SCHOLAR Study Guide

Advanced Higher Physics
Investigating physics

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SCHOLAR Study Guide Advanced Higher Physics: Investigating physics

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The content of this Study Guide is aligned to the Scottish Qualifications Authority (SQA) curriculum.

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Topic 1

Initial planning, using equipment and recording data

Contents

Learning objective

By the end of this topic you should be able to:

- be able to make an initial plan and make a timeline for the investigation;
- know how to look up ideas for suitable experiments and who to talk to about accessing and using equipment;
- understand how to take suitable pictures and draw relevant diagrams for your investigation.

1.1 Introduction

As part of the Advanced Higher Physics course you will have to do a project on a suitable Physics topic and complete a written report at the end. This report will be marked by the SQA and is worth a total of 30 marks, (scaled to 40).

The purpose of the project is to allow the you to carry out an in-depth investigation of a physics topic and produce a project report. You are required to plan and carry out the investigation.

Project overview

The project assesses the application of skills of scientific inquiry and related physics knowledge and understanding.

You should choose your topic to investigate. To make sure you are successful you should agree your topic with your teacher. This is to ensure that the project is at a suitable potential level of difficulty and achievable with the resources you can access. This discussion should take place as early in the investigation cycle as possible. As at National 5 and Higher you are asked to investigate/research its underlying physics.

Most of the project will be autonomously, i.e. without your teacher's supervision. The is open-ended, giving you the freedom to pursue your ideas in greater depth. You should keep a record of your work. The record is usually called a daybook. Often the daybook is a jotter, but it can be sheets in a ring binder or an electronic file. This will l form the basis of your report. The daybook should include your thoughts on potential topics, draft procedures and all the details of your research, experiments and recorded data.

Your teacher will need to access your record regularly during the project to make sure your project is your own work.

When planning your project, take time to understand what is being asked of you. The project is an opportunity to demonstrate these skills, knowledge and understanding by:

- extending and applying knowledge of physics to new situations, interpreting and analysing information to solve more complex problems;
- planning and designing physics experiments/investigations, using reference material, to test a hypothesis or to illustrate particular effects;
- recording systematic detailed observations and collecting data;
- selecting information from a variety of sources;
- presenting detailed information appropriately in a variety of forms;
- processing and analysing physics data (using calculations, significant figures and units, where appropriate)
- making reasoned predictions from a range of evidence/information;
- drawing valid conclusions and giving explanations supported by evidence/justification;
- critically evaluating experimental procedures by identifying sources of uncertainty, and suggesting and implementing improvements;
- drawing on knowledge and understanding of physics to make accurate statements, describe complex information, provide detailed explanations, and integrate knowledge;

- communicating physics findings/information fully and effectively;
- analysing and evaluating scientific publications and media reports.

This may change from year to year, always check the SQA website for the most up to date mark scheme and assessment information.

To complete the investigative stage of the project you must make independent and rational decisions. These must be based on evidence and interpretation of scientific information. That involves analysing and evaluating your results.

The project report requires you to use your literacy skills. You may need to develop your skills in literature and internet research. The project asks you to write clear, concise final project with a logical structure.

1.2 The planning cycle and initial plan

The first stage in the process is to set up a timeline for the project such as one like this:

Phase	Start date	Tasks	Deadlines
Research and choose a topic	Now!	Check with teacher for suitability and equipment	
Experiment 1			
Experiment 2			
Experiment 3 (+ 4 etc.)			
Write report			
Hand in first draft			
Hand in final draft			

Secondly you need to research topics that you are interested in and perhaps trial some experiments to see if it will make a viable investigation. Research could be from the internet or from textbooks and journals. If you use books you should give the author, title, edition and page numbers and if you use the internet the full URL is needed. Both will need the date you looked at them too. The final report will need a minimum of two correctly referenced references mentioned to achieve the mark.

These are the correct way to record your references:

1. Research found from the internet - a full URL with the date accessed.

   http://www.cyberphysics.co.uk/topics/forces/young_modulus.htm - accessed on 10/10/2018

2. Research found from a textbook.

   Tom Duncan, A Textbook for Advanced Level Students, 2nd Edition, Pages 228 - 229. Read on 06/02/2019

You will have to check with your teacher whether equipment is available Sometimes a visit to a University can be arranged or equipment borrowed, and most schools will have some equipment available. Some students even construct their own equipment for the project but bear in mind this will take up a lot of extra time.

Some ideas for experiments can be found here:

- https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/investigation-ideas/

1.3 Using equipment and recording experimental data

Don't be surprised if the practical work takes many more hours than you planned, this is normal. Good planning will help here, making sure all equipment is ready in advance and your daybook is clearly laid out with dates and clearly drawn up tables of collected data. An account of the experimental procedures should also be written and written in the third person form.

