LAB REPORT GUIDE

From the Elite IB Graduates at

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Contents

Writing a lab report can be daunting with all technical language and strict format you must follow. Luckily scientists love formulas. This guide hopes to unravel and demystify the formula to making a perfect lab report. We will go step by step through each of the sections of lab reports with useful checklists along the way to make sure you do not forget anything! Don't forget the subject specific tips at the end of this guide.

This guide will focus on the marking criteria for the IB internal assessments in the sciences so that you can maximize your IB score! But don't fret, all of these steps are excellent advise for any lab report.

For all those writing their IB IAs the best advice I ever received was to check out the marking criteria and get advice from friends. The marking criteria, summarized below, is exactly the same for all the science and both SL and HL classes. We will take each of these step by step so you can maximize your grade! Your teachers cannot offer significant feedback on your work but that doesn't mean you are all alone! Reviewing your classmates work is a great way to get feedback as well as understand how you are marked better.

Marking criteria	Personal engagement	Exploration	Analysis	Evaluation	Communication	Total
Points	0-2	0-6	0-6	0-6	0-4	0-24
Percentage of total (%)	8	25	25	25	17	100

To succeed in a lab report you need to think like a scientists during planning, execution and when you write the actual report. The nice thing is you can make mistakes as long as you evaluate what you did wrong! Let's get started,

COMMUNICATION

Worth almost a 5th of the total IA mark, communication is why it is always a good idea to leave some time to polish up your final document. If you are anything like me, I dread attempting to correct my own grammar. Luckily, a lab report is not like writing a novel. We should aim to be as clear and concise as possible. Complex sentences and extravagant words hinder understanding. Keep sentences and words simple. The only fancy words you need are the sciency ones!

Unlike essay, lab reports come with a given structure. I always start my lab reports by writing down the titles of the sections. I then never forget a section and it feels pretty good as I fill out each section, one at a time. Here is a list of suggested sections with a brief description of what is inside.

Introduction/Background information: Provide all the scientific theories that led you to your research question. What methods have been used in the past to investigate such concepts? Why are you interested in this?

Research question: Concise question, typically in the form of How does __ (insert independent variable)__ affect __(dependent variable)__?

Hypothesis: What do you think the answer to your research question is?

Method: List of variables, apparatus, and steps taken.

Raw data: The measurements you obtained, typically organized as a table.

Analysis: A description of all calculations done and any final tables or graphs to summarize the results

Evaluation: Conclusions describing how your analysis supports your hypothesis and how the experiment can be improved and extended.

Bibliography: Don't forget to add all sources you used for your background information and the accepted values you used for comparison.

Here is what we should be aiming for **communication** to get top marks:

The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes.

The report is **well structured** and **clear:** the necessary information on focus, process and outcomes is present and presented in a coherent way. The report is **relevant and concise** thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.
The use of **subject-specific terminology** and conventions is appropriate and correct. Any errors do not hamper understanding.

Checklist 1: communication!

- All the section titles are present
- Title clearly reflects the research question
- Science terminology is used consistently
- The writing is clear and simple
- Sources are cited

CHOOSING THE RESEARCH QUESTION

You are asked to come up with your own research topic, how is this possible? I struggled with this. How do I know what a "good topic is?" Thinking about whether it is "good enough" isn't the best way to go about it. They do not expect a nobel prize winning original piece of research. Your topic just needs to satisfy two criteria:

1) A topic related to the science you have learnt
2) A topic you find interesting

To think of a good topic you can approach it from two directions. The first is thinking about something you are passionate and then relating that to a scientific concept. For example, if I find surfing cool and I do physics, I could investigate water waves in different depths of water. The second method is starting from the science you find interesting and then finding an interesting angle to investigate that topic. For example, if I am a biologist and I find plant biology and photosynthesis really interesting, I could plan an experiment where I investigated how plants grow under different colors of light.

While it may be easiest to just copy an experiment, you will lose points for personal engagement. You can still use these experiments as inspiration. Try changing the independent variable slight or try changing one of the controlled variables. For example, if they are looking at the boiling point of water, investigate the boiling point of cooking oils because you love to cook! The textbook experiment then becomes are great place to find advise on your methodology, how to measure temperature best?

