IB Lab Report Suggestions—from http://www.physicsrocks.com

IB Internal Assessment Criteria and Aspects

Design

Design

ASPECTS

Levels/Marks	Defining the problem and selecting variables	Controlling variables	Developing a method for collection of data
Complete/2	Formulates a focused problem/research question and identifies the relevant variables.	Designs a method for the effective control of the variables.	Develops a method that allows for the collection of sufficient relevant data.
Partial/1	Formulates a problem/research question that is incomplete **or** identifies only some relevant variables	Designs a method that makes some attempt to control the variables.	Develops a method that allows for the collection of insufficient relevant data.
Not at all/0	Does not identify a problem/research question **and** does not identify any relevant variables.	Designs a method that does not control the variables.	Develops a method that does not allow for any relevant data to be collected

Research Question/Problem

This is a single sentence which clearly and specifically states the objective of your investigation. For a Design lab, the teacher cannot give you detailed information and guidance. Instead, you'll be given a general, open-ended problem such as "Investigate the factors that affect X". You must do some thinking to recognize the nature of the problem that has been set, the factors (variables) that will affect the outcome, and how they affect it (the hypothesis). So if a general question has been posed, make it more specific and relevant to your individual experiment.

Your research question must clearly identify the manipulated and responding variables for your experiment.

Hypothesis(es)

A hypothesis is like a prediction. It will often take the form of a proposed relationship between two or more variables that can be tested by experiment: "If X is done, then Y will occur." (Examples: "The rate of transpiration will increase as wind speeds and temperatures rise" or "Brand X toothpaste will be more effective in preventing the growth of the bacteria which causes plaque on your teeth").

You must also provide an **explanation** for your hypothesis. This should be a brief discussion (paragraph form) about the theory or 'why' behind your hypothesis and prediction. For example, why should raising the air temperature cause an increase in the speed of sound? Why do you think a more massive object going to accelerate faster than a less massive object? Note: there is no exact place in the Design criterion that addresses the hypothesis, but you WILL BE EXPECTED TO HAVE A COMPLETE ONE for any design lab in order to receive full credit for your class grade.

Be sure your hypothesis is related directly to your research question and that the manipulated and responding variables for your experiment are clearly written into your hypothesis.

Variables

All reasonable variables that might affect the outcome should be identified. State variables explicitly, and explain why each is relevant. Indicate which variable(s) is/are manipulated variables (ones that you will change) and which are the responding variables (ones that will respond to what you did). Indicate which variables must be controlled (kept consistent) and *why* those variables must be controlled.

Controlling Variables

Aspect two refers to controlling variables, but this does not only refer to the actual controlled variable(s) for your experiment. You must indicate how you plan to maintain the consistency of your manipulated and responding variables as well.

You will have one manipulated variable and one responding variable. You must describe how you will be measuring each of those variables, and what you plan to do in order to minimize the systematic and random errors in those measurements. You will also be describing, for each variable you indicate is controlled, how you intend to keep that variable consistent.

For example:

Problem: "What effect does the launch angle of a tennis ball have on the maximum horizontal displacement it will land away from the launch position?"

(Hypothesis would go next, but I'm not going to write a sample here ☺)

Manipulated Variable: Launch Angle

The launch angle will be measured with the protractor that is located directly on the marble launcher. The angle will always be measured to the nearest 0.5° by looking at where the tip of the point on the back end of the launch barrel is pointing to the protractor.

Responding Variable: Horizontal Displacement

A line of masking tape will be placed on the floor in order to mark the initial position of the marble launcher. The front of the marble launcher will always be placed so that it just touches the tape. A test marble will be launched and, and one lab partner will be positioned to locate the general landing area of the marble. Carbon Paper will be placed under a piece of computer paper and both will be taped to the floor in the location indicated by the first launch. After all launch trials are complete, a metric measuring tape will be used to measure the displacement from the initial launching position; the 0.00 m mark on the tape will always be placed at the base of the marble launcher, and the position of each mark on the carbon paper will always be measured to its center.