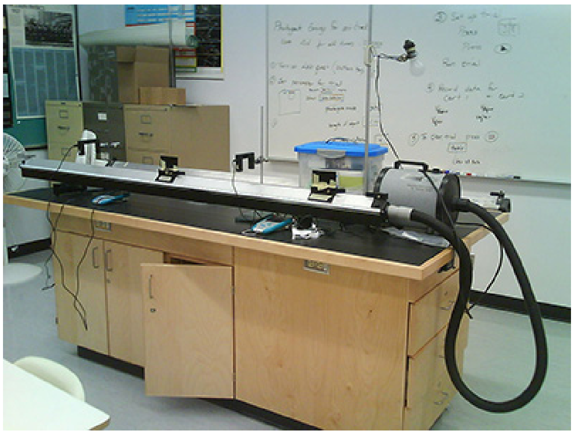
Images

A **labelled** diagram of apparatus should be drawn (this can be in rough in the daybook) and take pictures of the apparatus too which can also be used in the final report. With pictures try and avoid background objects or overly crowded pictures which detract from the details in the image.

This image is a bit cluttered and not clear to the reader

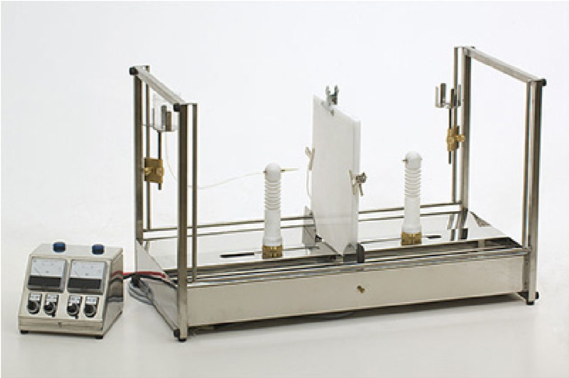
"Bomb Calorimeter" by Akshat Goel, licensed under CC BY 3.0

Slightly better though still with a distracting background



"Air Track with photo-gates and a reverse vacuum" by Bhavesh Chauhan is licensed under CC BY 3.0

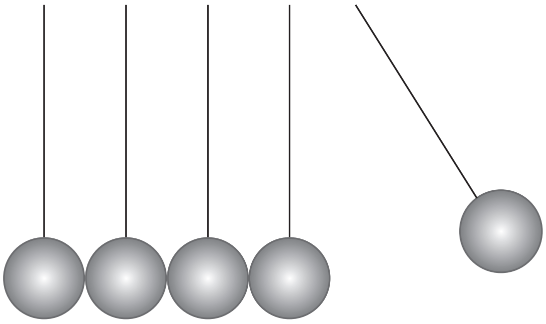
Nice clear equipment with no distracting background which can be clearly labelled



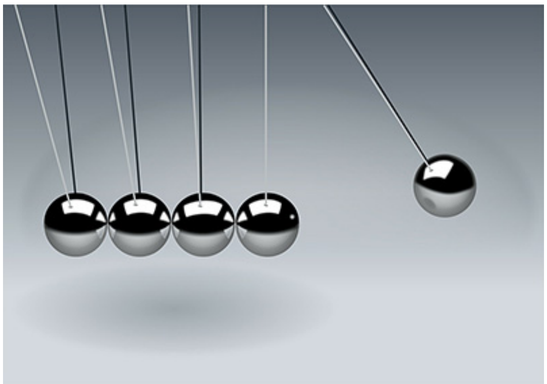
"An Electrospinz Ltd Doris type laboratory electrospinning machine", by Robert Lamberts, licensed under CC BY 3.0

Diagrams

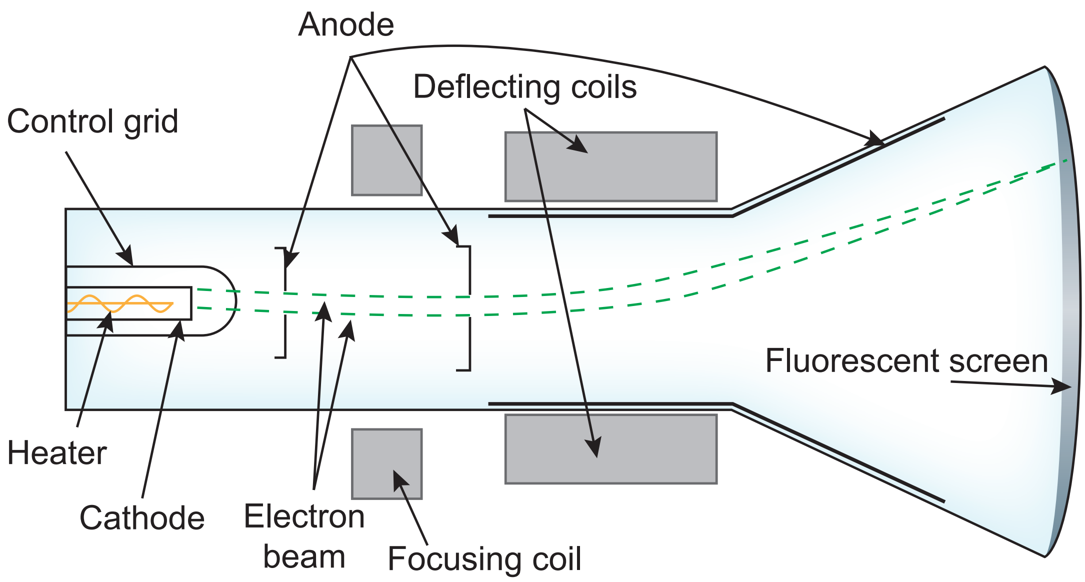
Similarly diagrams should be fully labelled and clear 2D diagrams not 3D works of art, try and think.