One you have a topic, we then craft this into a research question. This starts with identifying the independent variable and the dependent variable. The independent variable is what we are changing, in the above example the color of light. The dependent variable is what we are measuring, in the above example how much the plant grows. The research question can then be phrases as How does **(independent variable)** effect **(dependent variable)**?

Checklist 2: Research question!

- Have I expressed why I am interested in the topic
- Have I approached the topic from an original angle
- Do I know the variable I am changing, the independent variable
- Do I know the variable I am measuring, the dependent variable
- Does my title reflect the research question

BACKGROUND INFORMATION

Once you have decided on your topic you need to layout the science. Supply the reader with enough information to support your research question and your hypothesis. Think of it like a funnel. Start with the wide opening, the very basic of your topic such as what is an acid, what is an enzyme or what is a force. Then introduce scientific principles that relate to the concept you are investigating. If you will need to do calculations make sure you introduce the formula you will use here. Background information is not just about theories but also about how scientists have conducted experiments like your before. Try to mention how your topic has been investigated previously. You should end up at your research question. Explicitly state your research question! Then state your hypothesis and use the science to explain why you think it is true. Always right a hypothesis before you do your experiment! It is just as interesting if you show your hypothesis is wrong as long as in the end you explain the right science. That is what experimentation is all about! You will not be marked down for an incorrect hypothesis, that's just part of science, trust me! Once you have cited your research question, the whole rest of the lab report goes towards answering that question using the science you have just laid out.

Personal Engagement: At some point in your funnel you will come across the section you have an interest in. Make sure you outline why you have an interest in that! Another way to show personal engagement is by commenting on the previous experiments you found. Do you like there method, is there a way to make it more feasible for you?

You obviously did not know all the background information yourself, so make sure you do not forget to cite your sources!

Checklist 3: exploration!

- Did I start by introducing the big picture?
- Did I mention all the big theories and formuli I will use in answering my question?
- Did I mention how scientists have conducted experiments in my topic?
- Did I show personal engagement through interest in the topic?
- Did I show personal engagement through analysing what experimental methods may work for me?
- Did I cite all my sources?

PLANNING THE RESEARCH DESIGN

Now we know what we are investigating and the question we need to answer, it's time to plan out how we are going to do this. One thing to not be scared of is changing your research question if it turns out you will not be able to answer it with the materials and time allotted to you. Lots of us are guilty of being way too ambitious at the start. It is best to have a manageable research question that you can actually collect data for than it is to have a super cool research question you don't even come close to answering.

It's time to list your variables! The first step you can get directly from you research question. Explicitly state you independent and dependent variable. When possible, make sure you can quantify these variables, give a value to it. Sometimes you will have to work with qualitative (not numbers) data, but it is best if you can figure out a way to measure your variables. Next you need to figure out your controlled variables. What other things could change the results. Things like apparatus, room temperature are normally applicable but you will need to think a little deeper to what things it is important to control in your experiment.

Now you get to list all the apparatus you will use! You can also add a picture of the apparatus setup, in addition to the list. Make sure you label all the apparatus in the picture! Don't forget to mention details about your apparatus like the size of beakers and measuring cylinders. This apparatus list is also useful on the day of the experiment, before you do anything make sure you have everything. It is the worst when you get halfway through an experiment and realize you are missing something! Pro tip: given you have a page-limit and not a word limit, making the apparatus list into columns can save you space!

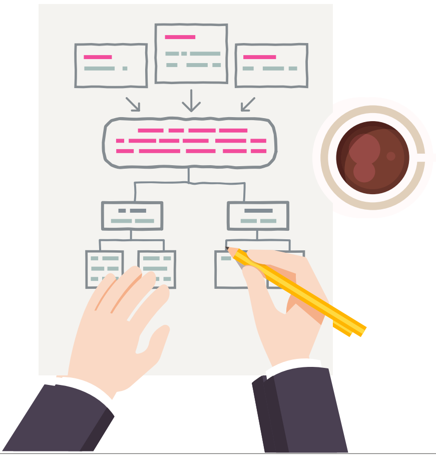
The last step is the method. You will likely have written this as a set of instruction before you did the experiment. It is important to realize that in your final lab report this is not a set of instructions but an account of what YOU actually did. If one trial something strange happened it should be mentioned. The method should be written in the past tense. One thing never to forget is to include how you kept track of your controlled variables! It is not enough to list them above. On the day of the experiment you need to be checking that your controlled variable aren't changing! If they do change make sure you mention this in your results.

