Name: ______________________________ **Date:** ______________________________

Title: ____

Design ***achievement level ....***

1. Defining the problem and selecting variables	▪ States a **focused** problem or research question. ➢ i.e. To determine a relationship between ____________ and ____________. • Relevant background information is included. • If sources are consulted they are properly cited.		C P N
	▪ States the **dependent** (measured) variable. ▪ States the **independent** (manipulated) variable. ➢ Be specific with both independent and dependent variables. Do not say "the size of the crater" but rather "the depth of the crater as measured from the normal sand level".		
	▪ States all the **controls** (variables to keep constant).		
2. Controlling Variables	▪ Selects appropriate **apparatus** or materials. ▪ Diagram showing arrangement where appropriate. ▪ Specifies precision and size of any measuring instruments.		C P N
	▪ The method is **step by step** and clearly explains how to set up and perform experiment.		
	▪ The method **clearly explains** how the independent and dependent variable will be measured (quantitative date) or judged appropriately (qualitative data).		
	▪ The method clearly **explains** how **each control** will be held **constant**. ▪ If the control of variables is not practically possible, the method clearly explains how the variable will be monitored (attempted to be held constant).		
3. Developing a method for collection of data	▪ The method allows for the collection of **sufficient relevant data**.		C P N
	▪ The method clearly states **how** the data will be collected.		
	▪ Chooses an **appropriate range** of independent variables (>5). ▪ The values of the independent variables are explicitly stated.		
	▪ Chooses an **appropriate number** of trials for each independent variable (>5).		
	▪ If necessary, the plan has shown an appreciation for the need of a **trial run** and repeats until consistent results are obtained.		

Data Collection and Processing ***achievement level ....***

1. **Recording raw data**	• Records all **raw** (not calculated) data appropriately.		C P N
	• Presents raw data clearly and correctly in **tables**. ➢ Each table is numbered and has a title. ➢ Each column has a correct **heading.** ➢ Each column has correct **units**. ➢ Each column has **estimated** uncertainties**.** ➢ Each value in a column has the same number of **decimal places**.		
	• **Uncertainties** in **all** quantitative data rounded up to **1 significant figure**. (i.e. +/- 0.2 not +/- 0.13) • Significant digits in the data and the uncertainty in the data are **consistent**. The number of decimal places in the data does not exceed the limit of the uncertainty (i.e. if the uncertainty is +/-0.2, the measurement should only be quoted to one decimal place) • Even if you will later calculate an uncertainty, there must be estimated uncertainties in the header of each column. • Uncertainties reflect the precision of the measurement. (i.e. uncertainties are reasonable) • **Comment** on how you arrived at the uncertainty in the table.		
	• Comment on any observations you made that might be relevant later. (There may be none).		
	• If students have pooled data, students have clearly **indicated** which data is their own.		
2. **Processing raw data (Data Tables not containing raw data)**	• Calculations and uncertainty calculations are done **correctly** with correct significant figures.		C P N
	• Puts **results** of calculations in **tables**. ➢ Each table is numbered and has a title. ➢ Each column has a correct **heading.** ➢ Each column has correct **units**. ➢ Each value has a **calculated** uncertainty. o You may want to create another column for the uncertainties of each value. ➢ Each value in a column has the same number of **decimal places**.		
	• **Uncertainties** in **all** quantitative data rounded **up** to **1 significant figure**. (i.e. +/- 0.2 not +/- 0.13) • Significant digits in the data and the uncertainty in the data are **consistent**. The number of decimal places in the data does not exceed the limit of the uncertainty (i.e. if the uncertainty is +/-0.2, the measurement should only be quoted to one decimal place)		
	• **Sample** calculations are shown. ➢ Calculations are explained and presented logically. ➢ Formula, substitution and answer shown for one sample calculation. ➢ Formula, substitution and answer shown for one sample uncertainty calculation. (i.e. for repeated measurements: greatest residual)		
3. **Presenting processed data (graphs)**	• **Graphs** are **correctly** drawn. ➢ If the data represents a straight line, the best fit line is straight. ➢ If the date represents a curve, the best fit line is curved. ➢ Curved graphs are straightened. ➢ Slope calculated. ➢ The equation of the line has been stated (y=mx+b) ➢ Dots have not been connected. • If the data represents a straight line, the **slope** is calculated **correctly** including the units.		C P N
	• **Graphs** are numbered and have clear titles, appropriate **scales**; axes **labelled** correctly with **units**, and accurately plotted **data points.**		
	• Includes **uncertainty bars** on both axes, unless explicitly justified because they are too small. • Uncertainty bars are on every point.		
	• Using the error bars from the first and the last data points, draws lines of **minimum and maximum slopes.** Minimum and Maximum lines should go through all error bars. Use the first and last points to start, but your lines may need to be adjusted to intersect all error bars. • Determine the **uncertainty** in the best straight-line **slope using** the **minimum** and **maximum** slopes.		

