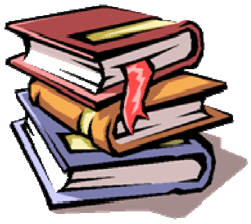
Grade 9 & 10 Course Reference

Grade	**9 & 10**
Title	**Grade 9 & 10 Course Reference**
Student	

Areas of Interaction

Approaches to learning (ATL)



How do I learn best?

How do I know?

How do I communicate my understanding?

Community and service

How do we live in relation to one another?

How can I contribute to the community?

How can I help others?

Human Ingenuity

Why and how do we create?

What are the consequences?

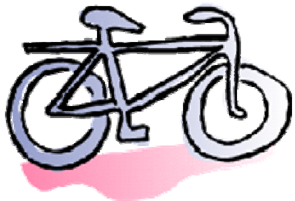
Environment

Where do we live?

What resources do we have or need?

What are my responsibilities?

Health and social education

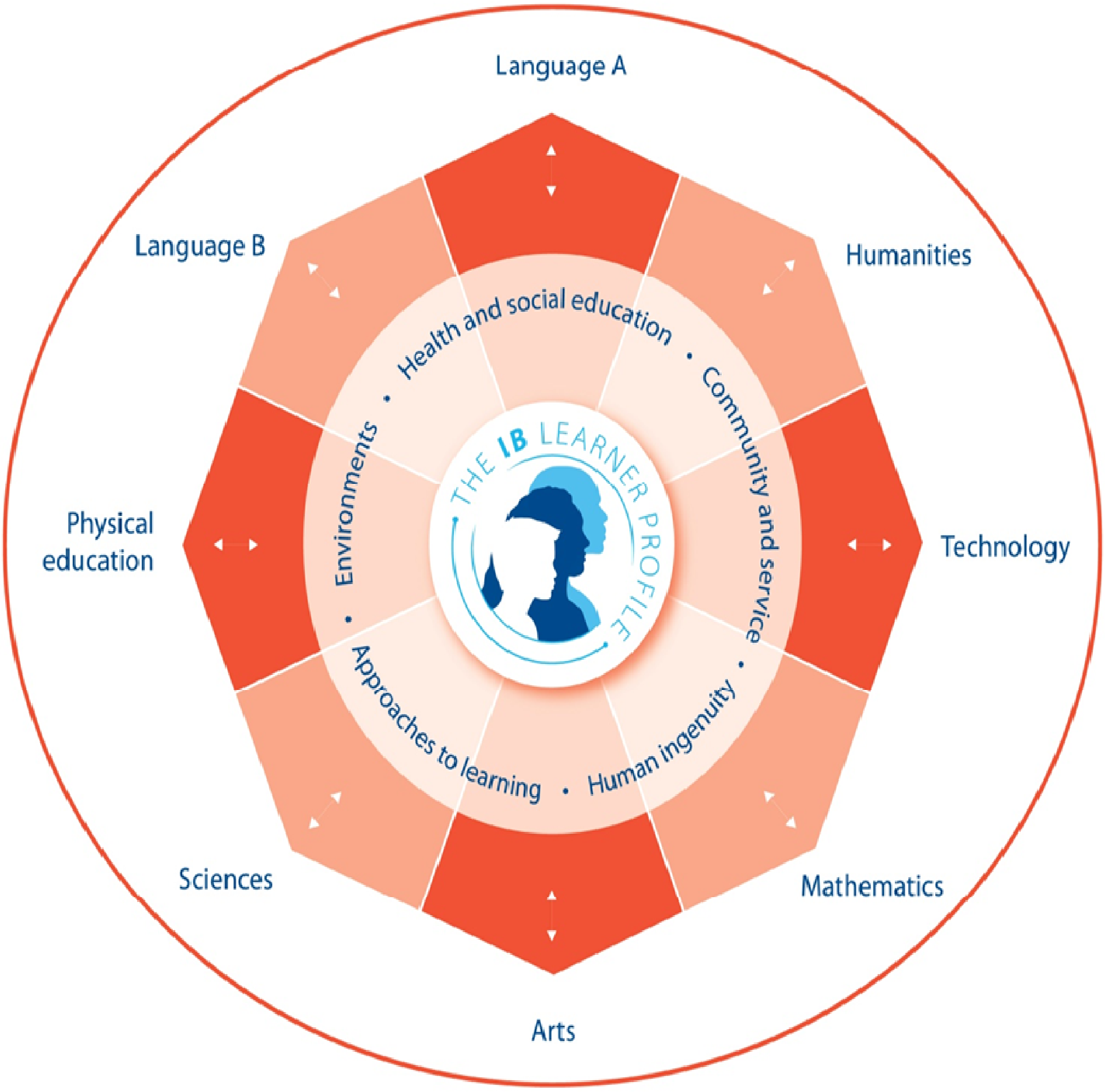


How do I think and act?

How am I changing?

How can I look after myself and others?

The MYP Programme



The Science programme in the MYP is delivered through Areas of Interaction;

- Community and Service
- Human Ingenuity
- Environment
- Health and Social Education

Science MYP Objectives

A One world

To understand how science and society are linked together.
To understand the consequences of science on our lives.
To understand that science can be used to solve local & global problems.

B Communication in science

To develop communication skills in science.
To develop presentation skills of scientific information.
To develop processing skills of scientific information.

C Knowledge and understanding of science

To understand the main ideas and concepts of science.
To apply scientific information to solve problems.
To develop critical and reflective thinking skills.

D Scientific inquiry

To define the research question to be investigated.
To design and carry out a scientific investigation.
To analyse and evaluate the investigation.

E Processing data

To collect and record data appropriately.
To present data using appropriate methods.
To draw reasoned conclusions.

F Attitudes in science

To safely and skilfully carry out scientific investigations.
To work effectively as members of a team.
To show respect for themselves, others and the environment.

Grade 9 Overview

Details	Semester	Biology	Chemistry	Physics
Title	1	The Building Blocks of Life	The Building Blocks of Matter	The Building Blocks of Measurement
Area of Interaction		Health & Social Education	Human Ingenuity	Community & Service
Unit Question		How does Life continue?	How useful are Scientific models?	How can we measure what we cannot see?

Title	2	Looking for Patterns in Behaviour	Looking for Patterns in Reactions	Looking for Patterns in Waves
Area of Interaction		Community & Service	Environment	Environment
Unit Question		Why is it important to understand behaviour?	How can we use Resources more efficiently?	How can we explore the world around us?

Grade 10 Overview

Details	Semester	Biology	Chemistry	Physics
Title	1	The Chemistry of Life	Making Useful Materials	Predicting the Next Move
Area of Interaction		Human Ingenuity	Community & Service	Health & Social Education
Unit Question		How are living things controlled by Chemistry?	How can we make useful materials?	How can we make journeys more safely?
Title	2	Predicting the Future of Life	Predicting Reactions	Extreme Measurements
Area of Interaction		Environment	Health & Social Education	Human Ingenuity
Unit Question		Will anything be smarter than us?	How much do we need? How much will we get?	What are the extremes in the Universe?

Science Command Terms

Key word	Meaning
Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in a new situation.
Calculate	Find a numerical answer showing the relevant stages in the working.
Define	Give the precise meaning of a word, phrase or physical quantity
Describe	Give a detailed account.
Distinguish	Give the differences between two or more different items
Draw	Represent by means of pencil lines.
Estimate	Find an approximate value for an unknown quantity
Identify	Find an answer from a given number of possibilities
Label	Add labels to a diagram
List	Give a sequence of names or other brief answers with no explanation.
Measure	Find a value for a quantity.
Outline	Give a brief account or summary.
Analyse	Interpret data to reach conclusions
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout.
Construct	Represent or develop in graphical form
Deduce	Reach a conclusion from the information given.
Derive	Manipulate a mathematical relationship(s) to give a new equation or relationship
Design	Produce a plan, simulation or model
Determine	Find the only possible answer
Discuss	Give an account including a range of arguments for and against the relative importance of various factors, or comparisons of alternative hypotheses.
Evaluate	Assess the implications and limitations
Explain	Give a detailed account of causes, reasons or mechanisms
Predict	Give an expected result
Show	Give the steps in a calculation or derivation
Sketch	Represent by means of a graph showing a line and labelled but un-scaled axes but with important features (for example, intercept) clearly indicated.
Solve	Obtain an answer using algebraic and/or numerical methods
Suggest	Propose a hypothesis or other possible answer

Laboratory Safety in Science

1. Do not enter any laboratory or science office unless your teacher has asked you to do so.
2. You must always follow the instructions given to you by your teacher. You must not use chemicals or apparatus for any other purpose.
3. Do a 'risk assessment'. Does the experiment you are doing have any risks (danger) for you or your neighbour? If so, take precautions. Make sure you:
   a. Wear an apron and goggles if necessary
   b. Take great care of any flames.
   c. Keep hair and loose clothes away from flames.
   d. Keep bags where people will not fall over them.
4. The following activities are not allowed in any of the laboratories:
   a. Running
   b. Throwing things
   c. Wearing outside coats
   d. Eating, drinking or chewing gum
   e. Doing your own experiments without permission
   f. Touching any science equipment without permission
5. Any accident or near- accident, or any breakage, must be reported to your teacher immediately
6. Make sure you know the emergency routines;
   a. Where is the eye wash equipment?
   b. Where is the fire blanket?
   c. Where is the nearest fire escape?
   d. Where is the fire extinguisher? Where is the nearest first aid kit?
   (you would not normally have to use these last two yourselves)
7. Most laboratory rules are just common sense. If you think you should not be doing something – then do not do it!

Assessment in Grade 9 and 10 Science

Assessment in Science

Assessment of Criteria A and B

Criteria A (One World) and B (Communication) assess students' ability to research, analyze and present scientific information. The general criteria in Biology, Chemistry and Physics are given in this booklet.

Students are expected to;

- Do the necessary research in their own time;
- Bring selected printed material, including pictures, to the teacher before starting the assessment.

Students will be given up to four lessons to handwrite this assignment in class under test conditions. In this case;

- Pictures / diagrams can be included in the assignment but these should be fully referenced in order to gain credit for them.
- All sources of work should be fully referenced using the **MLA** referencing style.

Assessment of Criteria D, E and F

Criteria D(Scientific Inquiry), E (Processing Data) and F(Attitudes in Science)will be assessed as a practical work during four lessons. The students will plan and perform an experiment in class.

After the allocated time for collecting the data, the teacher will inform students of the period of time during which they can hand in their final written assessment. In this case;

- The final written assessment should include **all raw data** collected in class.
- This period of time will be **1 week** in duration (the assessment hand-in week).
- Work handed in **after** the assessment hand-in week will **not be considered** for assessment.

A – One World

Level	A: One World	Advice and Clarifications
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **states** how science is applied and how it may be used to address a specific problem or issue in a local or global context. The student **states the effectiveness of science and its application in solving the problem** or issue**.**	• I have described the problem… • I have described how Science can be used to solve the problem… • I have stated some benefits or limitations of my solution to the problem….
3 - 4	The student **describes** how science is applied and how it may be used to address a specific problem or issue in a local or global context. The student **describes the effectiveness of science and its application in solving the problem or** issue. The student **describes the implications of the use and application of science interacting with at least one** of the following factors: moral, social, economic, political, environmental, cultural and ethical.	• I have described the problem … • I have described how Science can be used to solve the problem… • I have described how my solution to the problem affects at least one of the following factors: moral, social, economic, political, environmental, cultural and ethical. • My assessment is between 700 and 1200 words.
5 - 6	The student **explains** how science is applied and how it may be used to address a specific problem or issue in a local or global context. The student **discusses** the effectiveness of science and its application in solving the problem or issue. The student **discusses and evaluates the implications of the use** and application of science interacting with **at least two** of the following factors: moral, social, economic, political, environmental, cultural and ethical.	• I have explained the problem in detail… • I have discussed how effective my solution to the problem is……. • I have discussed and evaluated how my solution to the problem affects at least two of the following factors: moral, social, economic, political, environmental, cultural and ethical. • I am close to the word limit (1200 words).

A – Explanatory Notes

One world enables students to gain a better understanding of the role of science in society and allows them to explore how scientific developments and applications are applied and used to address specific problems or issues in local and global contexts.

This report, particularly in Grades 9 and 10, should be between **700** and **1200** words in length.