Finally, never forget to do multiple trials! We cannot trust our results from just one trial are accurate so let's always conduct at least 3!

Not quite done! We always need to consider safety, ethical, and environmental issues. If you are dealing with any dangerous chemical or extreme temperatures mention how you will protect yourself. Environmental consideration normally encompass how you will dispose of the chemicals. Finally, ethical consideration need to be present if you use animal or human subjects (see the biology section).

Checklist 4: research design!

- Dependent and independent variable are listed, they are quantitative where possible
- All controlled variables are listed and explicitly mentioned in the method
- Apparatus is fully listed
- Method is in past tense
  - Mentions how independent variable is changed
  - Mentions how dependent variable is measured
  - Mentions how controlled variable are kept constant
- Number of trials mentioned
- Have I mentioned safety, ethical, and environmental issues.



Here is what we should be aiming for **personal engagement** to get top marks:

The evidence of personal engagement with the exploration is clear with significant **independent thinking, initiative or creativity.**

The **justification given for choosing the research question and/or the topic** under investigation demonstrates personal significance, interest or curiosity.

There is evidence of **personal input and initiative in the designing, implementation or presentation of the investigation.**

Here is what we should be aiming for **exploration** to get top marks:

The topic of the investigation is identified and a relevant and **fully focused research question** is clearly described.

The **background information** provided for the investigation is **entirely appropriate and relevant** and enhances the understanding of the context of the investigation.

The **methodology of the investigation is highly appropriate** to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.

The report shows evidence of full awareness of the **significant safety, ethical or environmental issues** that are relevant to the methodology of the investigation.

ANALYSIS

The first thing to include is the raw data! This is the raw numbers you received before any calculations! It includes all trials, including any that failed! It is best to organize this in table form, normally, although some experiments output in graphical raw data. Check out the table and graph checklist to make sure you do not forget anything, this is the easiest place to lose communication points! There are a couple things you should not forget in your raw data. The first is your controlled variables. If you actually actively attempted to control your controlled variables you likely measured something, mention that (eg. room temperature 21°C). Second, qualitative observations should be included. This includes what you saw and felt, was the beaker hot? These qualitative observations show that you were engaged and if there is some trial that is an outlier often you can see what was strange about that trial from the qualitative observations. Third, uncertainties, uncertainties, uncertainties! There is no way you are measuring something completely precisely, every number you quote should come with an uncertainty. Remember uncertainty is half of the smallest increment measured. So if a measuring cylinder has $0.1cm^3$ markings the uncertainty is $0.05cm^3$. For digital measurements, like most scales, because we zero the scale and then also do the measurement we do not half the increment! So if the scale can measure 0.1g, the uncertainty is 0.1g.

Checklist 5: raw data

- Organized in a concise manner (table!)
- Shows results for each trial
- Uncertainties in all observations mentioned
- Qualitative observation mentioned
- Controlled variable measurements

Before doing calculations, what conclusions can you draw from the raw data. Does the trends you see in each trial make scientific sense? Make sure in your analysis section (after all the calculations) you refer back to the raw data at least once!

Now it's the calculations time! The aim is to process the data to get it to a form (often graphical) that best represents the answer to your research question. You are looking to create some graph or table that can essentially summarize your whole lab report! The calculations that need to be done vary immensely by topic. Each science has a data processing topic in the syllabus. Refresh your memory of that topic to get a good idea of what is expected of you especially regarding error propagation (how your uncertainties carry over as you calculate new values). Ideally the science formuli you need for your calculations were already introduced in your introduction. You must show how you take the raw data and process it. This is normally easiest by showing (and explaining!) one example calculation.

Checklist 6: data processing

- Did you show an example calculation?
- Did you explain why you left any trials out (outlier, procedure went wrong)?
- Did you explain the calculations briefly?
- Did you end up with a nice graph or table that directly relates to your research question?