Controlled Variables: Launch Velocity; Environmental Conditions; Vertical Displacement

The launch velocity will be controlled by always using the same spring setting on the marble launcher and by always releasing the spring mechanism in the same manner so that no extra force is given that will alter the initial velocity of the marble. The environmental conditions will be controlled by doing all trials inside and in the same hallway so there is no wind to alter the trajectory of the marble. The air temperature will remain as constant as possible throughout the lab as well, which should help maintain consistency in the amount of air resistance the marble encounters. The vertical displacement will remain constant because both the marble launcher and the floor will remain level throughout the experiment. The launcher is designed to launch the marble from a pivot point that remains at a constant position regardless of launch angle.

WOW—that seems like a lot of work! Well, maybe, but it's worth it. By thinking through all the factors that can affect your variables and by writing out how you will control those factors, you will be helping yourself (by being certain you have a good method!), and you will be helping anyone who is reading your lab report! You won't necessarily need to write quite as I much as I did in the example, but you get an idea of the format. ☺

Developing a method for collection of data

Aspect three is essentially for the actual procedure itself. You will need to include the following:

Apparatus and Materials

Consider making a *list* of your experiment and materials needed. Be as specific as possible. (Example: "50 mL beaker instead of 'beaker', type of lens with focal length, BRAND of equipment (manufacturer)). Include quantities of materials as specifically as you can. If it is a measuring tool, you must include the precision of that tool.

A diagram of how you set up the experiment **may** be appropriate, especially for more complicated experiments. Be sure your diagram follows the rules for lab drawings (i.e. have clear labels, make the diagram large enough to see and understand, etc.). You are not required to make a diagram, but if it will help clarify any part of your procedure, it is a very good idea.

Safety

List any safety precautions that must be taken during the lab.

- "Wear safety goggles throughout experiment."
- "Avoid breathing vapors of automobile exhaust."
- "Avoid touching a vibrating tuning fork to the glass resonance tube."

Method/Procedure

State or discuss the method (procedure) that you are going to use (or that you did use) in the experiment. This should be in the form of a list of step-by-step directions. Provide enough detail so that another person could repeat your work by reading your report! (But you don't have to go into detail about standard, well-understood actions such as "gather materials")

If you do something in your procedure to minimize an anticipated error, mention this as well. (Example: "Carefully cutting plant stem under water to reduce affect of air on transpiration rate.")

In your method, clearly state how you will collect data. What measuring device will you use? What data will you record? When? Or what qualitative observations will you look for (such as color change) and what will you do when you see this happen?

The procedure must allow collection of sufficient relevant quantitative data. This means that you should consider doing more than one trial where appropriate. A minimum of 5 trials **per "position"** or **"setting"** is advised; you should adjust your manipulated variable at least 5 times (5 "positions/settings"), but it is always appropriate to do as many "positions/settings" as possible. Most labs that are done in physics will require MORE than 5 positions/settings. You are also expected to space your positions out in an appropriate range for the lab that you are completing. For example, if you are changing the angle of a marble launcher, and the available angle settings are from 0.0° to 90.0°, your method should include taking data throughout most of this range (say from 5.0° to 85.0°). Collecting a lot of data, but limiting your range, will not likely show you a true pattern from which you can draw an appropriate conclusion.

Your procedure is strictly for the steps you must take to collect the raw data. Do **Not** include steps for analysis of that data. You do not need to include a step that clarifies "calculate the average time" or "calculate the kinetic energy of the marble" or "create a graph". Although it IS likely you will do each of those steps, that is considered data analysis and, therefore, you will make those steps clear through your presentation of your raw and processed data.