Students should be able to:

- **Explain** the ways in which science is applied and used to address a specific problem or issue.
- **Discuss** the effectiveness of science and its application in solving the problem or issue.
- **Discuss** and **evaluate** the moral, ethical, social, economic, political, cultural and environmental implications of the use of science and its application in solving specific problems or issues.

Assessment tasks should give students the opportunity to explore how science is used to address a specific problem or issue.

Students are required to critically discuss and evaluate the implications associated with the use and application of science by considering moral, ethical, social, economic, political, cultural and environmental factors.

Suitable assessment tasks for criterion A include written pieces of work, essays, case studies and research projects, as well as debates, oral and multimedia presentations.

Key word	Definition
Describe	to give a detailed account.
Discuss	to give an account including, where possible, a range of arguments for and against the relative importance of various factors and comparisons of alternative hypotheses.
Evaluate	to assess the implications and limitations.
Explain	to give a clear account, including causes and reasons or mechanisms.
State	to give a specific name, value or other brief answer without explanation or calculation.

B - Communication

Level	B: Communication	Advice and Clarifications
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **uses a limited range of scientific language correctly**. The student communicates scientific information with **limited effectiveness**. The student **makes little attempt** to document sources of information.	• I have presented my information using some scientific words or ideas • I have made an effort to present my information clearly. • I have made an effort to include a bibliography
3 - 4	The student **uses some scientific language correctly**. The student communicates scientific information with **some effectiveness**. The student **partially documents** sources of information.	• I have presented my information using some clearly described scientific terms and ideas. • I have made an effort to present my information clearly using both text and graphical sources, so that my audience can understand it, • I have included a bibliography.
5 - 6	The student **uses sufficient scientific language correctly**. The student communicates scientific information **effectively**. The student **fully documents** sources of information **correctly.**	• I have presented my information using a range of clearly described scientific terms and ideas. • I have presented my information clearly using text and graphics with impact, so that my audience can understand it. • I have included references to my sources at the point of use. • I have included a detailed bibliography.

B – Explanatory Notes

Communication in science enables students to develop the communication skills to become competent and confident when communicating information in science.

Students should be able to use different communication modes, including verbal (oral, written) and visual (graphic, symbolic), as well as appropriate communication formats (laboratory reports, essays, and multimedia presentations) to effectively communicate scientific ideas, theories, findings and arguments in science.

Students should be able to:

- Use **scientific language** correctly.
- Use appropriate communication modes and formats.
- Acknowledge the work of others and the sources of information used by appropriately documenting them using a **recognized referencing system**.

Suitable assessment tasks for criterion B include scientific investigation reports, research essays, case studies, written responses, debates and multimedia presentations among others.

- The first strand of the criterion requires students to use **scientific language** correctly. Teachers are expected to determine within the context of the task what constitutes acceptable evidence for “limited range”, “some” and “sufficient” scientific language and communicate this to students.
- Effective communication in this context implies that the work achieves what it intends to, including being successful and convincing, well structured and presented in a logical sequence, and supported by evidence as appropriate. It involves the use of appropriate communication modes and formats to communicate scientific ideas, theories or findings to a particular audience in a successful way.
- Criterion B can be used with a range of tasks such as written pieces of work as well as oral and multimedia presentations. In all cases students are expected to acknowledge the work of others and the sources of information used by **referencing** (or citing). The IB does not prescribe any particular referencing system. Schools are allowed to follow a recognized referencing system of their choice in a consistent manner.
- The statement “when appropriate to the task” means that, depending on the nature of the tasks (and generally for written pieces of work), students are required to **fully document the sources used.**

Key word	Definition
Document	to credit fully all sources of information used by referencing (or citing), following one recognized referencing system. References should be included in the text and also at the end of the piece of work in a reference list or bibliography.

C – Knowledge and Understanding

Level	C – Knowledge and Understanding	Advice and Clarifications
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **recalls some** scientific ideas, concepts and/or processes. The student applies scientific understanding to solve **simple problems**.	• I know about the main ideas in this topic (see previous page) • I can answer simple problems on this topic.
3 - 4	The student **describes** scientific ideas, concepts and/or processes. The student applies scientific understanding to solve **complex problems in familiar situations.** The student **analyses** scientific information by identifying parts, relationships or causes.	• I can describe and give examples of the main ideas in this topic (see previous page) • I can use information from tables and graphs. • I can write conclusions from the information given
5 - 6	The student **uses** scientific ideas, concepts and/or processes **correctly** to **construct scientific explanations**. The student applies scientific understanding to solve complex **problems including those in unfamiliar situations**. The student **analyses** and **evaluates** scientific information and **makes judgments supported by scientific understanding**.	• I can explain and give examples of the main ideas in this topic (see previous page) • I can use information from tables and graphs in problems that are new to me. • I can write conclusions and evaluations from the information given

C – Explanatory Notes

Knowledge and understanding of science enables students to demonstrate their understanding of science by applying scientific knowledge to construct scientific explanations, solve problems and formulate scientifically supported arguments.

Students should be able to:

- **Recall** scientific knowledge and use scientific understanding to construct scientific explanations
- **Apply** scientific knowledge and understanding to solve problems set in familiar and unfamiliar situations
- **Critically analyse** and **evaluate** information to make judgments supported by scientific understanding.
- The first strand of the criterion refers to students using scientific knowledge. It requires students to "recall/describe/use scientific ideas, concepts and/or processes". However, this list is not exclusive and may also include scientific models, laws, principles and theories as appropriate to the task.
- To reach the highest level of the criterion, students are required to make scientifically supported judgments about the **validity** and/or **quality** of the information presented to them. For this purpose assessment tasks could include questions dealing with "scientific claims" presented in media articles (newspapers, television, the internet, and so on), or the results and conclusions from experiments carried out by others, or any question that challenges students to critically analyse and evaluate the information and that allows them to formulate arguments about its validity and/or quality using their knowledge and understanding of science.

Key word	Definition
Analyse	to identify parts and relationships and to interpret information to reach a conclusion.
Complex problems	refers to problems that are set in a familiar or unfamiliar context and require analysis. These problems can often be broken down into sub-problems or stages, each of which requires the selection and application of the appropriate principle, rule, equation or method.
Evaluate	to assess the implications and limitations; to make judgments about the value of ideas, works, solutions and methods in relation to selected criteria.
Simple problems	refers to straightforward problems that are clearly stated and set in a familiar context, and require the student to apply the appropriate principle, rule, equation or method.
Unfamiliar situation	refers to a problem or situation in which the context or the application is modified so that it is considered unfamiliar for the student.

D – Scientific Inquiry

Level	D – Scientific Inquiry	Advice and Clarifications
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **attempts to state** a focused problem or research question. The method suggested is **incomplete**. The student **attempts to evaluate** the method and respond to the focused problem or research question.	• I have attempted to write an aim. • I have written a simple method. • I have attempted to evaluate the method.
3 - 4	The student **states** a focused problem or research question and **makes a hypothesis** but **does not explain** it using scientific reasoning. The student selects **appropriate** materials and equipment and writes a **mostly complete** method, mentioning **some of the variables** involved and how to manipulate them. The student **partially evaluates** the method. The student **comments** on the validity of the hypothesis based on the outcome of the investigation. The student **suggests some** improvements to the method or makes suggestions for further inquiry when relevant.	• I have written an aim and have described the independent, dependent and controlled variables. • I have written a hypothesis. • I have I have written a method that allows for the collection of relevant data. • I have described some difficulties in the method and ways that it could be improved. • I have compared my conclusion to my hypothesis. • I have described some ways that the investigation can be extended.
5 - 6	The student states a **clear** focused problem or research question, **formulates a testable hypothesis** and **explains** the hypothesis using scientific reasoning. The student selects appropriate materials and equipment and writes a **clear, logical** method, mentioning **all of the relevant variables** involved and how to control and manipulate them, and describing how the data will be collected and processed. The student **evaluates** the method, commenting on its **reliability** and **validity**. The student comments on the validity of the hypothesis based on the outcome of the investigation. The student suggests **realistic** improvements to the method and makes suggestions for further inquiry when relevant.	• I have written an aim and have described the independent, dependent and controlled variables appropriately for a fair test. • I have written a hypothesis using appropriate scientific ideas. • I have written a detailed method that allows for the collection of sufficient relevant data. • I have evaluated the method and have commented on the suitability of the instruments and whether it was a fair test. • I have given realistic and relevant improvements to my method that follow from my evaluation and I have described specific ways that the investigation can be extended.

D – Explanatory Notes

This criterion enables students to design and carry out scientific investigations independently.

Students should be able to:

- State a **focused problem** or **research question** to be tested by a scientific investigation.
- Formulate a **testable hypothesis** and explain it using scientific reasoning.
- Design and carry out scientific investigations that include variables and controls, material and/or equipment needed, a method to be followed, and the way in which the data is to be collected and processed.
- Evaluate the **validity** and **reliability** of the method.
- Judge the **validity** of the hypothesis based on the outcome of the investigation.
- Suggest improvements to the method or further inquiry, when relevant.
- To **explain** the hypothesis using scientific reasoning requires students to include in their explanations the scientific concepts, theories or understanding that support their thinking of why or how something might happen the way they have hypothesized or predicted.
- When designing a scientific investigation, students should develop a method that will allow them to collect sufficient data so that the research question can be answered and the reliability of the data evaluated.
- Students will be provided with an **open-ended** problem to investigate. An open-ended problem is one that has several independent variables from which students can/could choose one as a suitable basis for the investigation. This should ensure that students formulate a range of plans and that there is sufficient scope to identify both independent and controlled variables.

Key word	Definition
Explain	to give a detailed account of causes, reasons or mechanisms.
Reliability of the method	refers to whether the method allows for the collection of sufficient reliable data to answer the question. This depends upon the selection of the measuring instrument, the precision and accuracy of the measurements, errors associated with the measurement instrument, the size of the sample, the sampling techniques used and the number of readings.
Validity of the method	refers to whether the method allows for the collection of sufficient valid data to answer the question. This includes factors such as whether the measuring instrument measures what it is supposed to measure, the conditions of the experiment and the manipulation of variables (fair testing).

E – Processing Data

Level	E – Processing Data	Advice and Clarifications
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **collects some** data and **attempts to record** it in a suitable format. The student **organizes and presents** data using **simple numerical or visual forms.** The student attempts to identify **a trend, pattern or relationship** in the data. The student attempts to draw a conclusion but this is **not consistent** with the interpretation of the data.	• I have obtained some results in an experiment. • I have written my results in a simple table. • I have attempted to identify a pattern, trend or relationship in my results. • I have written a simple conclusion.
3 - 4	The student collects **sufficient** relevant data and records it in a **suitable format.** The student organizes, transforms and presents data in numerical and/or visual forms, with a few **errors or omissions.** The student **states** a trend, pattern or relationship shown in the data. The student draws a conclusion **consistent** with the interpretation of the data.	• I have obtained a range of results from my experiment. • I have written my results in a table. • I have processed my results and have presented them. • I have identified a pattern, trend or relationship in my results. • I have written a conclusion based on my results.
5 - 6	The student collects sufficient relevant data and records it in a suitable format. The student organizes, transforms and presents data in numerical and/or visual forms **logically and correctly.** The student **describes** a trend, pattern or relationship in the data and comments on the **reliability** of the data. The student draws a **clear** conclusion based on the **correct** interpretation of the data and **explains** it using scientific reasoning.	• I have obtained an appropriate range of results from my experiment. • I have written my results in a table, with a title, labels and units. • I have processed my results correctly and have presented them in an appropriate way. • I have calculated and commented on the precision and accuracy of the data. • I have identified trends, patterns or relationships in my results and calculated any values as appropriate. • I have written a correct scientific conclusion for my results.

E – Explanatory Notes

Processing data refers to enabling students to organize, process and interpret quantitative and qualitative data.

Students should be able to:

- **Collect** and **record** data using units of measurement as and when appropriate.
- **Organize, transform** and **present** data using numerical and visual forms analyse and interpret the data.
- Draw conclusions **consistent** with the data and supported by **scientific reasoning**.
- Suitable assessment tasks for criterion E include scientific investigations carried out by students, as well as laboratory reports and studies that provide students with sufficient raw data for processing and further analysis.
- Suitable assessment tasks can include scientific investigations carried out by students where students collect and record raw data for themselves, as well as data from investigations carried out by others (generally data from scientific articles in journals, books or the internet).
- Assessment tasks where the data is provided in preformatted tables with columns, headings and units of measurement are unlikely to allow students to reach the highest level of achievement for this criterion.