Checklist 7: tables

- Title
- Units for every variable
- Units in column heading, not next to each value
- All values in column have same amount of decimal places
- Absolute uncertainties expressed to 1 significant figure
- All on one page

Checklist 8: graphs

- Title
- If made from a table, the graph axis labels should match the table row and column titles
- Gridlines visible, so that values can be easily read off the graph

Here is what we should be aiming for **analysis** to get top marks:

The report includes sufficient relevant **quantitative and qualitative raw data** that could support a detailed and valid conclusion to the research question.

Appropriate and sufficient **data processing** is carried out with the accuracy required to enable a conclusion to the research question to be drawn that is fully consistent with the experimental data. The report shows evidence of full and appropriate consideration of the **impact of measurement uncertainty** on the analysis. The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

EVALUATION

We are at the home stretch! Now we just have to talk about all the science we just did. While doing this have your research question always by your side. It is so easy to go onto tangents and waste precious space! We are going to break this into steps.

Step 1: Through your analysis did you find evidence to help answer your research question? Remember we are not mathematicians, we do not prove anything. The evidence you collect can either **support your hypothesis or not support your hypothesis.**

Step 2: Compare your conclusion to an accepted answer. One of the worst feelings is ending up with data that does not match the accepted answer. Luckily for you, the IB is not interested in whether you obtained perfect results, they are interested in how you analyse and evaluate the data you do obtain! Make sure you cite were you found the accepted scientific answer. If your results are quantitative compare your conclusion with percentage error! Percentage error can be calculated by subtracting your result by the accepted result and dividing by the accepted result! Even if you did obtain very accurate results (results essentially equivalent to the accepted results, <5% percentage error), there are always improvements you can make especially in precision (how large your uncertainties are).

Step 3: Does this all make scientific sense? Relate the science you explained at the very start to your results. Refer to graphs and raw data commenting on whether it makes scientific sense.

Step 4: Comment on your precision. How large was you uncertainties?

This brings as to the final step in evaluation: errors and improvements. The key place to search for improvements is your method. Was there a particular apparatus that was very imprecise (like a cylinder that could only measure volume to the nearest 10cm3!). IB loves it when you can evaluate your own experimental design! Once you have the list of possible errors you will analyse these independently.

1) What was the source of the error?
2) Was is systematic or random?
3) If it was systematic did it cause your final answer to be larger or smaller?
4) How could you improve it next time?

Here are some errors to consider

- Systematic errors (made your accuracy low)
  - Error in equipment calibration (did you forget to zero the scale)
  - Apparatus didn't work properly (note what specific trial!)
  - User read/used apparatus incorrectly
  - Some place where heat/energy/light/etc was lost
- Random errors (contributed large uncertainties)
  - More trials/larger sample size will always increase precision!
  - Background noise like a random disturbance
  - Instrument not sensitive enough to notice all changes
  - You can always note human error, no human can read apparatus perfectly!

In the final step you can get creative and show your personal engagement. How could you extend your experiment? Could you test the same question on a different material you are particularly interested in? This is where we finally get to open that funnel back up and go beyond our research question and show some personal interest

Checklist 9: evaluation

- Have I mentioned whether my data supports my hypothesis?
- Have I mentioned how the data answers the research question, or whether it even does?
- Have I compared my results to accepted results?
- Have I used science to explain my results?
- Have I commented on my precision/uncertainties?
- Have I identified sources of systematic errors, which direction the effect my results and how they could be improved?
- Have I identified sources of random error and how they could be improved
- Have I identified improvements to my method?
- Have I offered a creative extension.

Here is what we should be aiming for **evaluation** to get top marks:

A detailed **conclusion** is described and justified which is entirely **relevant to the research question** and fully **supported by the data presented.**

A conclusion is correctly described and justified through **relevant comparison to the accepted scientific context.**

Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence of a **clear understanding of the methodological issues** involved in establishing the conclusion.

The student has discussed realistic and relevant suggestions for the **improvement and extension** of the investigation.

BIOLOGY

For biology there is a very wide range of research questions you can choose from. One good place to look is skim through the option section of your textbook. There are some cool things you could investigate in there, but there is also plenty in your core curriculum. If you are not inspired by the topics you have covered so far there is plenty of inspiration in your textbook including the higher level material and the options!