IB Internal Assessment Criteria and Aspects

Data Collection and Processing

Data Collection and Processing			
	ASPECTS		
Levels/Marks	**Recording raw data**	**Processing raw data**	**Presenting processed data**
Complete/2	Records appropriate quantitative and associated qualitative raw data, including units and uncertainties where relevant	Processes the quantitative raw data correctly.	Presents processed data appropriately and, where relevant, includes errors and uncertainties.
Partial/1	Records appropriate quantitative and associated qualitative raw data, but with some mistakes or omissions.	Processes quantitative raw data, but with some mistakes and/or omissions.	Presents processed data appropriately, but with some mistakes and/or omissions.
Not at all/0	Does not record any appropriate quantitative raw data **or** raw data is incomprehensible	No processing of quantitative raw data is carried out **or** major mistakes are made in processing.	Presents processed data inappropriately **or** incomprehensibly.

There are two aspects to Data Collection. You must collect and record raw data accurately. But equally important—you must present the raw data so the reader can easily interpret it. This means it must be *organized* and *legible*. The best way to collect and present data is by using data tables.

Give an identifying, specific *title* to each data table. Number tables consecutively through the report.

Qualitative observations are just as important as quantitative measurements! Make sure you take note of and record the physical characteristics of substances or solutions involved in the experiment, their changes, whether something is hot or cold, etc. Some researchers like to organize these qualitative observations in a separate data table – intermingling them with quantitative data is often confusing and hard to read.

A measurement without units is meaningless! If you show the units in a column heading of a data table, you do not have to write them again after each number in the table. Common ways of recording measurements in biology are: volume in liters, mass in grams, length in meters, and time in seconds. The following example shows different ways to express the same unit.

Initial velocity (centimeters per second)
Initial velocity (cm/s)
Initial velocity (cm s^{-1})
→ note: this format is most appropriate

All measurements have uncertainties and you must indicate them in your data tables. This is best done by paying attention to significant digits, and by using the 'plus-or-minus" (+/-) notation. Examples:

Mass of a penny on a centigram balance: 3.12g (+/- 0.01g)
Temperature using a typical lab thermometer: 25.5°C (+/- 0.5 °C)

For our purposes, the accuracy of a measurement device is one half of the smallest measurement possible with the device. So, for example, the rulers in class measure to the millimeter (0.1 cm). So, the ruler's measurement uncertainty is +/- 0.05 cm. If you ask, I will assist you in determining the accuracy of the lab equipment we use. Just as for units, in a column of data you can show the uncertainty in the column heading and then you don't have to keep re-writing if for every measurement in the table (unless for some reason it is different for various trials.

The integrity of raw data is important from a scientific standpoint and from an ethical standpoint! Raw data and observations will always be recorded in a bound laboratory notebook (your physics journal!).

Aspect 2: Processing Raw Data

This is the part of the report in which you take your raw data and transform it into results that answer (hopefully!) your research question. Here you will show the calculations that give you a numerical result. Or it may involve making a graph of some type to show a trend or a relationship. It might involve both of these. But just as in Data Collection, there are two important aspects: *processing* the data correctly, and also *presenting* the processed data effectively and legibly so the reader can clearly see the results.

In Physics labs, EXPECT TO GRAPH YOUR DATA!! If you cannot graph the data you are collecting, you either need to rethink your analysis, or you need to go back and collect different data. We should always be able to graph our data in order to assist us in making connections. Graphs also allow us to easily make note of the precision/accuracy of our results.

Calculations of Results

- You will often have to show calculations. Use plenty of room; make sure they are clear and legible. Show the units of measurements in all calculations.
- Pay attention to significant digits! Don't lose accuracy by carelessly rounding off.
- Identical, repetitive calculations do not have to be repeated. Show one sample calculation (labeling it as such) and then you don't have to repeat it for all the trials, but only show the results obtained.
- When calculating an average value from repeated trials, don't average the raw data. Instead, calculate a result from each trial. Then average the results from each trial to get your final experimental average.