Key word	Definition
Numerical forms	may include mathematical calculations such as averaging, or determining values from a graph or table. Qualitative data: refers to non-numerical data or information that it is difficult to measure in a numerical way.
Quantitative data	refers to numerical measurements of the variables associated with the investigation.
Transforming data	involves processing raw data into a form suitable for visual representation. This process may involve, for example, combining and manipulating raw data to determine the value of a physical quantity (such as adding, subtracting, squaring or dividing), and taking the average of several measurements.
Suitable format	may include tables with appropriate headings and units, large clearly labelled diagrams or concisely worded observations.
Visual forms	may include drawing graphs of various types appropriate to the kind of data being displayed (line graphs, bar graphs, histograms, pie charts, and so on).

F –Attitudes in Science

Level	F – Attitudes in Science	Student Description
0	The student does not reach a standard described by any of the descriptors given below.	The student does not reach a standard described by any of the descriptors given below.
1 - 2	The student **requires some guidance** to work safely and **some assistance** when using material and equipment. The student requires **some guidance to** work responsibly with regards to the living and non-living environment. When working as a part of a group, the student needs **frequent reminders to** cooperate with others**.**	• I attempted the experiment but often needed help. • I had to be reminded about working safely • I found that working with other students was difficult and had to be reminded about cooperation several times
3 - 4	The student requires **little guidance** to work safely and **little assistance** when using material and equipment. The student **works responsibly** with regards to the living and non-living environment. When working as part of a group the student cooperates with others on **most occasions**.	• I carried out the experiment with only occasional help. • I had due regard for the safety of myself, others and the environment. • I found that working with other students was straightforward.
5 - 6	The student requires **no guidance** to work safely and uses material and equipment competently. The student **works responsibly** with regards to the living and non-living environment. When working as part of a group, the student **cooperates with others**.	• I carried out the experiment without any help. • I had due regard for the safety of myself, others and the environment • I found that working with other students enhanced the experiment

F – Explanatory Notes

Attitudes in science encourages students to develop safe, responsible and collaborative working practices when carrying out experimental work in science.

During the course students are expected to:

- Work **safely** and use material and equipment **competently.**
- Work **responsibly** with regards to the living and non-living environment.
- Work **effectively** as individuals and as part of a group by collaborating with others.

Evidence of performance for this criterion should be collected from the observation of students when working individually and in groups.

This criterion should be internally assessed but is not externally moderated.

AB Assessment Example

This article illustrates one way of referencing sources appropriately.

Introduction

Before the refrigerator was invented it was very difficult to preserve fresh food. Various ways of keeping food cool were used, depending on the culture. For example, snow was commonly used and still is in some parts of the world. (Encyclopaedia Brittanica - Refrigeration)

Each culture had its own way of preserving food. The ability to keep food fresh without altering its original taste and nutrients was and still is very important.

Development

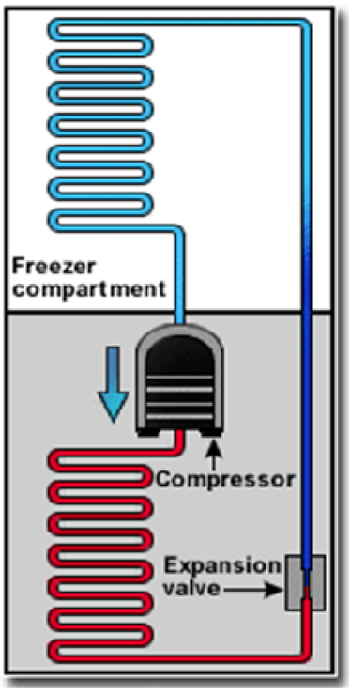
Early experiments in refrigeration were performed by Benjamin Franklin in 1758 (Wikipedia - Refigeration). He managed to cool objects down to temperatures of -14^{0}C and declared that; "From this experiment, one may see the possibility of freezing a man to death on a warm summer's day". (Wikipedia - Refigeration).

The Science of the Refrigerator – Volatile Liquids

All modern refrigerators make use of a volatile liquid - a liquid that will turn to a gas very easily. A common liquid in older fridges is Freon though this has now been banned because it is harmful to the environment.

In today's refrigerators another gas is used (HFC) which is less harmful for the ozone layer but is a powerful greenhouse gas causing global warming. Scientists are looking for environmentally friendly chemicals such as hydrocarbons that can be used in fridges. (How Things Work - How Does a Refrigerator Work?)

(Graphic from (How Things Work - How Does a Refrigerator Work?).



Graphic courtesy: Science Treasure Trove

AB Assessment Example

The Science of the Refrigerator – Removing Heat Energy

The volatile liquid is pumped through a network or circuit of fine tubes at the back of the fridge.

The liquid takes heat energy out of the fridge compartment and in doing so turns to a gas. On the way back around the circuit the gas is then turned back into a liquid by a compressor.

In taking heat out of the fridge compartment, the contents will have become colder.

The effect is rather like sweating – on a hot day you will sweat. The sweat will take heat energy from you and so turn to a gas and evaporate. In doing so you lose heat energy, so you cool down.

Social, Cultural and Economic Impact

Refrigeration led to a more varied diet and improved health. Exotic foods can be imported and enjoyed all over the world.

Refrigeration is a competitive industry and has a big impact on the global economy (import and export). A fridge has become a necessity for every household and has changed our eating habits and culture. Refrigeration is also very useful in a wide range of other areas such as air conditioning in buildings and the storage of medicines (U.S. EPA - Refrigeration and Air Conditioning).

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Source4. 2012 <http://worldbookonline.com/student/article?id=ar463300&st=refrigeration>.
U.S. EPA - Refrigeration and Air Conditioning. February 2012 <http://www.epa.gov/ozone/snap/refrigerants/>.
Wikipedia - Refigeration. February 2012 <http://en.wikipedia.org/wiki/Refrigeration>.

DE Assessment Example

Scenario

Students carried out an investigation to look at a factor that affects the rate that a sugar cube dissolves. The students decided to look at the effect of temperature.

A previous class of students have performed a similar experiment. Their conclusion, as an **average for the whole class**, was that the sugar cubes should "dissolve in **less than 5 seconds** in a cup of tea".

Experimental Details

- They used a stopwatch to measure the time. They started the stopwatch when the sugar cube was dropped into a beaker of water at a certain temperature. One of the students then stirred the water until the sugar cube dissolved.
- They stopped the stopwatch when they could not see the sugar cube any longer. The students took turns to decide when to start and stop the stopwatch and stir the water.
- The thermometer used to measure the temperature of the water had a precision of ±0.5^{0}C and the stopwatch had a precision of 0.01s.

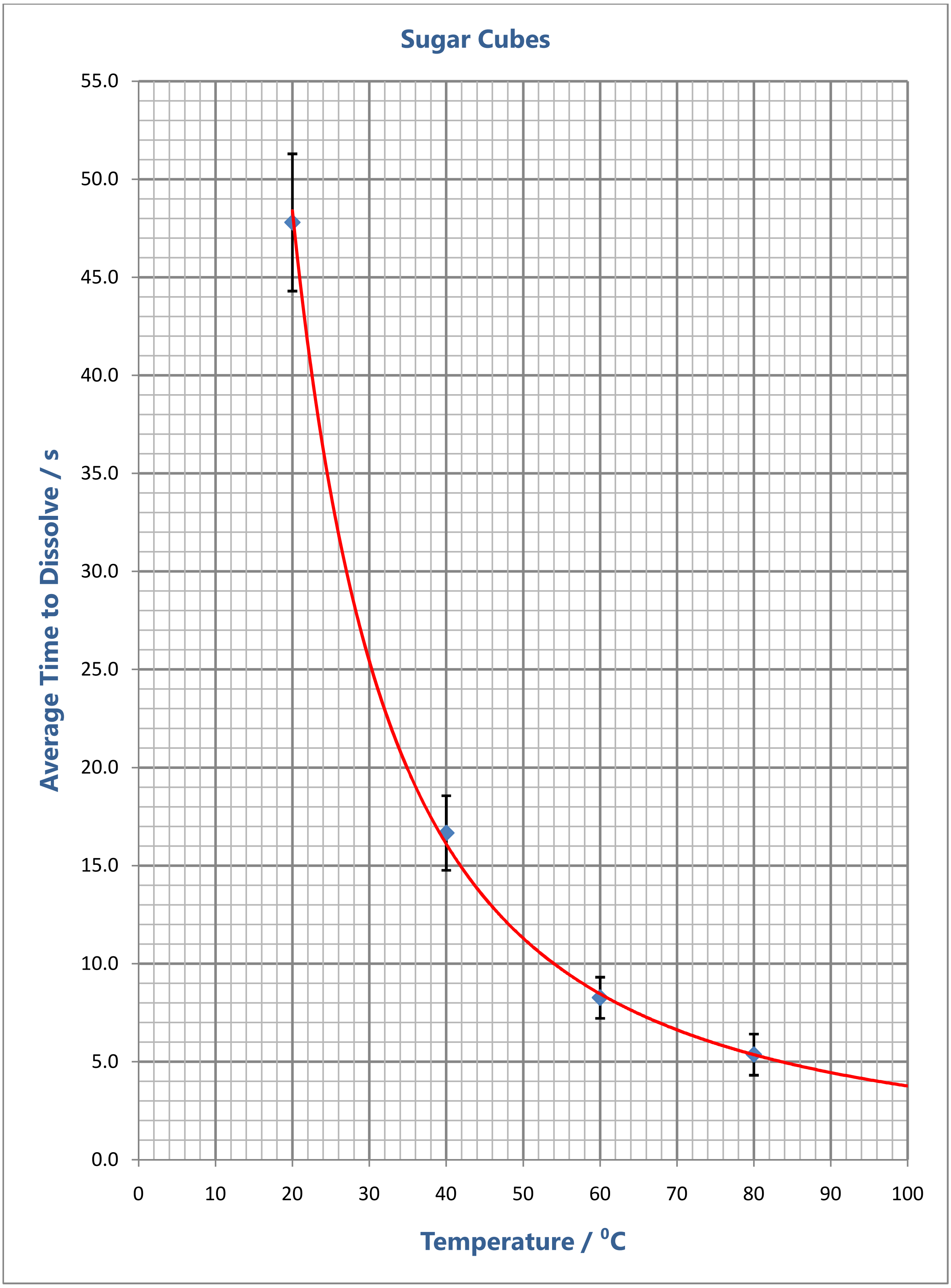
Results

Temperature of water	Time for sugar cube to dissolve		
^{0}C	s		
20	44.1	48.2	51.1
40	17.2	18.3	14.5
60	9.4	8.1	7.3
80	4.4	6.5	5.2

Processed Data

Temperature of water	Average Time to Dissolve	Range of Times to Dissolve	Uncertainty in Average Time (Half of range)	Percentage Uncertainty in Average Time
^{0}C	s	s	s	%
20	47.8	7.0	3.5	7.3
40	16.7	3.8	1.9	11.4
60	8.3	2.1	1.1	12.7
80	5.4	2.1	1.1	19.6
			Average % Uncertainty	**12.7**

DE Assessment Example



DE Assessment Example

Comments on the Validity of the Method

This deals with the question of a **fair test**. A test is fair if one, and only one, factor is changed and all other factors are fixed (controlled). The students might begin with something like this;

"We changed the temperature of the water and always used only one sugar cube. This aspect of our measurement was fair.

However, we all tried starting and stopping the stopwatch so we had different people doing the measuring. This might make the experiment less reliable because different people might have different opinions on when all of the sugar had dissolved.

Also, we stirred the water each time to make sure that the dissolving was happening in the same way everywhere in the water. This aspect of our method was definitely fair.

However, we might have all stirred the water slightly differently (faster or slower) and this might make our data less reliable. "

Comments on the Reliability of the Method

This deals with the **suitability of the method used**. The students might begin with something like this. You should talk about the possible sources of error in your method.

"We made sure that the temperature was always within 0.5^{0}C. The stopwatch was precise - to 0.01 seconds - so our method used appropriate equipment.