In biology we can do some pretty cool experiments to learn more about nature. However, we must be careful when involving living things that we do not cause harm. Are you using human or animal subjects?

Yes, human: Make sure you have all humans sign consent forms before collecting data on them.

Yes, human and it involved bodily fluid such as blood sample: you cannot do this experiment. Transmission of bloodborne diseases is too risky!

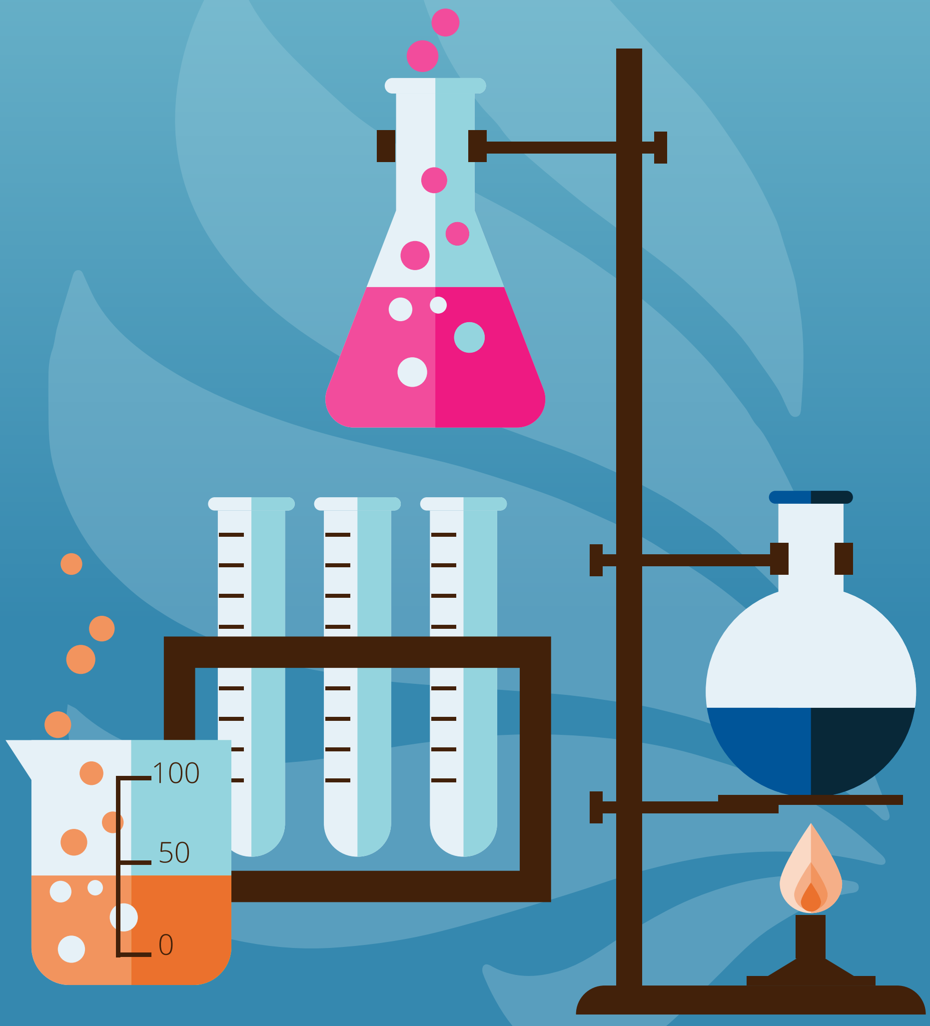
Yes, animal: Make sure you discuss your design with your teacher ensuring that it meets the IB animal experimentation policy. No experiment should harm your animal subjects.

No: you still need to consider safety issues to yourself and those around you.

Some ideas:

- Investigate how plants grow in different light environments. Get creative! This could be different levels of light, different colors of light, different angles of light etc.
- Investigate the distribution of your favorite coastal animal in the intertidal zone!
- Trace a genetic trait through your family or a family you have sufficient data on. Can you determine if the trait is recessive or dominant?
- Determine whether an enzyme inhibitor is competitive or non-competitive.

CHEMISTRY



Chemistry is a great subject to be writing a lab report in! Most of the units covered in IB have experiments you can reasonably carry out. The one caution when designing an experiment is make sure you have access to the chemicals before you get to in depth in the planning!