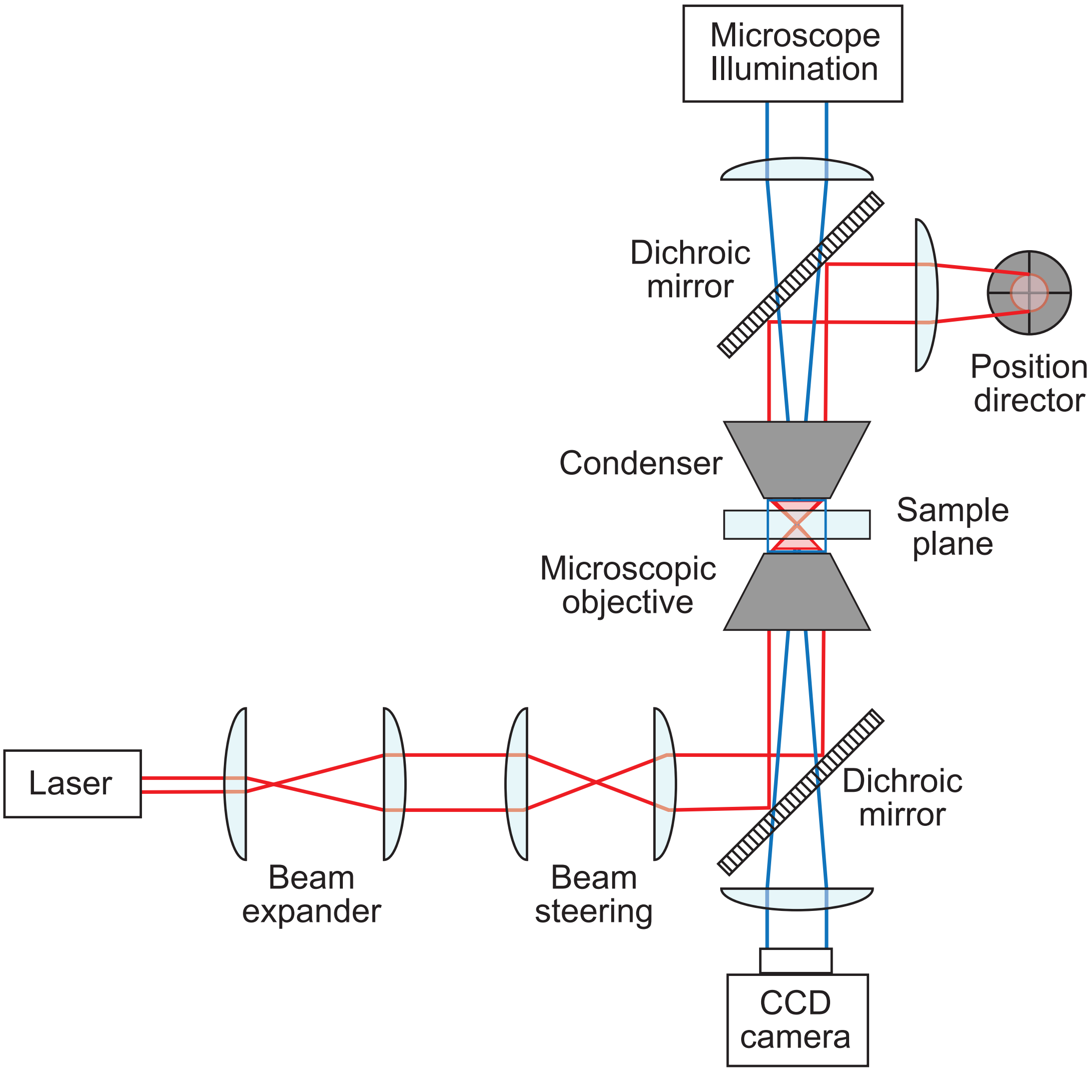


not →



Here are some examples of labelled diagrams that could be used in conjunction with labelled photos.





1.4 Summary

Summary

You should now be able to:

- be able to make an initial plan and make a timeline for the investigation;
- know how to look up ideas for suitable experiments and who to talk to about accessing and using equipment;
- how to take suitable pictures and draw relevant diagrams for your investigation.

Topic 2

Measuring and presenting data

Contents

Learning objective

By the end of this topic you should be able to:

- correctly complete results tables for your investigation;
- produce accurate graphs of the correct size and scale.

2.1 Result tables

Don't forget that tables of data need to have correct units and headings. A rough graph is useful to identify outliers which may affect your results. You may wish to use a spreadsheet program such as Excel or Numbers to produce the graph, but make sure the axes are correctly labelled, the scale is suitable and there are enough gridlines to clearly see the data points. The data points should be suitably small and not obscure the grid lines and ideally should be error bars not dots. (See tips for drawing graphs below for more information.)