We also repeated the measurements to ensure that we could take an average value rather than just one result. This also allowed us to see if our results were similar each time. It also allowed us to find out how spread out our results were at each temperature. A small range of results would suggest a reliable experiment. Our method gave us an average uncertainty of around 13%, which is quite large. So we would say that our method was not very reliable."

Comments on the Accuracy of the Measurements

This is where you compare a value that you get from your data to a **known or accepted value**. In this case, we can compare the time taken for the sugar cube to dissolve. Looking at the line of best fit on the graph, the students might start with;

"The other class state that the sugar cubes will dissolve in a cup of tea in less than 5 seconds. The line of best fit for our data goes below the 5 second line at approximately 83^{0}C. So our data suggests that our value is in agreement and therefore accurate provided that the temperature is above 83^{0}C. "

DE Assessment Example

Comments on the Precision of the Measurements

This is a comment on how **repeatable** your measurements are. It is best done using a calculation of the **average percentage uncertainty**, from the data. The students might start with;

"We calculated the uncertainty and then the percentage uncertainty for the data. For example, at 20^{0}C the formula that we used was;

$$Percentage\ Uncertainty = \frac{Uncertainty}{Average\ Value} \times 100$$

$$At\ 20°\mathrm{C}:\ Percentage\ Uncertainty = \frac{3.5}{47.8} \times 100$$

$$= 7.3\%$$

We did this calculation for each temperature. Then we calculated the average value for the percentage uncertainty and got a figure of 12.7%"

Comments on the Accuracy of the Measurements

This is where you compare a value that you get from your data to a **known or accepted value**. In this case, we can compare the time taken for the sugar cube to dissolve. Looking at the line of best fit on the graph, the students might start with;

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Tips for Planning

Aim
• **What** are you going to investigate?
• **How** are you going to do it?

Hypothesis
• What will be the effect of **changing** the independent variable?
• Explain using **scientific knowledge** why you think this will happen
• Have you any trial **preliminary data** to help you identify the significance of possible variables?

Variables
Make a list of your variables in the following way;
• **Independent** variable – the factor that you change and measure.
• **Dependent** variable – the factor that changes in your experiment that you will also measure.
• **Controlled** (fixed) variables – factors that you will keep the same to make it a **fair test**.

Apparatus
• Write a list of apparatus you will need in order to do your experiment.
• Draw a labelled diagram of your apparatus for each design that you make.

Method
Describe what it is you are trying to do in this investigation. It is good to make a plan that is a step by step guide, so that somebody else could follow it.
• Describe how you will make your experiment a **fair test**.
• Describe how you will make your experiment **safe.**
• Explain how you will make your measurements **precise**
• Explain how you will make your measurements **accurate**
• State the **number of measurements** that you intend to make.
• State the number of times that you intend to **repeat** your measurements.

Tips for Analysing and Evaluating

Data Collection
Make sure that all tables have;
• A heading (title) as appropriate – it should be clear what the data shows.
• **Labels** and **units** where appropriate
• **Uncertainties** for all raw data where appropriate.

Data Processing
• **Calculations** (e.g. average, range, uncertainty in the dependent variable, calculation of a theory…)
• An appropriate **graph** (an X-Y scatter graph for continuous data, a Bar chart for discontinuous data)
Make sure that all graphs have;
• A **title** – it should be clear what the graph shows.
• **Labels** and **units** where appropriate
• Uncertainties represented as **error bars**, where appropriate.
• A **line of best fit** through the uncertainties, where appropriate.

Conclusion and Evaluation
Describe what your results tell you – look for **trends and patterns** in your data.
Explain the results using **scientific knowledge** – is there a theory that you can use?
Compare your results to your hypothesis. Do your results **support** your hypothesis?
Evaluate the strengths and weaknesses of your experiment – calculate percentage errors.
Describe **another factor** that you could investigate and outline how you would do it.
Describe how you could **extend or modify** the investigation to look at a related area.
Complete a table as shown below

Problem	Why it is a problem	Possible Improvements

Average, Range, Uncertainty

Average, Range and Uncertainty

Look at the following table of results for the reaction time of a student;

Attempt	1	2	3	4	5
Reaction Time / s	0.45	0.32	0.51	0.25	0.39

a) Calculate the **average**;

$$Average = \frac{0.44 + 0.32 + 0.51 + 0.25 + 0.38}{5}$$

$$= 0.38\ s$$

Notice that the answer has the **same number of significant figures** as the numbers in the table.

b) Calculate the **range**;

$$Range = Highest\ value - Lowest\ value$$

$$= 0.51 - 0.25$$

$$= 0.26\ s$$

Again, the range has the same number of significant figures as the values used in the calculation.

c) Calculate the **uncertainty**;

$$Uncertainty = Standard\ Deviation\ of\ numbers$$

$$= 0.10\ s$$

d) Calculate the **percentage** uncertainty;

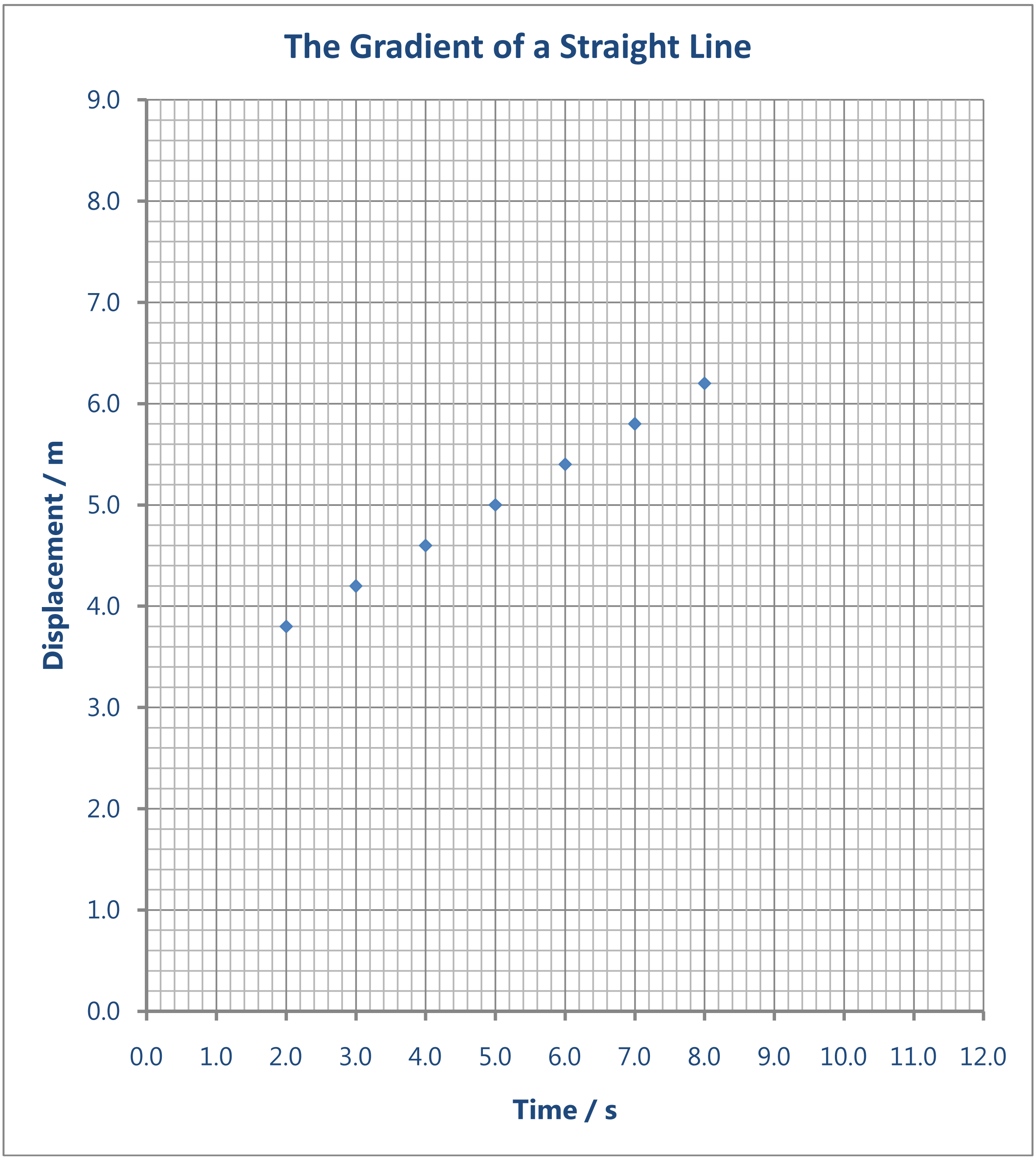
$$\%\ Uncertainty = \frac{Uncertainty}{Average\ Value} \times 100\%$$

$$= \frac{0.10}{0.38} \times 100$$

$$= 26\%$$

Gradients of Straight Lines

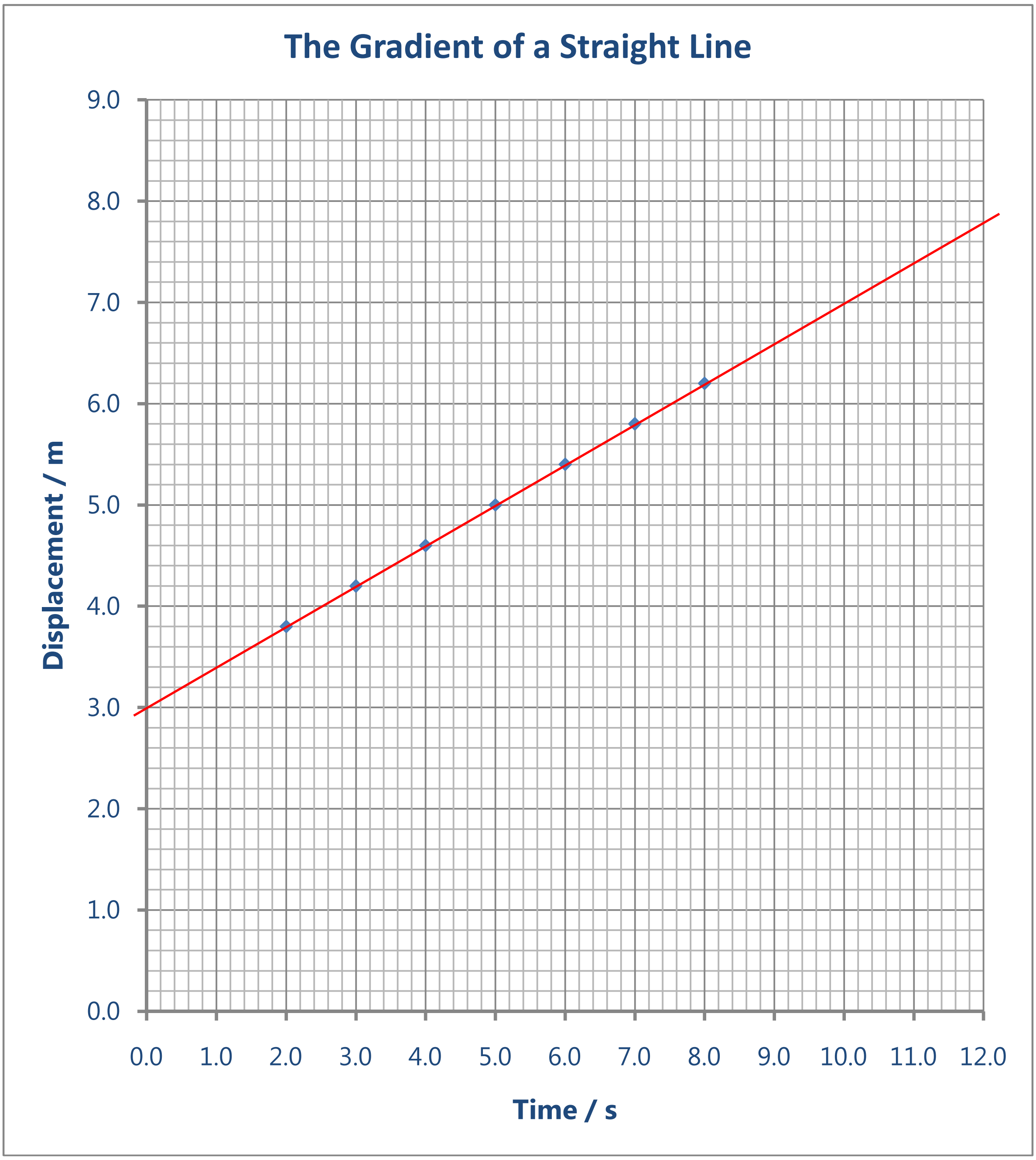
Suppose that we needed to find the gradient of a set of points, shown below. We will assume that there are **no uncertainties** in the data.



a) Start by drawing a smooth line of best fit through the data – extend the line so that it goes right across the page.