In chemistry, it is highly recommended to make qualitative observations. Most of chemistry lab report will involve some sort of chemical reaction. This involves changes in heat, often color, all things that can be seen and observed!

Here are some ideas:

- Titration is one of the best types of investigation to get maximum marks! But be creative with it! Titration can be used to find how much of a given substance is in a sample. For example, you can use titration to figure out which fruit has the most vitamin C! Be creative with your independent variable, it could be type of fruit or even cooking method.
- Experimentally determine the iodine numbers of various oils.
- Investigate the effect of ligands and metal centers in transition metal complexes on the color of the complex. (hint: use a colorimeter for quantitative values!)
- Investigate the pH of salt solutions at various temperatures.

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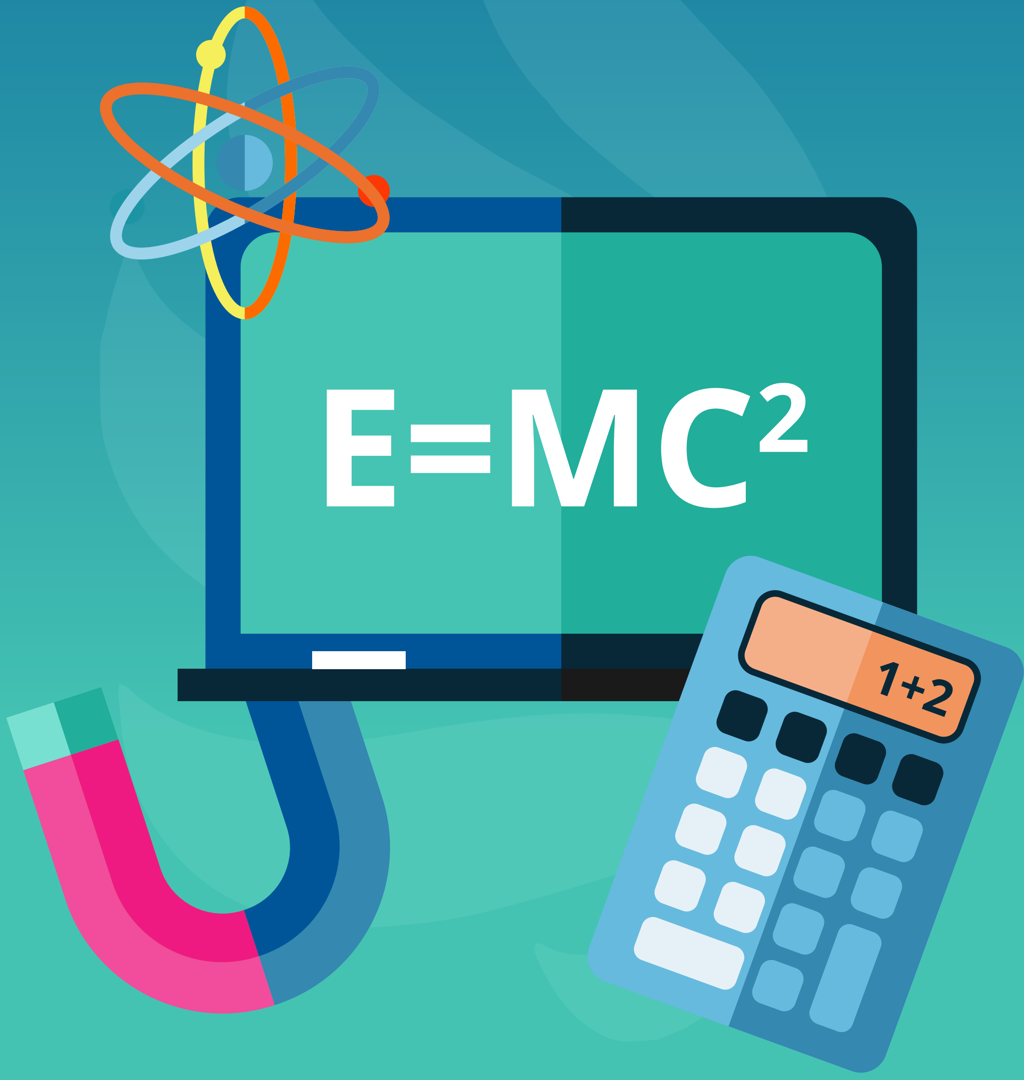
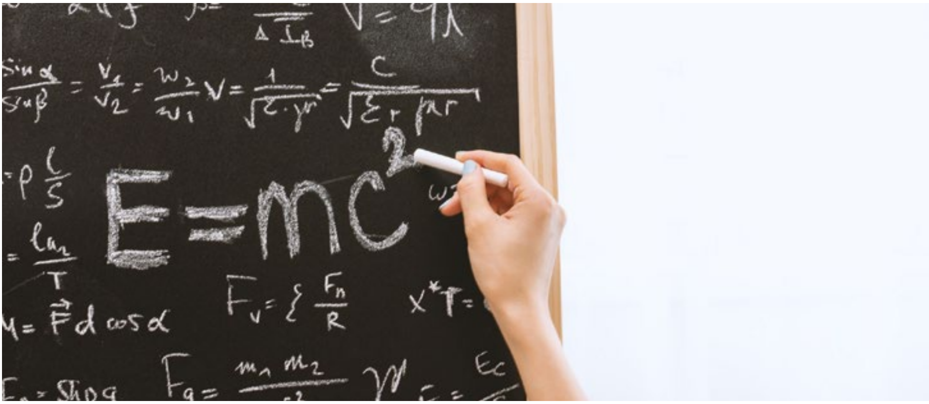
PHYSICS