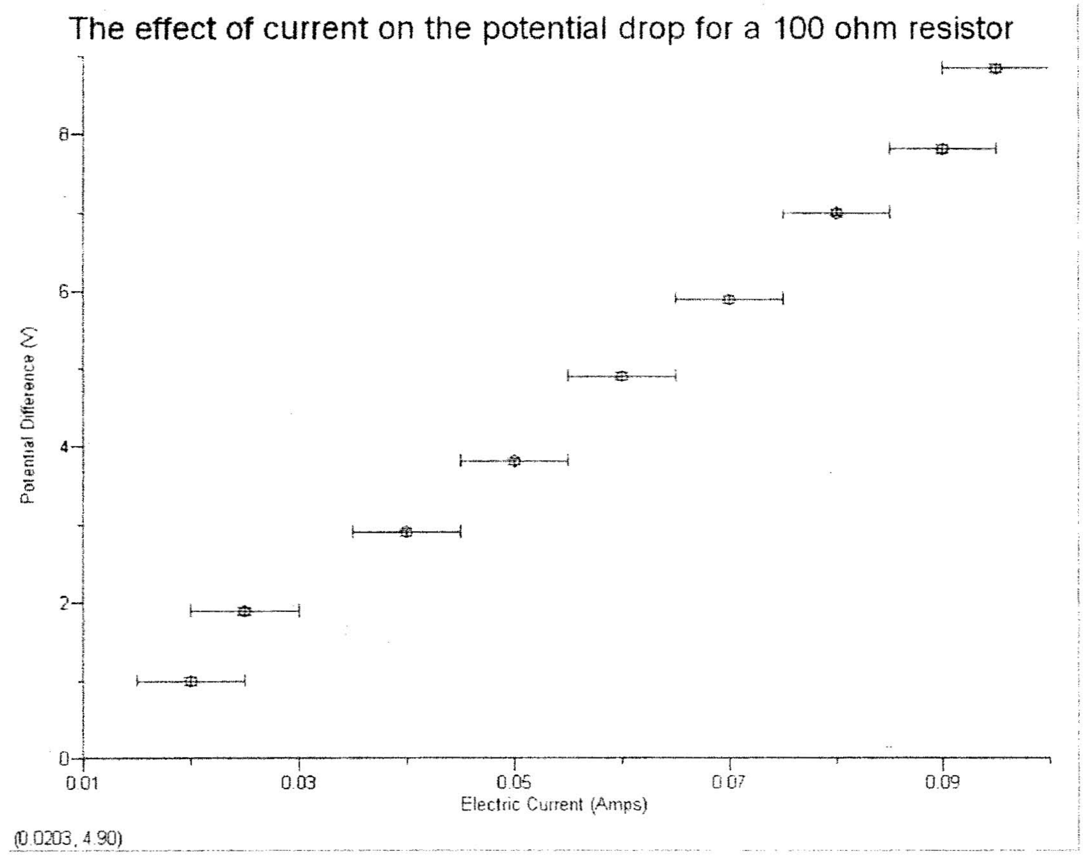
Presentation of Results

- There are many ways to present and display results. Tables and graphs are typically what will be used in physics. Your tables of processed data must be separate from your raw data tables, but created in the same format (title, table number, appropriate headings, units, etc.)
- You will be expected to complete your graphs using LoggerPro software. Each student will get a chance to check out a CD-ROM in order to install the program (from Vernier software) on your home computer, and the program is available on every computer in the school. It is located on the library server's application folders for science.
- The axes of graphs must be clearly labeled with the variable and the units used. Additionally, each graph must have a descriptive title that specifically states what the graph depicts. (Examples: Time vs. Temperature; Length of mitosis stage (reported data) vs. Length of mitosis stage (student data); The effect of changing mass on specific heat capacity for copper; The rate of change in velocity for a car rolling down an incline.) "Statement" titles are more descriptive (and therefore better) than X vs. Y titles.
- Graphs must have a best-fit line with a slope, and after your graph you should write a statement explaining what the slope is telling you. If your graph is initially NON-linear, you must manipulate the values you put on the x and/or y axis in order to get a relationship that is visibly linear. Do NOT simply put a linear fit on your data if it is not obviously linear. (i.e. if you have a graph that very obviously is parabolic in shape, square the values you put on one of the axes—you'll "force" your data to be linear). We'll practice this in class...no worries! ☺