A best fit line or curve should be added to aid with analysis of data. Excel can also give you an equation of a best fit line. Uncertainties will need to be taken into account and they will be looked at in more detail later. Also useful is to note down any difficulties encountered and how you dealt with them and any further improvements you can think of or further work you might like to look into. This will help greatly when writing up the evaluation part of the final report. Make sure you get plenty of data. When appropriate, a good scientist repeats readings enough times to calculate the random uncertainty and has a good range of data.

Example

This is an example of a seemingly well presented table of results for a Newton's Second Law experiment involving varying the unbalanced force applied to various masses. Note that this student has made a major mistake in their experiment and a few minor ones as well, can you spot their failings?

Mass (kg)	Force1 (N)	Force2 (N)	Force3 (N)	ForceAVG (N)	Acceleration
1.0	3.4	3.6	3.5	4	4
2.0	2.8	2.2	3.1	3	1.5
3.0	1.9	1.4	1.6	1.6	0.5
4.0	8.6	7.8	8.5	8	2.0
5.0	10.0	11.2	12.8	11.3	2.3
6.0	6.5	6.3	6.5	6.4	1.1
7.0	3.6	4.5	7.2	5	0.7
8.0	7.5	7.8	8.1	8	1.0
9.0	4.5	4.7	3.8	4.3	0.5

Things to note:

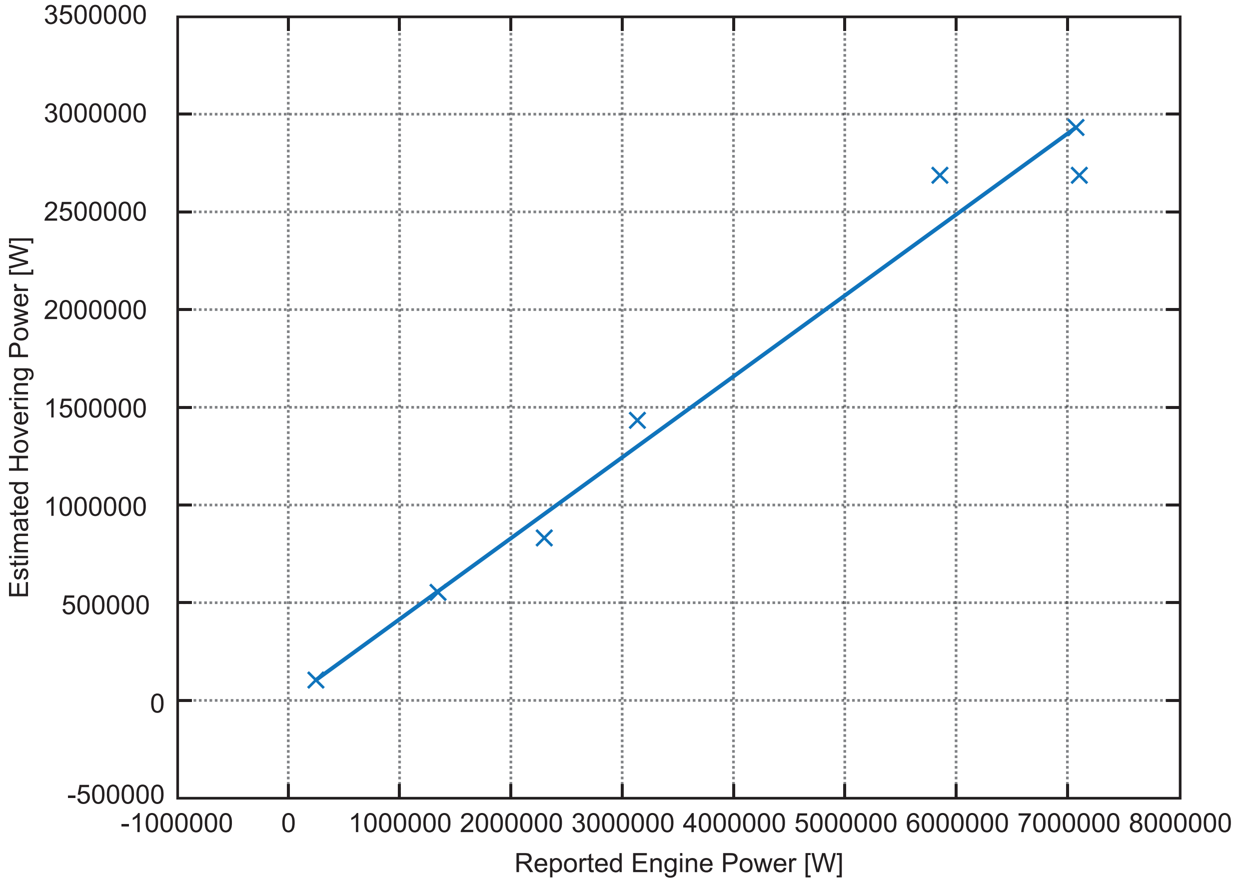
- Your results should have the correct number of significant figures/decimal places as appropriate. This will aid graph drawing later.
- You must have all headings labelled with the correct units.
- You may prefer to use a program such as Excel to perform the calculations in the columns for you, e.g. in this table the average force and acceleration were calculated using this method. This can save you a lot of time compared to using a calculator. See Excel Help if your teacher can't help you with this method.