Gradients of Straight Lines

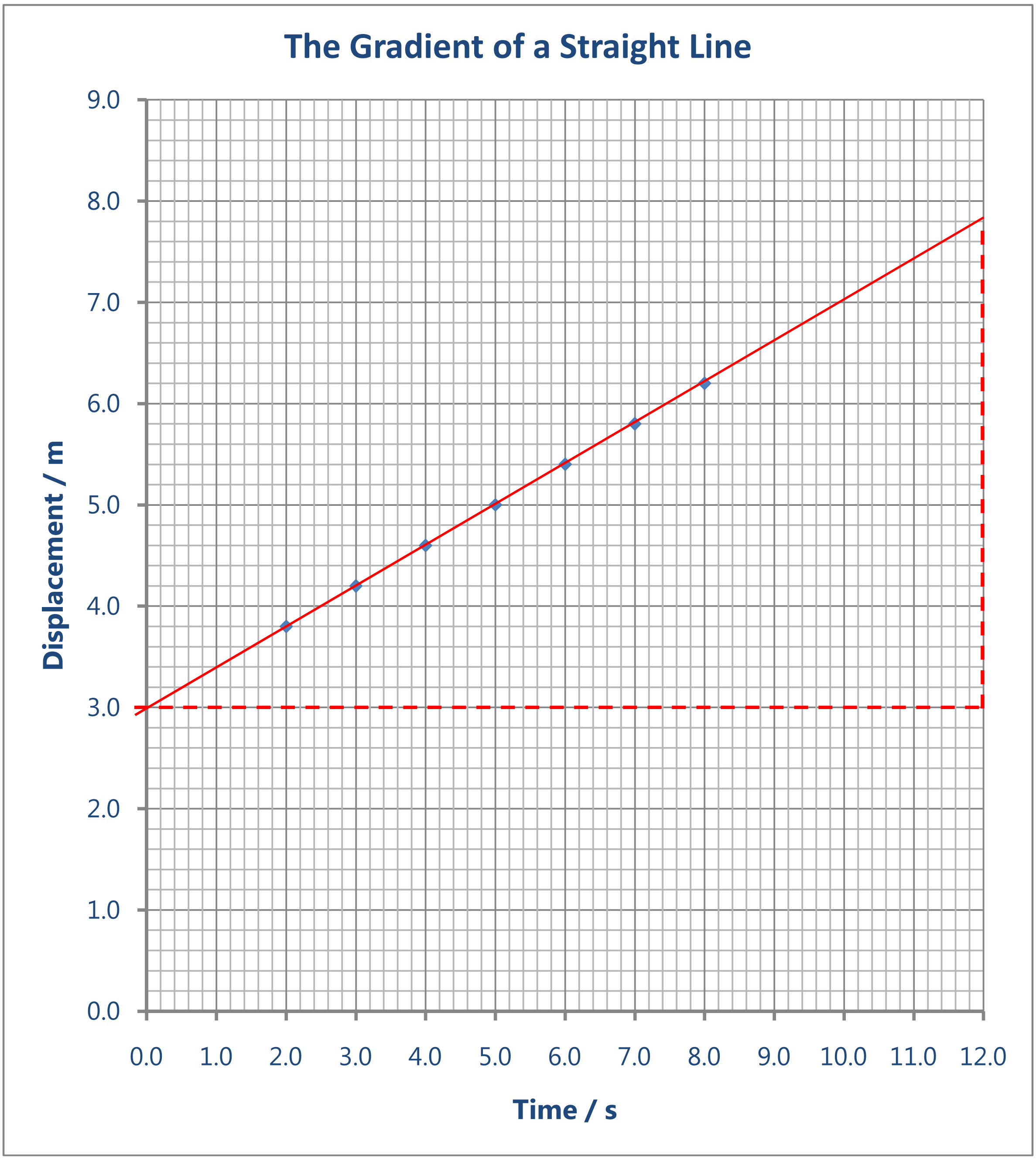
A line of best fit as shown (the simplest line or curve that passes through the uncertainties of the data points – in this case that would be a straight line through the data points themselves).



b) Then complete a triangle by drawing horizontally and vertically from the two ends of the line of best fit.

Gradients of Straight Lines

A line of best fit as shown.



c) Then complete a triangle by drawing **horizontally** and **vertically** from the two ends of the line of best fit.

d) Then find the **rise** (height of triangle) and **run** (width of triangle). Note that you **must** use the scales given on the graph.

Gradients of Straight Lines

From the graph we get;

$$Gradient = \frac{Rise}{Run}$$

$$= \frac{(7.8 - 3.0)\ m}{(12.0 - 3.0)\ s}$$

$$= \frac{4.8\ m}{9.0\ s}$$

$$= 0.53\ ms^{-1}$$

Notice that the gradient will almost always have a **unit**. The unit for the gradient is the unit of the y-value divided by the unit of the x-value. In this example it would be "metres per second".

Questions. Give the unit of the gradient in each case.

a) If the x value was "seconds" and the y value was "metres per second".

b) If the x value was "seconds" and the y value was "cm^3".

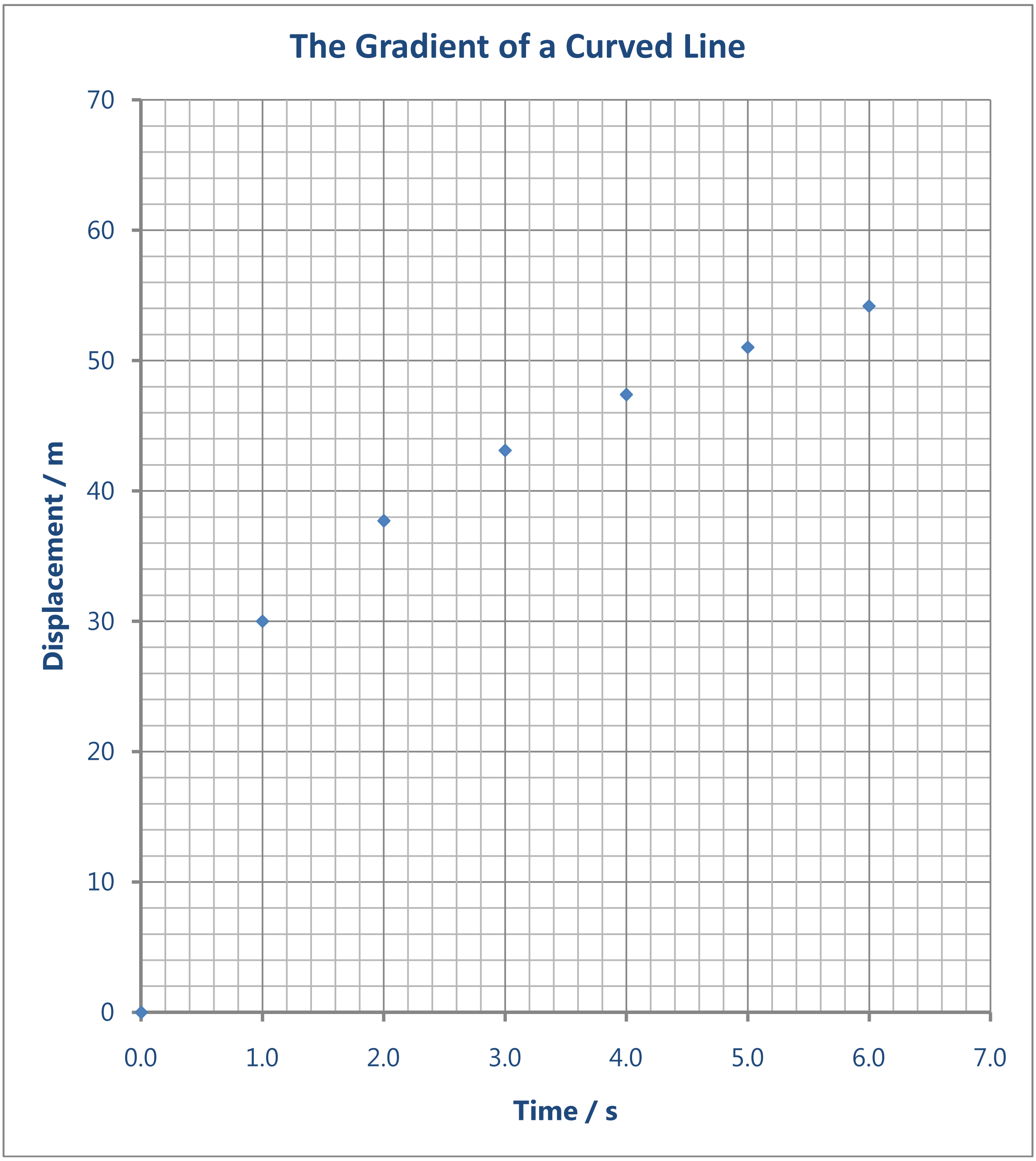
c) If the x value was "metres" and the y value was "newtons".

d) If the x value was "minutes" and the y value was "beats per minute".

Gradients of Curved Lines

Suppose that the displacement – time graph from the last example now had points that did not lie on a straight line.

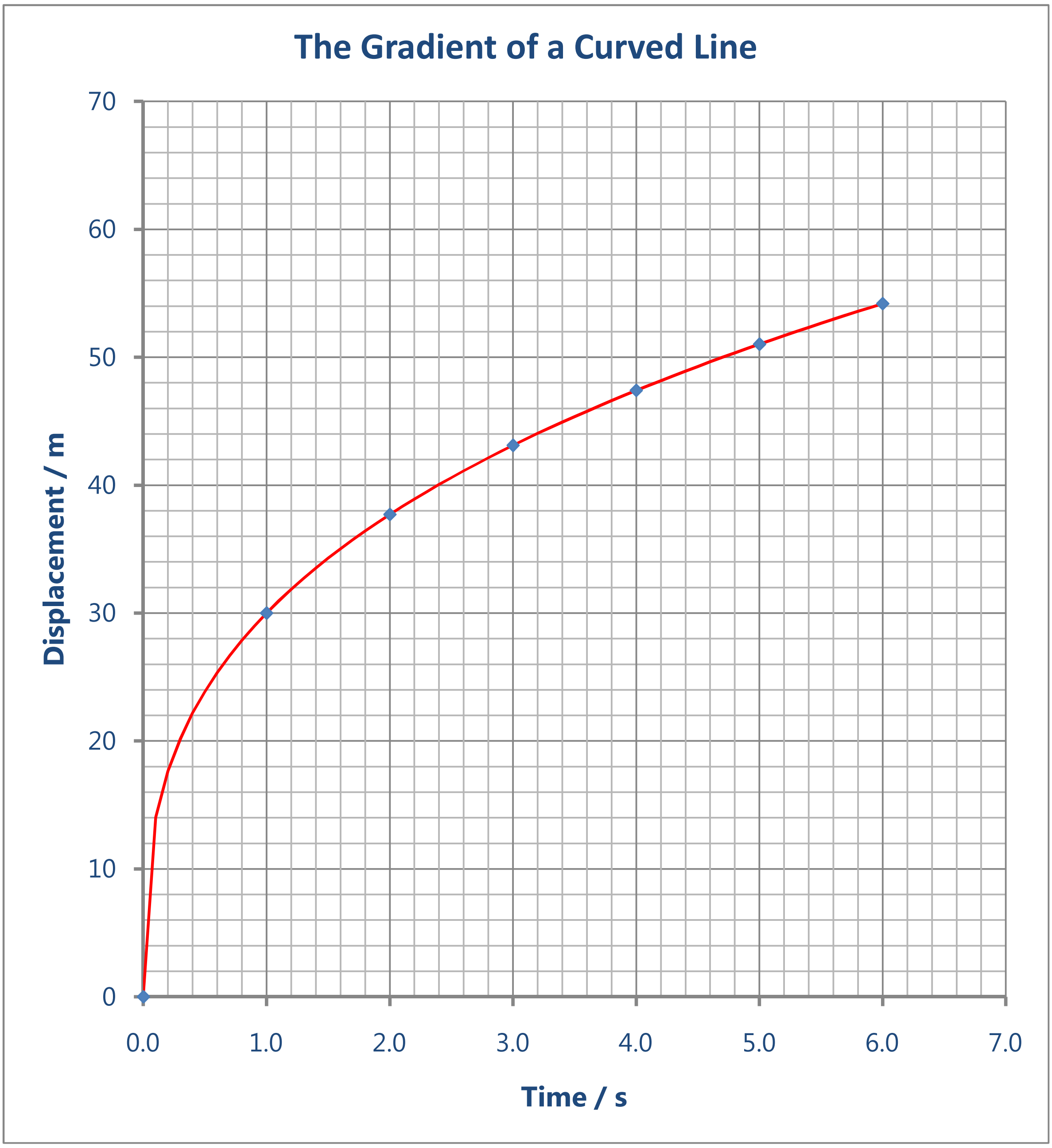
Once again assume that the data points have no uncertainty.



a) Proceed as before and draw an appropriate line of best fit – this time a **smooth curve**.