So much of the physics syllabus is filled with investigation you can conduct! Unfortunately, some of the modern physics we learn such as nuclear physics and astrophysics is out of reasonable scope for a seconcondary student lab report but there is still plenty of cool experiments we could do! Here are some examples:

- Determine the coefficient of static friction of a trolley on a ramp.
- Determine g! You can do it in a variety of ways using what you know from mechanics or simple harmonic motion!
- Investigate how springs in parallel or series affect the total force (extend Hooke's law, similar to how we can add together resistors in a circuit!)
- Determine the resistivity of pencil lead.
- Investigate how temperature affects refractive index.
- Determine the latent heat of fusion of your favorite substance (make sure it has a reasonable melting point!)
- Determine absolute temperature. (hint: use Charles's law!)

Physics expects excellent calculations and error propagations. It is normally recommended for physics to do at least 4 trials to get more precise results. You learned all the error propagation in unit 1 make sure you use them on your lab report!



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ENVIRONMENTAL SYSTEMS AND SOCIETIES (ESS)

ESS is a very interesting subject where we investigate complex systems using a holistic approach, and therefore it allows us to choose an IA from many different topics. If you are more interested in the human aspect of the course, you can take your IA in this direction. Alternatively, you can choose to conduct a more biological investigation. The options in ESS are truly endless, making the ESS IA extremely exciting! Once again, your textbook should provide plenty of directions you can go in, but you can get inspired by anything around yourself.

Since ESS is a multidisciplinary subject, you need to be careful when choosing your research methodology. If you are interested in human systems, you can conduct questionnaires. If you'd rather look at how some factor affects food production systems, you can conduct an experiment where you examine plant growth. Alternatively, you could even go out into nature and do some fieldwork for a more ecological IA.

The only thing to keep in mind is that whatever your method of choice is, it must answer your research question, and you must be able to effectively collect and analyse data with the resources available to you. Keep in mind that if you plan to do experiments involving human behaviour or animal studies, you need to fulfill the conditions for these kinds of IAs (see the biology section).

Here are some ideas:

- Most students choose to do experiments involving plant growth. One idea would be to look at how pesticide use affects the growth of plants in the lab. (Hint: What parts of the safety assessment would you need to consider for this experiment?)
- If you're interested in abiotic resources, you could look at how runoff from irrigated soil affects the chemistry of bodies of water (pH, dissolved ions, etc.).
- By doing a little planning, you could conduct an IA where you collect water from a river, pond, or lake periodically for a period, and analyse the changes in one or two species' populations over time. For example, this could be during the change from winter to spring.

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- If you are interested in the environmental value systems, you could conduct a questionnaire and see if there is a correlation between their knowledge of climate change and their environmental values.

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