Mistakes in table:

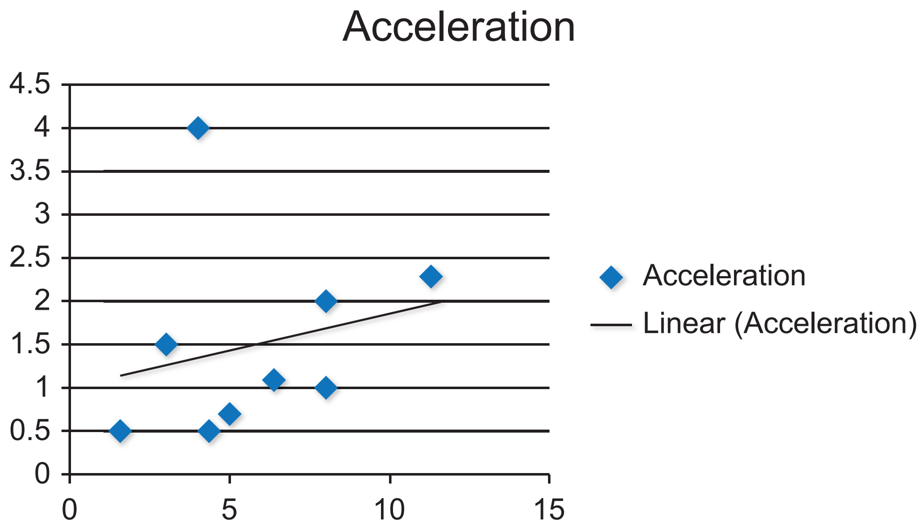
- The student above has varied the mass **and** the unbalanced force making it difficult to plot a valid graph of results for their experimental data.
- Units for acceleration are missing.
- To calculate the random uncertainty in the Force, you would be advised to have two more repeats.
- Some of the Force and Acceleration values are only quoted to one significant figure.

Tips for drawing graphs

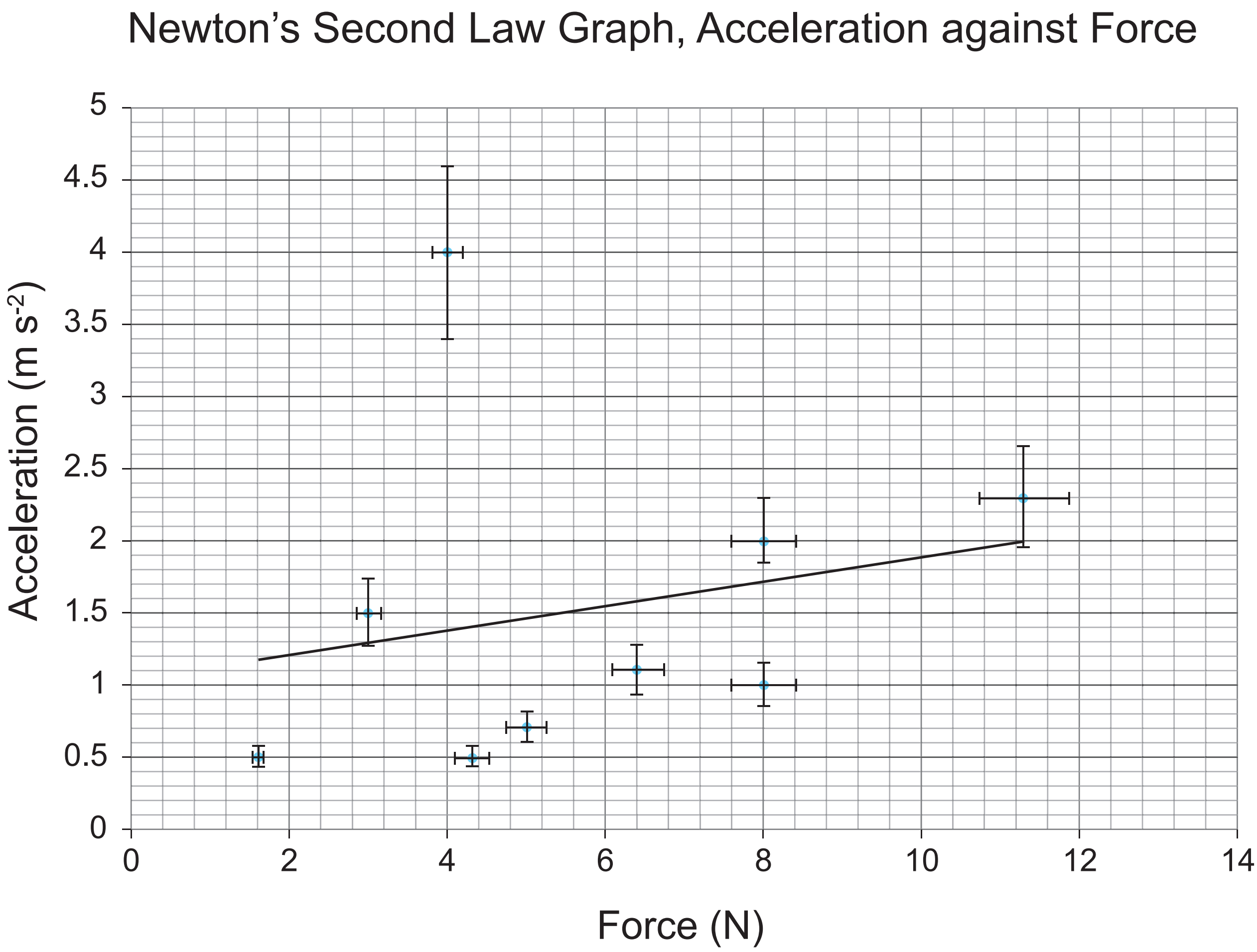
Be careful when using computer programs to draw graphs for you, computers tend not to show minor grid lines, leaving you with floating points which are not at all accurate:



Another graph shown as follows is way too small on the page, the axes have not been labelled, the points are too large and so on.



A much better version of the same graph would be:



This graph has clearly labelled axes, major and minor gridlines and the large points have been replaced with error bars showing the uncertainties in the mass and acceleration. The point at 4N is an outlier and worthy of comment or even removal and the computer could also be used to calculate the gradient of the line for the conclusion. LINEST is a useful feature on excel for working out the uncertainty in the gradient if desired. Quite often a sharp pencil and a graph paper will enable you to be accurate enough if you prefer the paper and pencil method and the parallelogram method of uncertainties can work out the error in the gradient and intercept. (See Unit 5 for more information on this method).

2.2 Summary

Summary

You should now be able to:

- correctly complete results tables for your investigation;
- produce accurate graphs of the correct size and scale.

Topic 3

Evaluating findings

Contents

Prerequisites

- Evaluating & drawing conclusions (Higher).

Learning objective

By the end of this topic you should be able to:

- evaluate your results and draw conclusions;
- understand some tips for completing the evaluation sections of the report.

3.1 Evaluating findings

Evaluating your scientific findings - general tips.

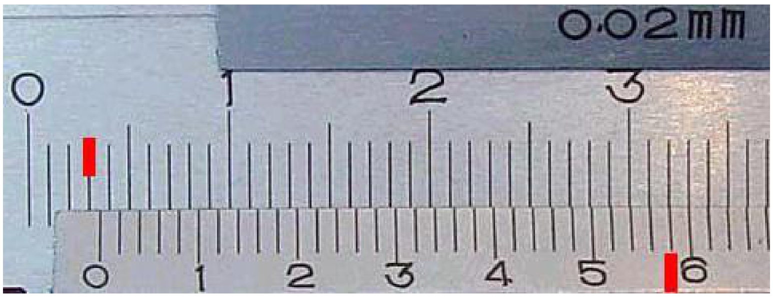
This is a section that many candidates find it hard to pick up full marks and candidates are advised to use the following points to structure the discussion. Each experiment should have it's own conclusion and evaluation with a final overall evaluation at the end of the report.

Conclusions need to be valid and **related to the aim** of the investigation and they tend to take the form of the calculation of the gradient of a graph with appropriate uncertainties for example.

In the evaluation try and comment on all of the following:

1. **Accuracy of experimental measurements**

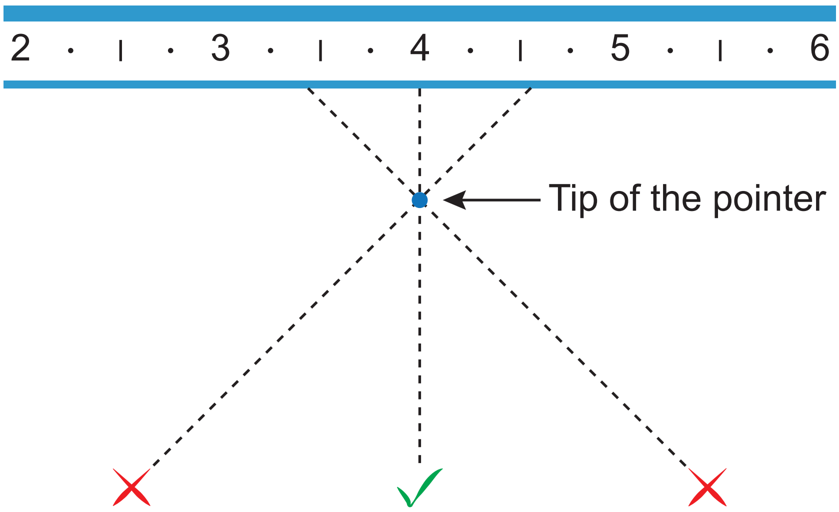
   How did you ensure that each result was as accurate as it could be?

   Zoom-in on "Messschieber.jpg" made by Ultraman,Wikimedia, licensed under CC BY 3.0

   Using a Vernier scale instead of a regular ruler will vastly reduce your reading uncertainty.

   Or being aware of effects such as PARALLAX, where the reading can change depending on how you look at it.

2. **Adequacy of repeated readings**

   Did you have enough readings to calculate an accurate random uncertainty? Was the equipment accurate enough to give you similar results each time?

3. **Adequacy of range over which variables are altered**

   Quite often equipment restraints will prevent you having the range you desire, can you think of any ways to extend the range of your variables or at the least comment on these restraints?