Gradients of Curved Lines

The line (curve) of best fit should look something like this (the simplest line or curve that passes through the uncertainties of the data points – in this case that would be a **curve** through the data points themselves).



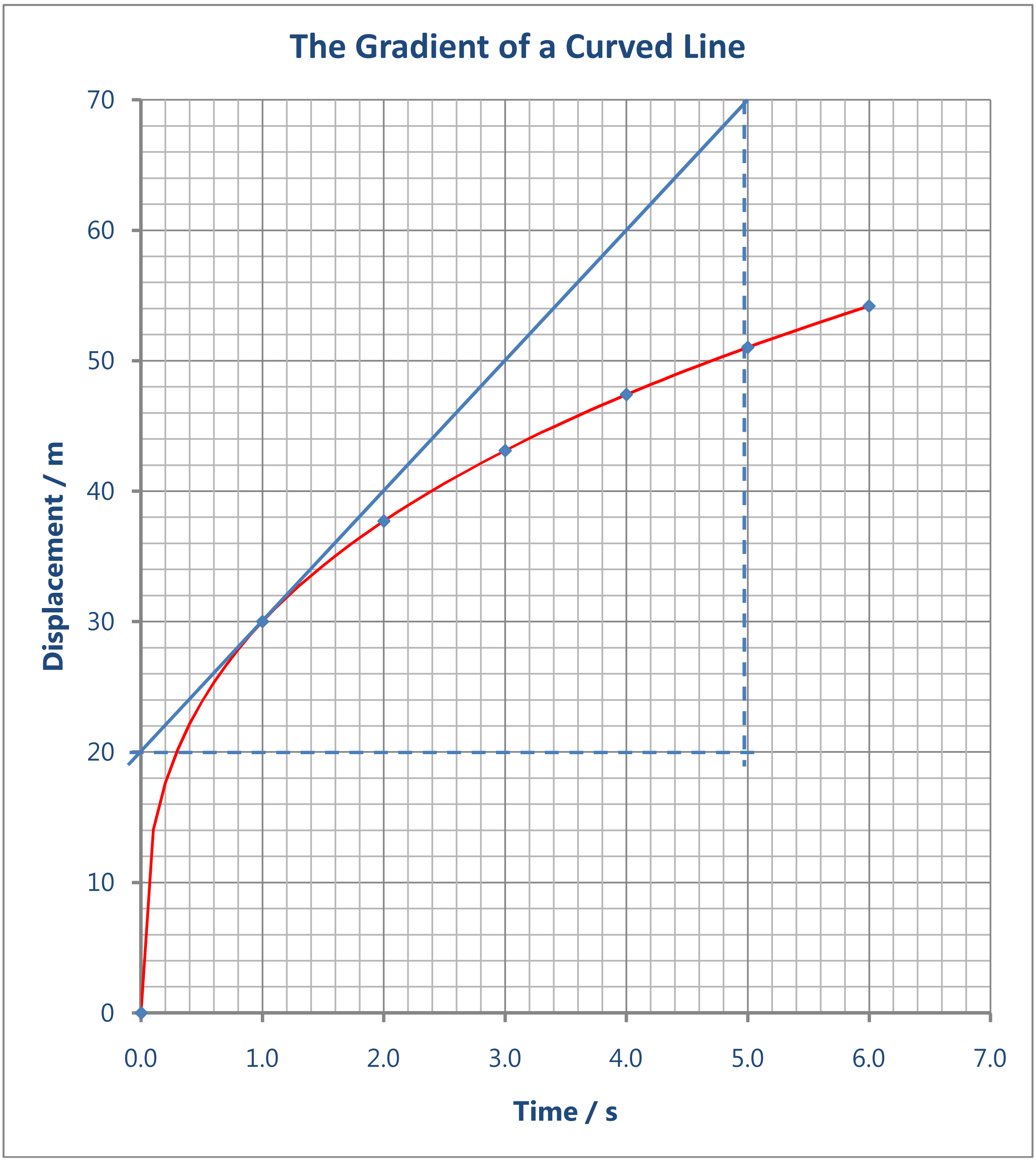
b) Suppose we needed to find the gradient of this curve at one particular time, say 1.0 second.

You would have to **estimate** the slope at 1.0 second by eye. The idea is that this line is **parallel** to the line of best fit at that particular point.

This is shown next, along with the usual construction lines to form a triangle.

Gradients of Curved Lines

The estimate of the gradient at 1.0 second should look something like this;



c) Now proceed as before to find the gradient.

$$Gradient = \frac{Rise}{Run} = \frac{(70 - 20)}{(5.0 - 0)} = 10\, ms^{-1}$$

Plotting Uncertainties

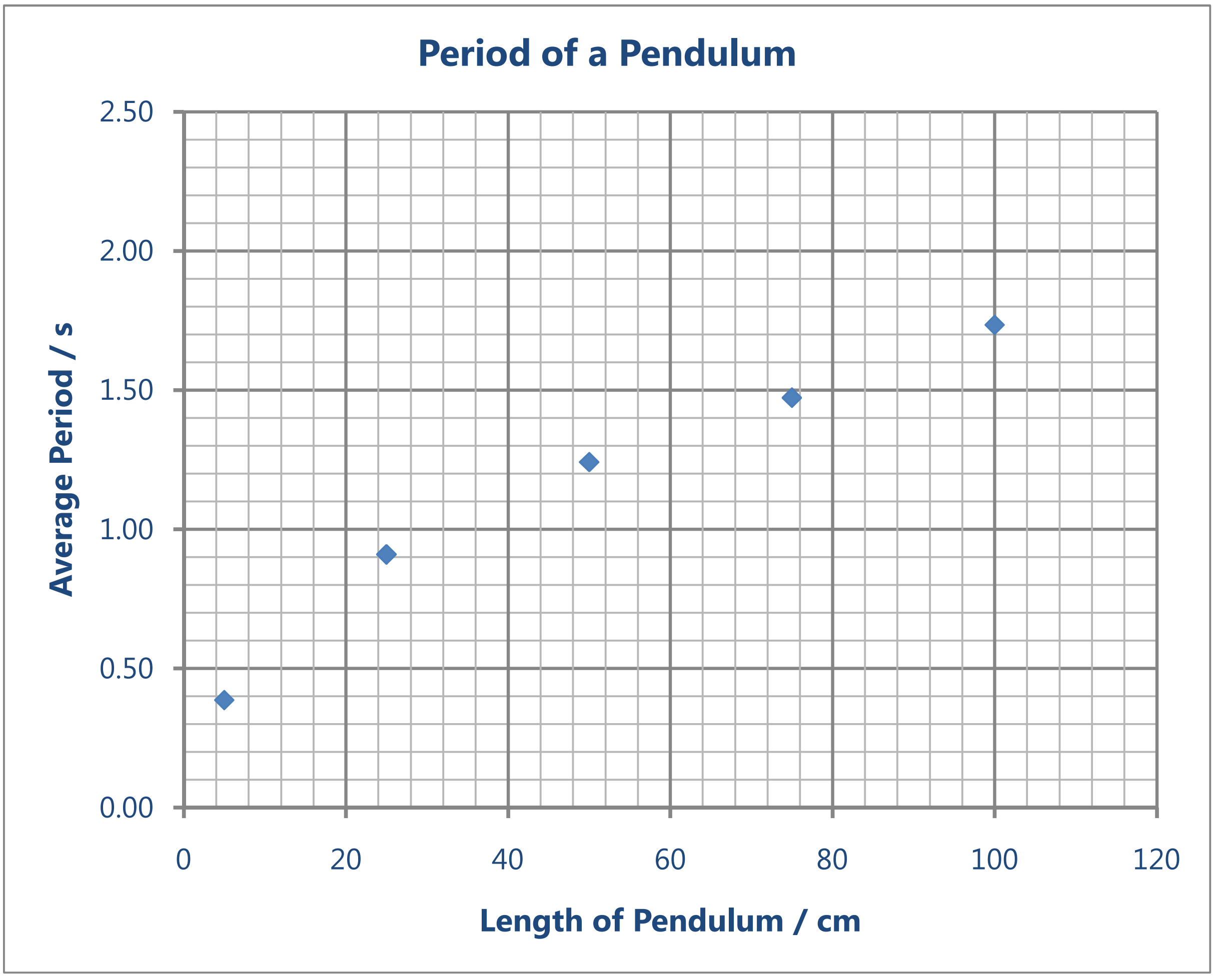
Suppose you perform an experiment to look at how the length of a pendulum affects its period.

You time 10 swings of the pendulum for different lengths, shown below.

Length	Times for 10 swings				Average Period	Uncertainty in Period
cm	s					
5	4.00	3.77	3.99	3.86	0.39	0.01
25	8.50	8.53	9.49	9.50	0.90	0.06
50	13.56	11.83	13.97	11.43	1.27	0.13
75	16.60	15.53	14.36	17.05	1.59	0.12
100	19.77	18.44	16.58	17.66	1.81	0.13

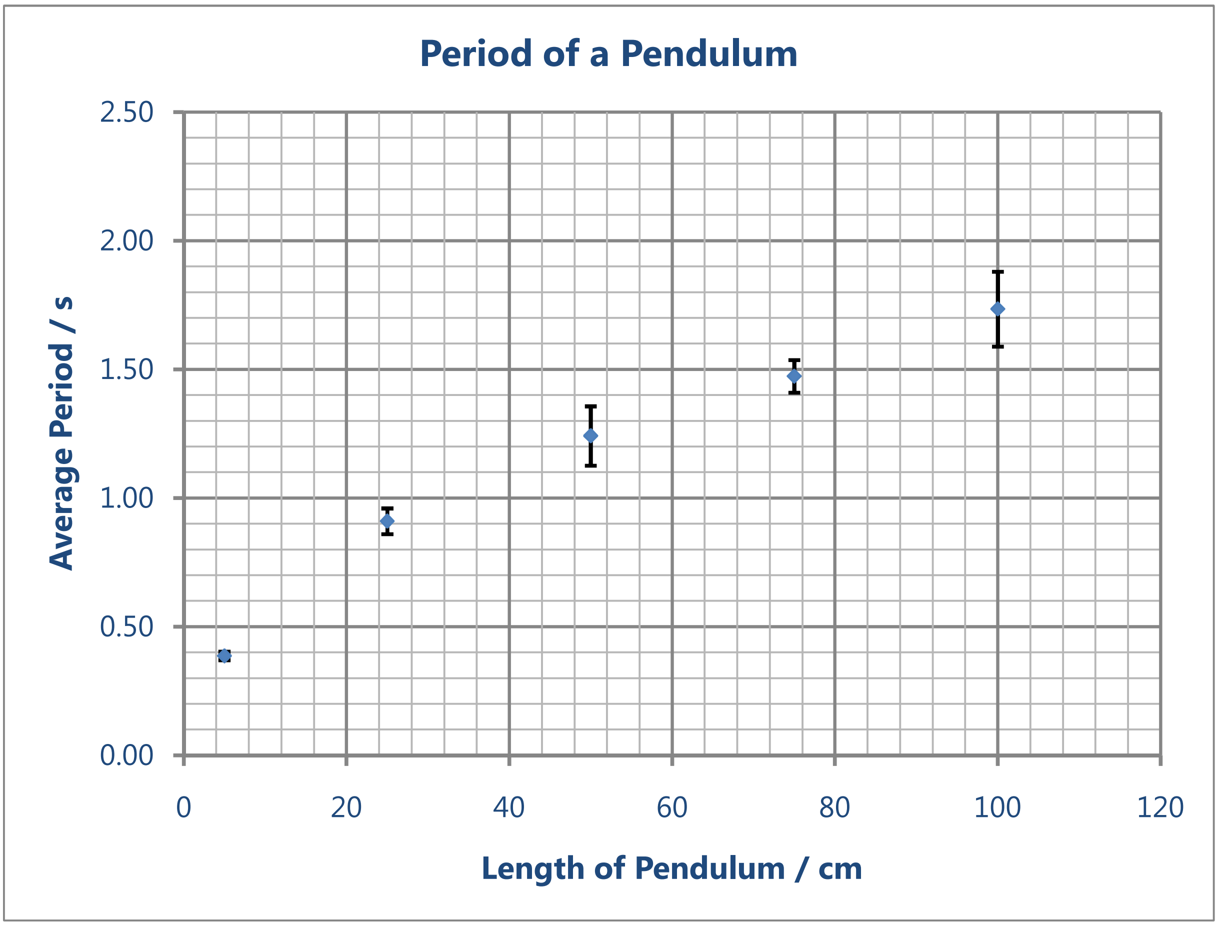
The average period (time for 1 full swing) and the uncertainty (standard deviation) are worked out in the usual way.