IB Internal Assessment Criteria and Aspects

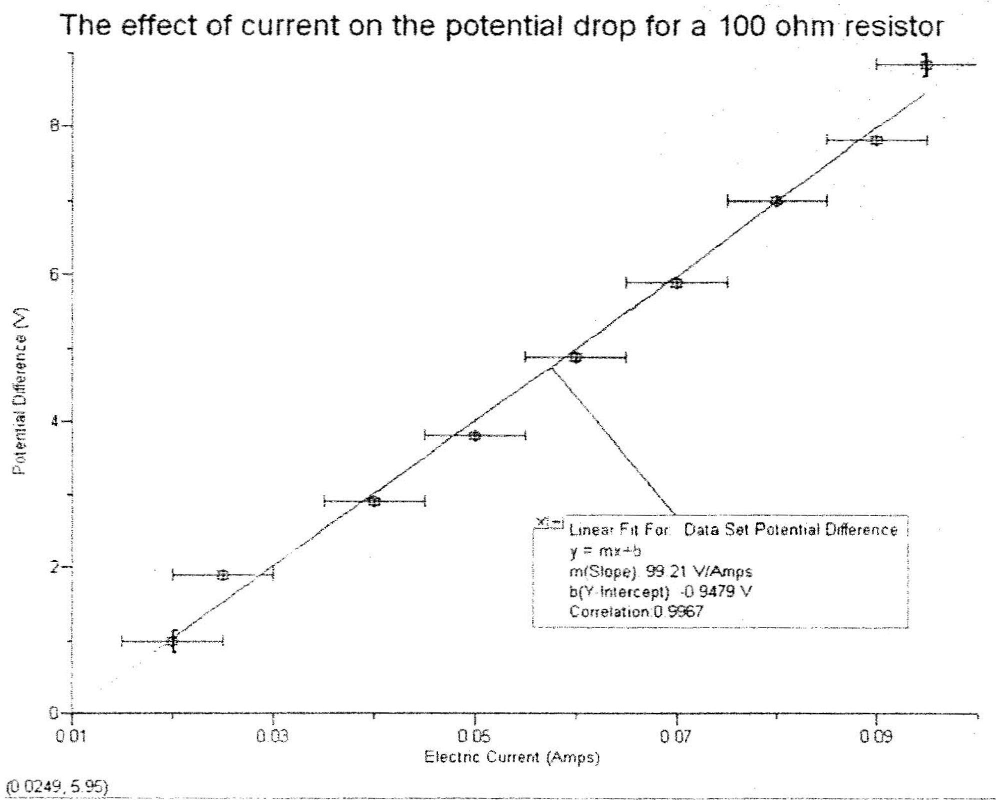
Uncertainties in measurements and in calculations

- For all measured data, you need to report a level of uncertainty, as we discussed earlier.
- When calculations are made with the data that already has some uncertainty, we must report an error in your calculated result as well.
- To report your uncertainty on a graph, you must use <u>Error Bars</u> for at least one of the axes—most of the time it is perfectly acceptable to only put error bars for the value with the largest magnitude uncertainty (usually, but not always, the responding variable (Y-axis))
    - Error bars show the absolute uncertainty for that measurement or calculated value as a "+/-" range around the plotted data point:



- For the graph above, there are error bars for both axes, but only the x-axis errors are large enough to really be concerned about...
- (note: the axis labels should include the uncertainty range along with the units, too)
- Do NOT connect the data points! You must use a best-fit line on all graphs!