4. **Adequacy of control of variables**

   How did you reduce uncertainties in each variable? How many fixed variables were there in your experiment and how did you control them?

5. **Limitations of equipment**

   Most school equipment will have some failings, systematic uncertainties are quite common, look out and check for these. For example a Voltmeter that is always 0.2 mV out, a wooden ruler that is 0.5mm shorter than it once was, etc.

V-O-M (Volt-Ohm-Meter) / Multimeter, Author: Steve C, Source: Flickr

6. **Reliability of methods**

   Be self-critical here, how reliable was your method and how could it be improved?

7. **Sources of errors and uncertainties**

   Think about whether the uncertainties are most likely calibration, scale, reading etc or if human error is a major factor. Looking at the uncertainty calculations will make this much easier to target the largest sources of error.

The overall conclusion and evaluation of the investigation as a whole should mention:

- **Problems overcome** - During all three (or more) experiments.

  Examples:

  - A darkroom was needed to eliminate background light but one wasn't available.
  - The school multimeter/digital balance/data logger only has a limited range/large percentage uncertainty at smaller readings.
  - My school equipment wasn't advanced enough so I had to contact Scotland University for help with my project.
  - I had to limit the current to xA due to wires heating up.
  - etc.

- **Modifications to procedures and suggested future experiments** - If you had an unlimited budget, what would you like to do to improve and enhance your experiments?

- **Significance/interpretation of findings** - Can you find any similar work to compare yours to? Can you see a bigger picture from your findings? Can you link your results back to your background theory?

More detail of what to write in the evaluation can be found in the next topic, which takes you through the process of writing up the scientific report.

3.2 Summary

Summary

You should now be able to:

- evaluate your results and draw conclusions;
- understand some tips for completing the evaluation sections of the report.

Topic 4

Scientific report

Contents

Learning objective

By the end of this topic you should be able to:

- understand how to approach the project write up and will be familiar with the mark scheme used by the SQA.

4.1 Scientific report

When you come to write up your project report, you need to make sure it is between 2500 and 4500 words in length. Too short and it will not be detailed enough to pick up some of the marks in the mark scheme and too long - over 4950 words (10% over the maximum) and you will suffer a penalty. The total mark is 30 marks and you should make sure you hand in drafts to your teacher well in advance of the submission date for checking and re-editing. The most successful candidates may hand in two or even three rough drafts before the final submission.

The best tip is to pay close attention to the mark scheme and tick off each section as you complete it. The following instructions are taken direct from the SQA website and give detailed instructions on how the marks are awarded with a few extra tips to make sure you get the best out of your report writing process.

https://www.sqa.org.uk/files_ccc/AHPhysicsCourseSpec.pdf

Sections you should include in the report

1.	Abstract	1 mark
2.	Underlying Physics	4 marks
3.	Procedures	7 marks
4.	Results	8 marks
5.	Discussion	8 marks
6.	Presentation	2 marks
	Total =	**30 marks**

More detail on each section in the report

1. **Abstract (1 mark)**

   A brief abstract (summary) stating the overall aim(s) and finding(s)/conclusion(s) of the investigation.

   The abstract must be:

   - relevant to the investigation;
   - demonstrating an understanding of the physics theory underpinning the investigation;
   - of an appropriate Advanced Higher Physics level;
   - **immediately following the contents page** and should be under a separate heading. The abstract must be separate from and placed before the 'introduction';
   - the overall findings must be consistent with the conclusion(s) given in the 'discussion' and should relate to the aim(s).

2. **Underlying Physics (4 marks)**

   - Candidates must include an account of the underlying physics that is relevant to the investigation. All terms and symbols used should be clearly defined. Simply stating equations is not sufficient - derivation of formulae should be given and all symbols in the equations must be explained with correct units. Candidates must demonstrate a good understanding of the physics behind these equations.
   - Candidates may (and should) draw on a variety of sources of information when researching their chosen topic. Don't base all your theory on one website of information.
   - Downloading directly from the internet or copying directly from books may suggest that the candidate has not understood the physics involved and will be considered as plagiarism. Where the vast majority is believed to have been copied verbatim then the candidate is not demonstrating understanding.
   - Complicated diagrams copied and pasted from an internet source are perfectly acceptable, especially when the reference is cited in the text and listed at the back of the report.

3. **Procedures (7 marks)**

   <u>Labelled diagrams and/or descriptions of apparatus</u> (2 marks)

   - Candidates must include labelled diagrams and / or descriptions of the apparatus that they used for experimental work. Photographs of assembled apparatus, with appropriate labelling, are acceptable. A satisfactory photograph showing clear detail should be labelled as covered in Topic 3, and if possible use a labelled photograph and a labelled diagram for clarity.

   <u>Clear descriptions of how the apparatus was used to obtain experimental readings</u> (2 marks)

   - Candidates must also give clear descriptions of how they used the apparatus to obtain their experimental results.
   - The report should be written in the *past tense and impersonal voice*. (3rd person)
   - Bulleted / numbered points are not recommended for the method and must be made up of complete sentences. Use proper paragraphs to write your third person description.