One possible graph of the results would be like this;



Plotting Uncertainties

You can display the uncertainties on the graph as error bars, like this;



The uncertainties, in this example, are in the **y-values**. In general there could be uncertainties in x-values or y-values, or both.

The **y-error** bars extend **upwards** and **downwards** from the data points. As an example, take the last point;

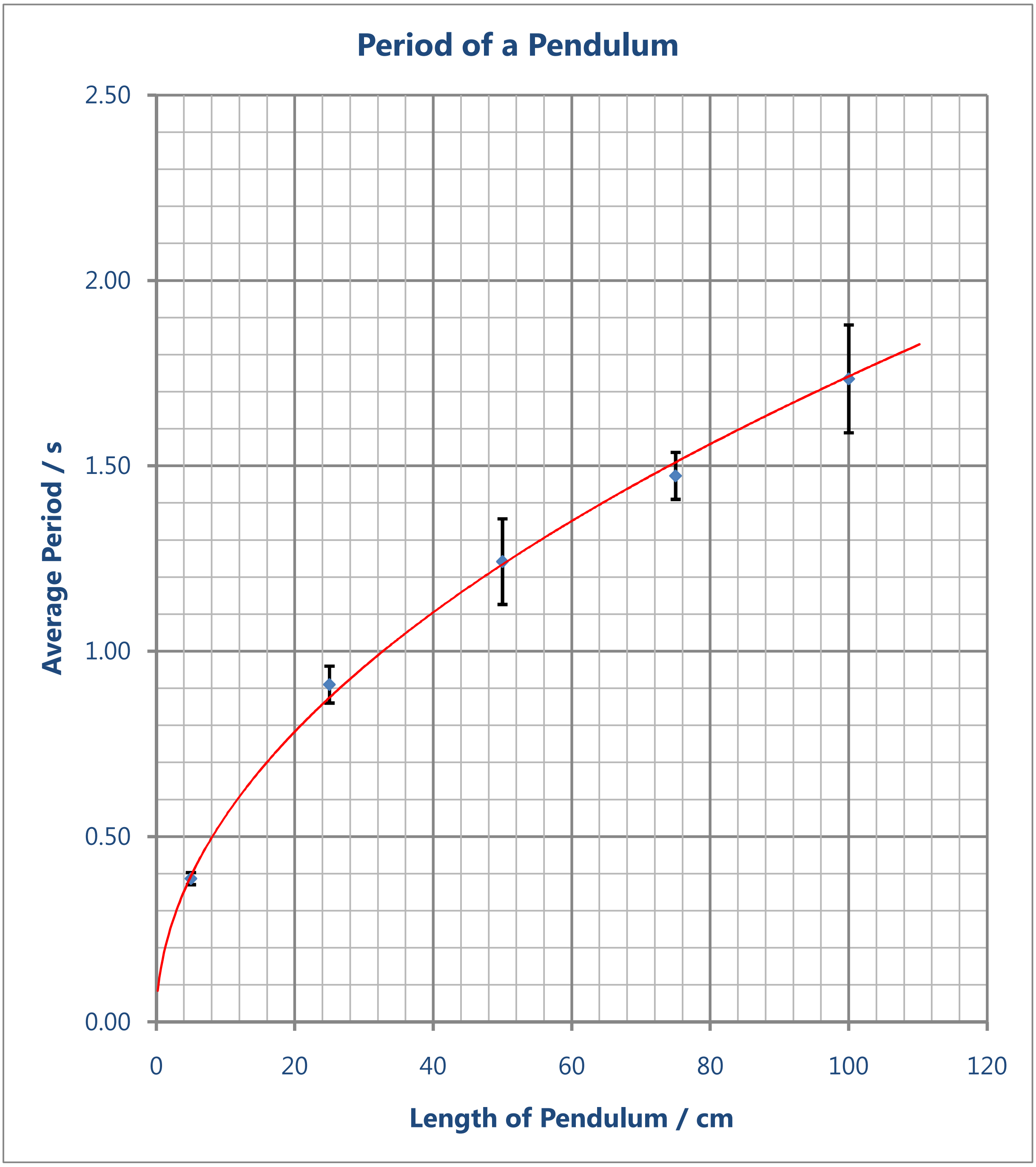
Average Period	Uncertainty in Period
s	s
1.81	0.13

This means that the error bar extends upwards from the data point by 0.13 s and downwards by 0.13s from the data point. The tips of the error bar would then be at (1.81 + 0.13) = 1.94s and (1.81 – 0.13) = 1.68s.

Notice that the error bar for the first data point is too small to see on this scale.

Plotting Uncertainties

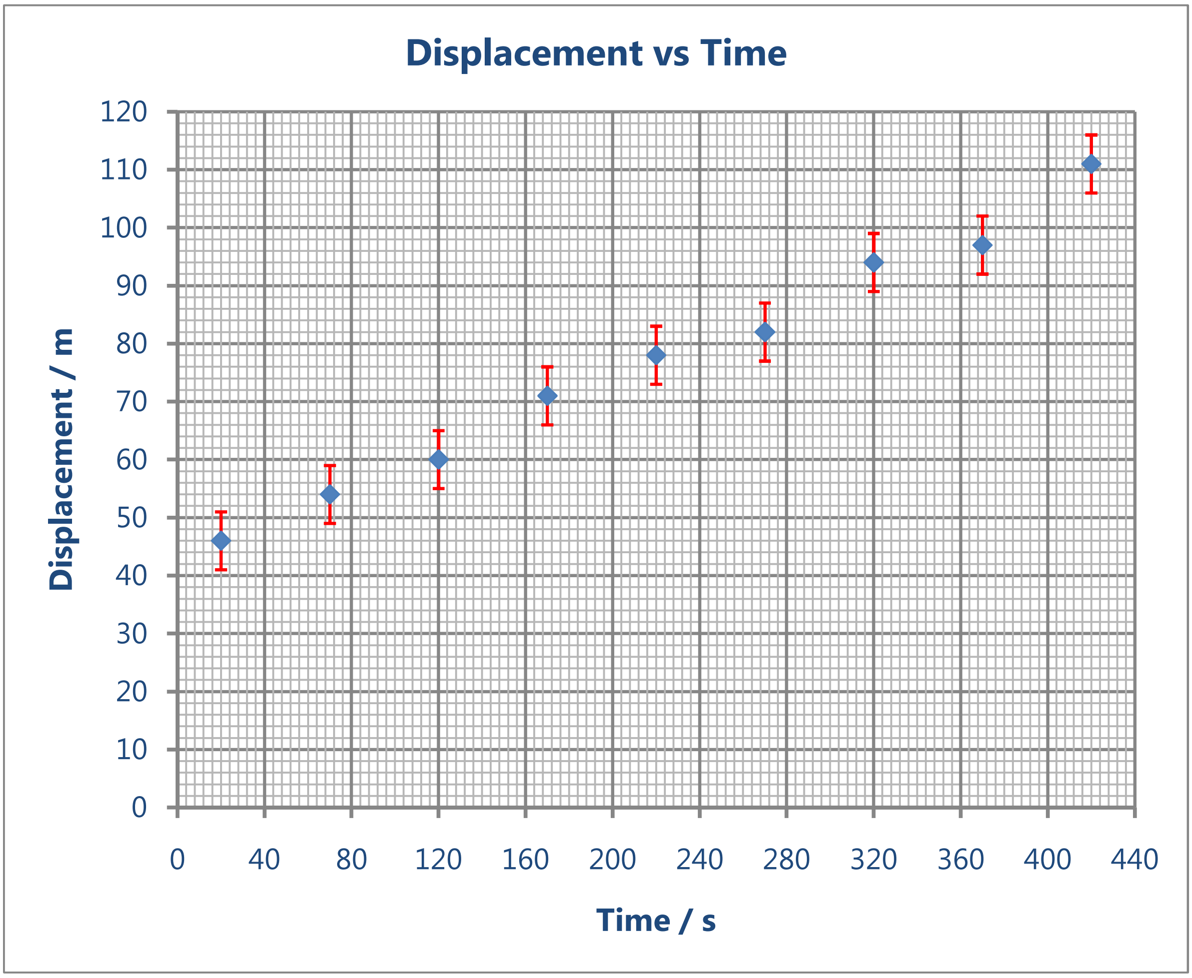
Now that the uncertainties have been plotted, we are in a position to draw a smooth line of best fit. The rule for drawing a line of best fit is that is should be the simplest line or curve that passes **through the uncertainties** of the data points. In this case that would be a curve like the one shown below.
Notice that the line of best fit **does not** have to pass through the data points, only the **uncertainties**.



Steepest and Shallowest

It is quite common to obtain a **linear trend** in Science – a straight line trend. In this case it is possible to get some very useful information from your data. Suppose that you obtain some results like the ones shown below, which give displacement and time for a toy car.

Following the usual procedure, the data points have been plotted and the uncertainties have been shown as error bars. You can see that a straight line will pass through the points. The question is – **what about the line of best fit**?