- Error bars give you an acceptable range for your data. When you create a best-fit line for your graph, all data points SHOULD have the line at least pass through part of their error bar:



- If a data point does NOT hit the line with its error bars, then there is some significant experimental error (more than likely a random error) that has occurred.

- Do NOT throw out that data point unless you have a substantial number of other data points to work with! You can keep the point, and be sure to talk about the random error that may have affected that piece of data when you complete your conclusion!!

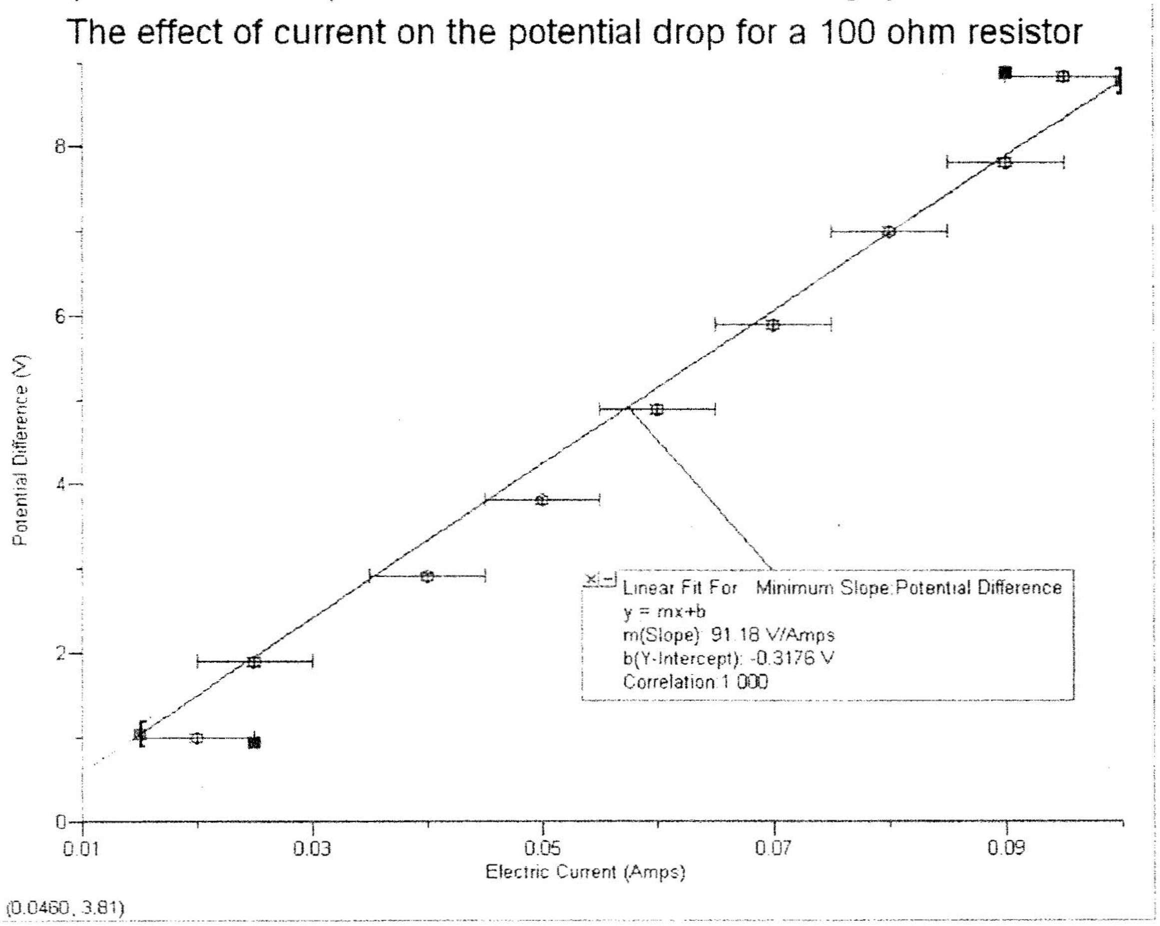
Maximum and Minimum Slope: this is different than last year. For ALL graphs, you are required to have both a minimum and a maximum slope determined for your data.