Conclusion and Evaluation *achievement level ....*

1. Concluding

- A conclusion **supported** by the **data** is stated.
  - Is the graph linear? (Must go through all uncertainty bars to be linear)
  - Is the graph proportional? (Must be linear (and go through all uncertainty bars) and also go through the origin (within uncertainty (i.e. the origin must be between the max and min lines).
  - Is the original graph curved? If so, explain what was done to straighten it and why and answer first two questions above.
  - Are there points in the linear graph which appear to be a mistake (anomalous)? Maybe it is best to remove these and plot the line again.

- If the graph has a slope, the units and uncertainty are stated and the **meaning** of the **slope** is explained.
  - The uncertainty of the slope was found in DCP. State it here.
- What does the intercept mean? Explain. (x and/or y intercepts)
- **Compares** different graphs if possible.

- The conclusion takes into account any **systematic** or **random** errors.
  - Systematic errors occur if the y-intercept is different then expected. Comment on this taking into account uncertainty bars. What is the effect on the conclusion of the systematic error? What is the direction of the systematic error?
  - Random errors are represented by the uncertainty bars on each data point. Comment on these. Was the uncertainty too big? Was the uncertainty too small? Explain.

- If measuring an accepted value of a physical quantity, **compares** the experimental value to the **accepted value** with a **% error.** (% error = (your value – accepted value) / accepted value x 100%)
- If measuring an accepted value of a physical quantity, comment on whether the accepted value falls within your experiment value. (within its uncertainty range)

- The literature consulted is fully **referenced** using correct MLA notation.

C P N

2. Evaluating procedures

There will be overlap here with Conclusion aspect 1. Don't repeat yourself here if you have already addressed it above.

- Is the conclusion reasonable?
  - Must supply evidence from your results (i.e. your graph or from your observations)
  - Don't say friction was a problem unless you have evidence.
- Comment on the uncertainty bars. Were they a reasonable size? For example:
  - Were they too big and the line easily goes through them? Explain.
  - Were they too small and an almost perfectly straight line does not go through them? Explain.
  - Is your graph clearly a curve even though a straight line goes through all the uncertainty bars?
  - Relate size of the horizontal and vertical uncertainty bars to the physical errors in the experiment.
- Comment on the intercept.
  - Is it supposed to be (0,0)? If not, what caused the systematic error?

If you comment on the following four points, also relate your comments to the uncertainty bars. Again, don't repeat yourself if you have already discussed them above.

- Comment on whether you managed to keep the control variables constant.
- Comment on the equipment used, the method in which you used it and/or time management.
- Comment on the range of values and the number of repetitions.

- Discusses **reliability** of the results and comments on **anomalous** points.

(Note: Two ways to explain reliability: 1. *Multiple trials where one should get the same result for each trial*: Data is reliable if the trials are fairly close. Data is not reliable if the results are significantly different when they should be the same. 2. *Graphing the results and analysing the trend line*. If the trend line is within all the error bars, data is reliable. If they are not, data is not so reliable. Anomalous results occur when most of the data is reliable but a data point or two may be way off).

C P N

3. Improve

- **Every** weakness and limitation identified in aspect 2 has an **improvement**.
  - Each improvement is linked to your results (i.e. your graph)
  - Improvements look at ways of reducing your uncertainties. Comment on how your improvements will reduce your uncertainty bars.
- If you had a wider range or more repetitions, would it improve your results?
- Is there any modification to your apparatus that would improve the results?
- If you made improvements during the experiment, state them here and you will get credit.
- Modifications are **realistic** and **clearly specified**. (i.e. it is not sufficient to simply state "better equipment")

C P N