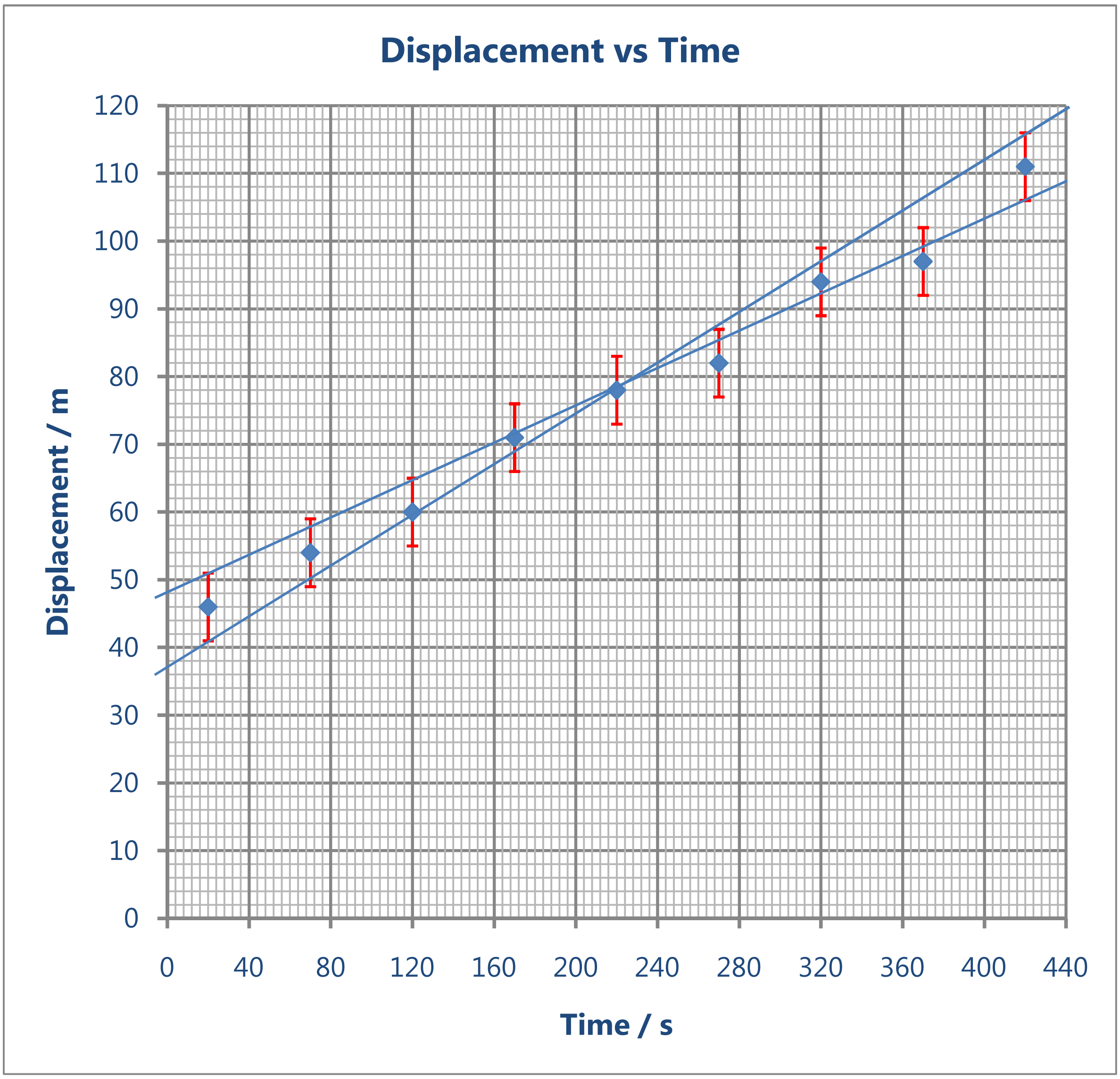


Remember the rule about drawing a line of best fit – it is the simplest line or curve that passes through the uncertainties of the data points. In this case, there are many possible straight lines that would pass through the data points – so which is the best? The solution is to draw;

- The **steepest** possible line of best fit and
- The **shallowest** (least steep) possible line of best fit.
- These represent the two extremes and would look something like the graph on the next page. You can draw them by using the error bars for the **first and last data points** only.

Steepest and Shallowest

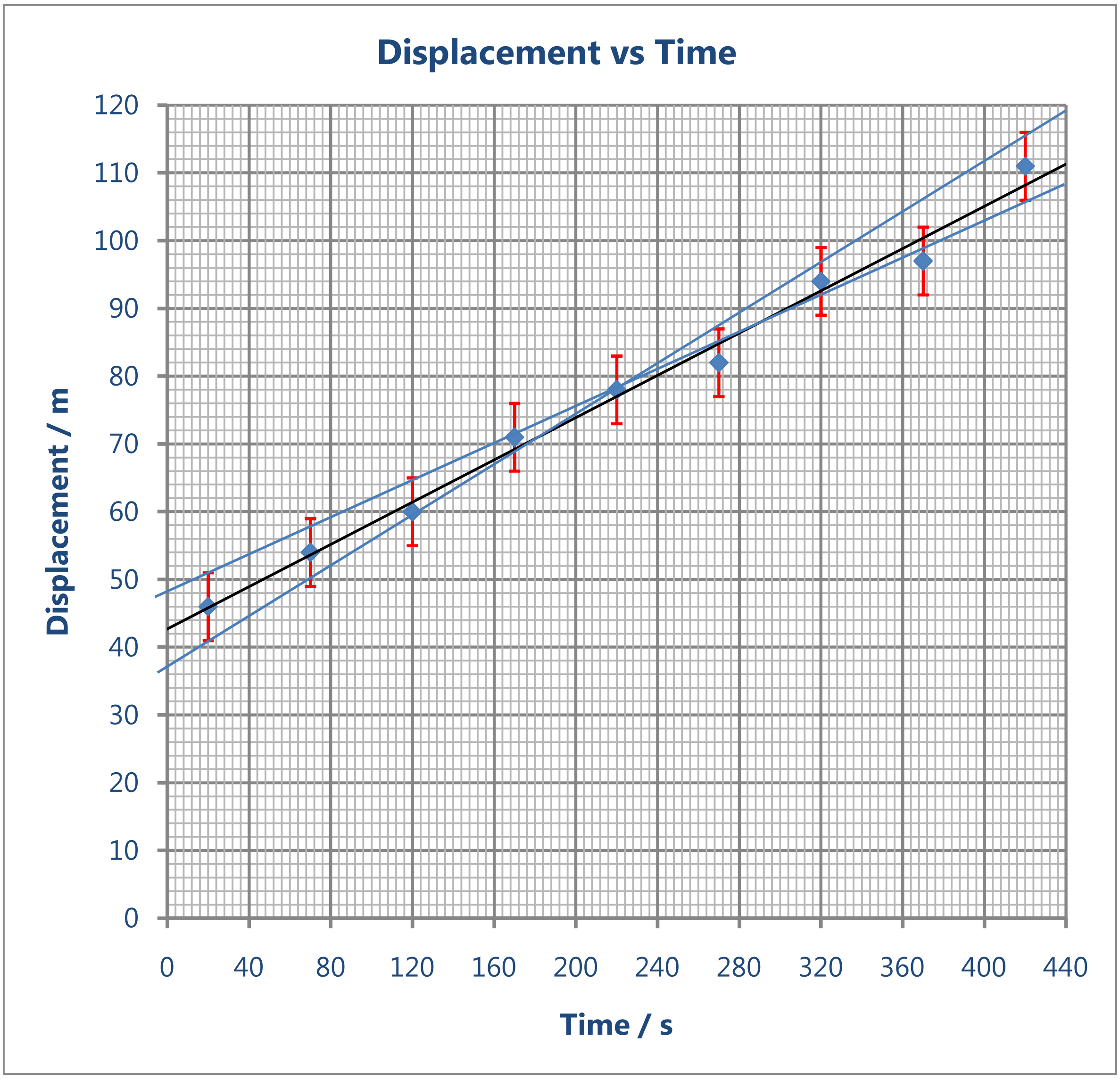
The steepest and shallowest (least steep) are shown below. They **just** pass through the tips of the error bars for the first and last data points.



You can see that both of these lines pass through all of the uncertainties – even if only just through the error bars for the first and last data points. So they are both valid lines.

The "best" line of best fit will usually fall about **half way** between these two extremes. This is shown on the next page.

Steepest and Shallowest



A straight line of best fit is useful because it is possible to calculate the **gradient** and the **intercept**. In Science, these quantities are usually **significant**.

$$Steepest \rightarrow Gradient = \frac{0.91}{440} = 0.21\,ms^{-1}; Intercept = 38\,m$$

$$Shallowest \rightarrow Gradient = \frac{0.60}{440} = 0.13\,ms^{-1}; Intercept = 48\,m$$

$$Best\ Fit \rightarrow Gradient = \frac{0.69}{440} = 0.16\,ms^{-1}; Intercept = 43\,m$$

Steepest and Shallowest

Why is it important to find the gradient and intercept of **all three** lines on the graph?

Your data has **uncertainties** – plotted as error bars on the graph. This means that the gradient and intercept of your line of best fit will also each have an uncertainty. To find this uncertainty you can use the figures from the 3 lines of best fit.

$$Uncertainty\ in\ Gradient = \frac{Range\ of\ Gradients}{2}$$

$$= \frac{(0.21 - 0.13)}{2}$$

$$= 0.04\ ms^{-1}$$

$$Uncertainty\ in\ Intercept = \frac{Range\ of\ Intercepts}{2}$$

$$= \frac{(48 - 38)}{2}$$

$$= 5.0\ m$$

Remember that the gradient and intercept of a straight line are usually significant in Science. In this case the gradient gives the velocity of the toy car and the intercept gives the initial position of the toy car.

So we can finally give our values for the gradient and intercept as;

$$Gradient = velocity\ of\ toy\ car = \ 0.16\ \pm 0.04\ ms^{-1}$$

$$Intercept = initial\ position\ of\ toy\ car = \ 43\ \pm 5.0\ m$$

Prefixes and Standard Form

Prefixes and Standard Form			
Prefix	**Symbol**	**Power of 10**	**In words**
Peta	P	10^{15}	One thousand million million
Tera	T	10^{12}	One million million
Giga	G	10^{9}	One thousand million
Mega	M	10^{6}	One million
Kilo	k	10^{3}	One thousand
Hecto	h	10^{2}	One hundred
Deca	da	10^{1}	Ten
(one)	One	10^{0}	One
deci	d	10^{-1}	One tenth
centi	c	10^{-2}	On hundredth
milli	m	10^{-3}	One thousandth
micro	µ	10^{-6}	One millionth
nano	n	10^{-9}	One thousand millionth
pico	p	10^{-12}	One million millionth
femto	f	10^{-15}	One thousand million millionth

Equations in Physics

Standard Units for Physical Quantities		
Quantity	**Unit**	**Symbol**
Mass	Kilogram	kg
Length	Metre	M
Time	Second	S
Quantity	Mole	Mol (1 mole = 6.0×10^{23})
Speed	Metre per second	ms^{-1}
Acceleration	Metre per second squared	ms^{-2}
Force	Newton	N
Momentum	Kilogram metre per second	kg ms^{-1}
Power	Watt	W
Temperature	Kelvin	K (0^0C = 273 K)
Potential difference	Volt	V
Current	Ampere	A
Resistance	Ohm	Ω
Charge	Coulomb	C
Frequency	Hertz	Hz (s^{-1})

Equations in Physics

Equations of Motion

$$average\ speed = \frac{total\ distance\ travelled}{total\ time\ taken}$$

$$average\ velocity = \frac{change\ in\ displacement}{change\ in\ time} \rightarrow v = \frac{\Delta s}{\Delta t}$$

$$average\ acceleration = \frac{change\ in\ velocity}{change\ in\ time} \rightarrow a = \frac{\Delta v}{\Delta t}$$

$$momentum = mass\ \times velocity\ \ \rightarrow p = m\ v$$

$$force = mass\ \times\ acceleration\ \rightarrow F = m\ a$$

$$work\ done = force\ \times change\ in\ displacement$$

$$= in\ the\ direction\ of\ the\ force\ \rightarrow \Delta E = F\ \Delta s$$

$$Kinetic\ Energy = \frac{1}{2} \times mass \times\ (velocity)^2\ = \frac{1}{2}\ m\ v^2$$

$$g = gravitational\ field\ strength$$

$$= acceleration\ due\ to\ gravity$$

$$Weight = mass\ \times g\ \rightarrow W = mg$$

$$GPE\ = mass \times\ g \times\ change\ in\ height\ = m\ g\ \Delta h$$

$$Power = \frac{work\ done}{time\ taken} = \frac{\Delta E}{\Delta t}$$

Wave Equations

$$wave\ velocity = frequency\ \times wavelength\ \rightarrow v = f\ \lambda$$

$$wave\ period = \frac{1}{frequency} \rightarrow T = \frac{1}{f}$$

Equations in Physics

Ideal Gas Equations

$$Pressure \times Volume = no.moles \times R \times Temperature$$

$$P\,V = n\,R\,T$$

$$where\ \ R = 8.3\,J\,K^{-1} mol^{-1}$$

$$T = absolute\ temperature$$

$$for\ a\ fixed\ amount\ of\ an\ ideal\ gas \rightarrow$$

$$\frac{PV}{T} = constant$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Atomic and Nuclear Physics Equations

$$1.0\ Million\ electron\ volts = 1.6 \times 10^{-19}\ Joules$$

$$1.0\ MeV = 1.6 \times 10^{-13}\ J$$

Electrical Equations

$$p.d. = current \times resistance \rightarrow V = I\,R$$

$$charge = current \times time \rightarrow Q = I\,t$$

$$power = p.d. \times current \rightarrow P = V\,I$$

$$p.d. = \frac{work\ done}{charge} \rightarrow V = \frac{\Delta E}{Q}$$

Note: p.d. stands for **potential difference**, the correct term for "voltage"

Equations in Physics