- the easiest way to do this is to look at your first and your last data point, and do the following: First, create a **new data set**—Rename this data set as "Maximum Slope"
  - for Maximum Slope:
    - First (lowest) Data point:
      - SUBTRACT the uncertainty from the responding variable's value (*y*)
      - ADD the uncertainty to the Manipulated variable's value (*x*)
    - Last (highest) Data Point:
      - ADD the uncertainty to the responding variable's value
      - SUBTRACT the uncertainty to the Manipulated variable's value
    - **Plot a linear fit through those two new data points**

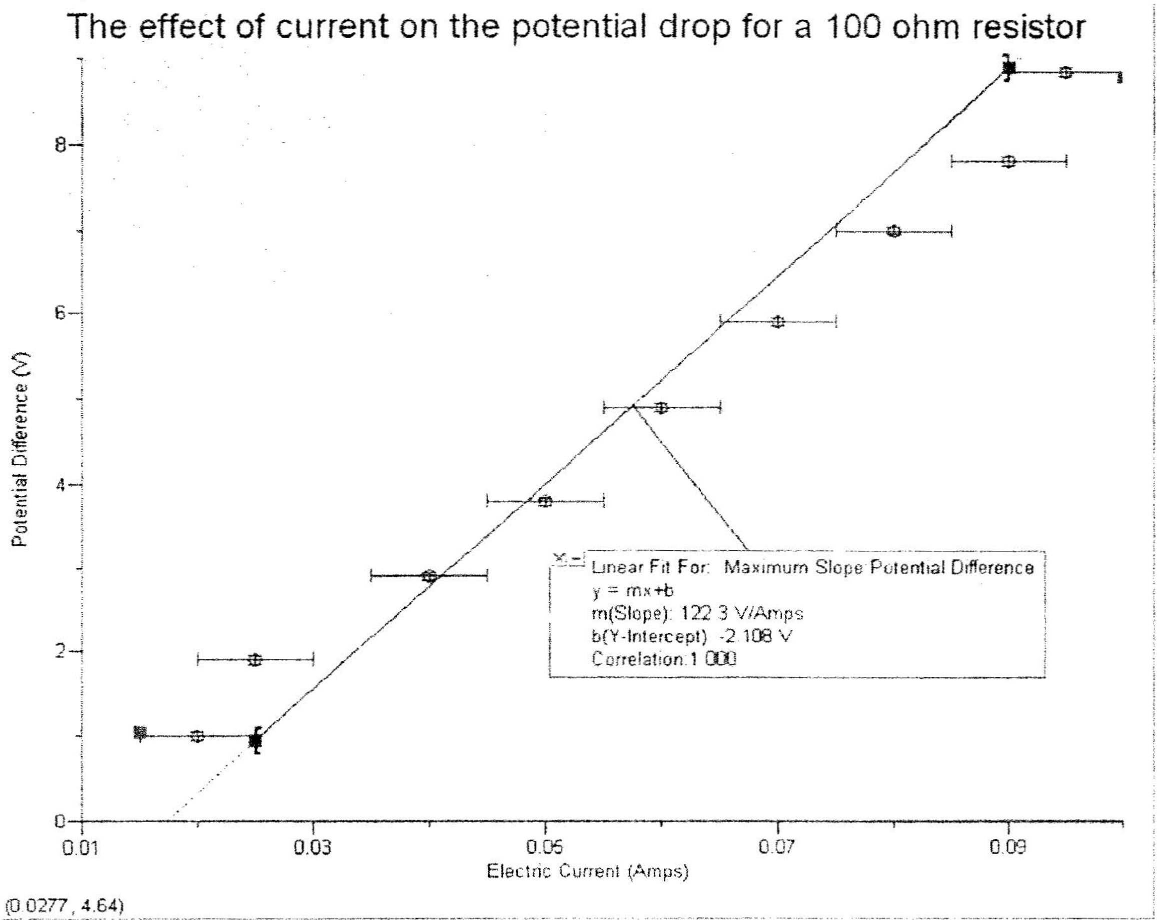
Create another new data set—rename this one "Minimum Slope"

