illustrations, tables of results and graphs (optional)
- Summary (overall purpose and main findings)
- Introduction (including the physics involved)
- Procedures (apparatus, techniques, details of measurements)
- Readings/Results/Uncertainties (clear and logical presentation)
- Conclusions and Evaluations (you may prefer separate headings for each)
- References (a list of references and brief comments if necessary)
- Acknowledgements

The following pages which are taken from the NAB Physics Investigation unit (AH) published by SQA provide a full *Advice to Candidates*.

Physics Investigation (AH): Advice to Candidates

Maintaining a record of an investigation in Physics

This advice is designed to help you maintain a record to meet the Outcomes and performance criteria of the Advanced Higher Physics Investigation unit.

Choosing your Investigation

a. It is important to note that the Investigation should consist of a study of a problem in **physics** and that group work and joint Investigations are not permitted.

b. The Investigation will involve both planning and the collection and analysis of information obtained from the appropriate experimental work.

c. You can select any suitable topic for investigation provided the physics is at an appropriate level of demand.

d. The topic covered may be outwith the physics covered in the other units of the Advanced Higher Physics course.

e. In consultation with your teacher/lecturer, try to select a topic in which you are genuinely interested.

f. Do not be over ambitious. Simple Investigations completed in the time available are likely to be the most successful.

g. Consider the limitations that might confront you with regard to equipment, laboratory facilities, season of year, etc.

Outcome 1 Planning your Investigation

a. You should maintain a record of your work on your investigation. Your record should include:
   - regular entries during the investigation
   - notes/comments on ideas rejected
   - notes/comments on planning and design
   - contributions made by other individuals
   - notes/comments on selection of methods used
   - sources of all information used so that you or anyone else could easily check on their accuracy.

a. You should clearly state the aim/aims of your Investigation.

b. You should formulate hypotheses or questions relevant to the aims of your Investigation. In order to do this you should refer to texts and other literature, familiarise yourself with background theory related to your selected topic. The type of literature that might be consulted could include:
   - textbooks
   - journals and periodicals e.g. Scientific American or New Scientist
   - newspapers: be selective, try where possible to trace the original source of the information.

a. Devise a series of experimental techniques using appropriate apparatus, ensuring that each is appropriate to the problem being investigated.

b. Try to repeat measurements where appropriate.

Outcome 2 Collecting and analysing information obtained from your Investigation

a. You should collect your experimental information with due accuracy:
   - pay strict attention to safety codes and regulations when working in the laboratory.
   - in some cases, before commencing your Investigation proper, you may have to spend time becoming familiar with or practising a particular technique
   - record data accurately
   - form hypotheses where possible - this should lead you to further investigation
   - be prepared to modify your plan (e.g. apparatus design, materials used) as your investigation proceeds.

a. You must record your readings or observations (i.e. the raw data) in a clear table with correct headings, appropriate SI units and results/readings entered correctly. You should make careful observations from each experiment (or stage of your investigation) you carry out.

b. You should analyse and present your results using one or more of the following:
   - a table with suitable headings and units, showing averages or other appropriate computations
   - a graph with a line or curve of best fit, with suitable scales and axes labelled with quantity and units, and with data correctly plotted
   - error bars included if appropriate.

c. You must provide an analysis of your uncertainties which should include as appropriate:
   - calibration uncertainties, reading uncertainties and random uncertainties
   - a combination of individual uncertainties
   - an uncertainty in the numerical value of a measured quantity
   - uncertainties estimated from a straight line graph

Advice on writing Advanced Higher Physics Investigation reports

1. General

The final Investigation report is worth 20% of the total marks for the course award in Advanced Higher Physics. Your report is externally marked.

Your teacher/lecturer will award marks for how you :

- organised and carried out the work of the investigation in a self reliant manner
- adopted appropriate and safe working practices
- managed the investigation.

An external assessor will mark your Investigation report and will assess you by oral examination. During the oral examination the examiner will award marks for your application of knowledge and understanding during the oral and may adjust the marks given to the Investigation report in light of any additional information you may provide during the oral.

The length of the text should not exceed 2000 words, excluding tables, figures, graphs etc. The structure and details of the report should be sufficient to allow the investigation to be repeated.

2. Structure and presentation of the report

The first requirement of any report is that it should be easy to read and understand. This implies an accurate title, a logical structure, adequate cross-referencing and a clear statement regarding the conclusion(s) reached.

It is standard practice when writing a scientific report to divide it into sections. One possible pattern is given below.

a. Cover and title: this should display the title of the report, the name of the author and the name of the centre.

b. Table of contents: this should include page numbers. Pages should be numbered for ease of cross-reference.

c. List of tables, graphs and illustrations: these should be captioned and numbered, placed near the appropriate part of the text, and appropriate references to them should be made throughout the report.

d. Summary: a concise paragraph stating the purpose and overall findings of your work.

e. Introduction: this should include the background physics giving a brief account of the relevant theory.

f. Main body of report (in past tense, impersonal, passive voice):

  - Description of procedures: this should include details of all apparatus (including manufacturer's name and type number if considered important), techniques, methods and materials used; if these are not your own, then details of their origin should be given (along with an acknowledgement where necessary). Diagrams or photographs are preferable to lengthy written descriptions.

- Readings/ observations/ results/ uncertainties/ analysis : concise, logical and convenient presentation is essential.

- Conclusions, evaluation and discussion of results: you should demonstrate a reasonable depth of knowledge of the physics involved in discussing and drawing appropriate conclusions from the results of the investigation as a whole. You should take into account limitations of equipment, reliability of methods and sources of error when interpreting your results. Where appropriate you should show an appreciation of special features of economic or practical importance arising from the results.

a. References: these should be written in standard form and listed alphabetically under author's or editor's name as follow:

Books

Author (initials and surname), *Title*, Publisher, Place of Publication, Date, Page Numbers (optional)

e.g.

M.NELKON & P.PARKER, *Advanced Level Physics (6th Ed)*, Heinmann Educational Books, London, 1987.

Journals/Periodicals

Author (initials and surname), *Name of Journal*, Year, **Volume number**, Title of Article(optional), Page Numbers

e.g.

B.C.WEBSTER (1987). *New Scientist* 1987, **113**, Pulsed muons for Europe, pp 31-34.

Websites

These should be listed alphabetically

It is recommended that references be given at the end of the report and be indicated by numbers in the text.

b. Acknowledgements: to each person who assisted by offering advice, materials, etc.

Note. The above is only an example of how your Investigation might be divided. It need not follow this or any other fixed pattern.