- The procedure should be described well enough for another competent Advanced Higher Physics candidate to be able to repeat the procedure from the description.

Procedures are at an appropriate level for Advanced Higher (3 marks)

Factors to be considered include:

- range of procedures and number of repetitions;
- control of variables;
- accuracy;
- originality of approach and/or experimental techniques;
- degree of sophistication of experimental design and/or equipment.

Some of this is out of your hands due to equipment restraints but reading this list beforehand combined with talking to your teacher should help steer you in the correct direction to attain these marks. Use experiments completed in class as a rough guide to the standard required.

4. **Results (including uncertainties) (8 marks)**

   Data sufficient and relevant to the aim(s) of the investigation (1 mark)

   - The experimental data that candidates collect must be relevant to the aim(s) of their investigation. Also, the data candidates collect and present in their report must be sufficient in quantity and with a degree of accuracy and precision appropriate to their investigation - ie it must show all readings and not just the mean values. Don't forget too that data in tables is meaningless unless supplied with the correct labels and units.

   Appropriate analysis of data, e.g. quality graphs, lines of best fit, calculations (4 marks)

   - A candidate's report must include analysis of their experimental data that is appropriate to the investigation. This may involve drawing graphs or calculating and tabulating numerical values. Again further tables, graphs and calculations should still have the correct units and significant figures applied to them.

   Uncertainties in individual and final results (3 marks)

   - Candidates must include uncertainties in the values of each of the physical quantities that they measure and in the final result(s) of their investigation. Their analysis should show clearly how they have calculated/estimated the uncertainty in their final result(s). The best way to do this is with an example calculation for each method used, e.g. random uncertainty, percentage uncertainty, uncertainty in gradient of graph etc. Uncertainty calculations should all be at Advanced Higher level and all uncertainties (calibration, scale reading and random) that have a bearing on the accuracy on the experimental work should be mentioned. See Unit 5 for more information on uncertainties.

5. **Discussion (8 marks)**

   Conclusion(s) is/are valid and relate to the aim(s) of the investigation (1 mark)

   - Candidates must include overall conclusion(s) that are relevant to the aims(s) of their investigation and *supported by data* in the report and which are valid for the experimental results obtained.

Evaluation of experimental procedures (3 marks)

- Candidates must also include a critical evaluation of each experiment. It is often appropriate to include this after the 'procedures' and 'results' of each experiment. This should be a significant part of the candidate's report and should focus on the quality of their experimental work. See topic 4 for some more tips in writing this section. Candidates should include as many factors as possible and suggest improvements to procedures.
  - Accuracy of experimental measurements
  - Adequacy of repeated readings
  - Adequacy of range over which variables are altered
  - Adequacy of control of variables
  - Limitations of equipment
  - Reliability of methods
  - Sources of errors and uncertainties

  One tip here is to make sure you write something relevant for all seven points for each experiment being careful not to repeat yourself.

Coherent discussion of overall conclusion(s) and critical evaluation of the investigation as a whole (3 marks)

- Candidates must include a discussion of their overall conclusion(s) together with a critical evaluation of the investigation as a whole. This should be a more wide-ranging discussion of the investigation. It is an opportunity to explain what the candidate has learned as a result of the investigation and the significance of their findings. Candidates could also demonstrate the depth of their understanding of the physics related to the investigation.
  - Problems overcome
  - Modifications to procedures
  - Significance/interpretation of findings
  - Suggestions for further improvements to procedures
  - Suggestions for further work

Overall quality of the investigation (1 mark)

- This is a final quality mark for the standard of the investigation - not just the 'discussion' part of the report. This is for a good investigation well worked through, taking particular account of the physics involved and synthesis of argument.

6. **Presentation (2 marks)**

   Appropriate structure, including informative title, contents page and page numbers (1 mark)

- The report structure should be easy to follow. A *title, contents page* and structure are essential - the contents page must show *page numbers* and the pages throughout the report must be numbered. Occasional missing page numbers (e.g. on hand-drawn graphs) will not be penalised. A title page with a nice picture or diagram to catch the marker's eye and show something of what the report is about is not essential but highly recommended.

References cited in the text and references listed in standard form, acknowledgements, where appropriate (1 mark)

- At *least three references* must be *cited correctly* in the main body of the report and the same ones also listed correctly at the back of the report. Any additional references cited or listed incorrectly should not be penalised. Referencing must conform to either Vancouver or Harvard referencing systems.
- References must be relevant to the investigation and specific. References must be cited within the text of the candidate's report and in many cases these will occur in the 'Underlying Physics' section. At the end of the report, the candidate must include details on all of the references (e.g. books, journals/periodicals and websites) that they cited. Candidates must include sufficient information to allow a reader to consult the original work to confirm its relevance to the investigation. Candidates should only include details on references; do not include information on materials that were part of background reading but are not cited as references in the report.

Total marks = 30 for the report

Top tip

Quite a lot of the advice above is **Copyright ©Scottish Qualifications Authority** and may change from year to year, always check the website for the most up to date mark scheme.

4.2 Summary

Summary

You should now be able to:

- have a thorough understanding of how to approach the project write up;
- be familiar with the mark scheme used by the SQA and know how to get as many of the 30 marks available as you can.