- For Minimum Slope:
  - First (lowest) Data point:
    - ADD the uncertainty from the responding variable's value (*y*)
    - SUBTRACT the uncertainty to the Manipulated variable's value (*x*)
  - Last (highest) Data Point:
    - SUBTRACT the uncertainty to the responding variable's value
    - ADD the uncertainty to the Manipulated variable's value
  - **Plot a linear fit through those two new data points**

See the examples below:
Example 1: Minimum Slope for the Potential vs. Current data we graphed above:



Example 2: Maximum slope for potential vs. current data



You should be able to then discuss your confidence in your slope's accuracy based on the range of values you obtain through this process.

You may choose to put all three lines on one graph, or you may print out (or copy/paste, which is ideal—it puts your graph right in your report where you're talking about it!) all 3 graphs—just make sure everything is labeled clearly!

IB Internal Assessment Criteria and Aspects
Conclusion and Evaluation

Conclusion and Evaluation			
	ASPECTS		
Levels/marks	**Drawing conclusions**	**Evaluating procedure(s)**	**Improving the investigation**
Complete/2	States a conclusion, with justification, based on a reasonable interpretation of the data.	Evaluates weaknesses and limitations.	Suggests realistic improvements in respect of identified weaknesses and limitations.
Partial/1	States a conclusion based on a reasonable interpretation of the data	Identifies some weaknesses and limitations, but the evaluation is weak or missing.	Suggests only superficial improvements
Not at all/0	States no conclusion **or** the conclusion is based on an unreasonable interpretation of the data.	Identifies irrelevant weaknesses and limitations	Suggests unrealistic improvements

Drawing Conclusion

- One (or more) paragraphs in which you draw conclusions from your results, and whether or not your conclusions support your hypothesis (if there was one). Your conclusion(s) should be clearly related to the research question and the purpose of the experiment. You must also provide a brief explanation as to how you came to this conclusion from your results. (In other words, sum up the evidence).
- If a numerical value or result is the object of the lab, you must compare it with the literature value and if possible, calculate a percent error. Be certain to show your work for this calculation.

Limitations to Conclusion

- Considering how large the errors or uncertainties are in your results, how confident are you in the results? Are they fairly conclusive, or are other interpretations/results possible?

Limitations of the Experimental Procedure

- Identify and discuss significant errors and limitations that could have affected the outcome of your experiment. Were there important variables that were not controlled? Were there flaws in the procedure you chose which could affect the results? Are measurements and observations reliable? Is precision unknown because of lack of replication?
- Your emphasis in this section should be on systematic errors, not the random errors that always occur in reading instruments and taking measurements. You must identify the source of error and if possible, tie it to how it likely affected your results.
  - Acceptable Example: "Because the simple calorimeter we used was made from a tin can, some heat was lost to the surroundings—metals conduct heat well. Therefore, the value we obtained for the heat gained by the water in the calorimeter was lower than it should have been."
  - Unacceptable Examples: "The test tubes weren't clean.", "Human error", "Miscalculations."

Suggestions for Improvement

- Suggest improvements or fixes for the weaknesses you identified in the previous section. These suggestions should be realistic, keeping in mind the type of equipment normally found in high school or college general physics labs. Suggestions should focus on specific pieces of equipment or techniques you used. (Vague comments such as "We should have worked more carefully" or "we needed to do more trials" are not acceptable).

You should report your procedural weaknesses and improvements in a table format, if possible, so that you are certain to report an improvement for every weakness that you identified.