LAB REPORT GUIDE

From the Elite IB Graduates at

Lanterna education

Contents

info@lanternaeducation.com

Writing a lab report can be daunting, as there is a lot of technical language to understand and a strict format that you must follow. Luckily, scientists love formulas. The aim of this guide is to unravel and demystify the secret to making the perfect lab report. We will go step by step through each of the sections, and will provide useful checklists along the way to make sure that you do not forget anything! There are also 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 advice for any lab report.

For all those writing their IB internal assessments, the best advice that I ever received was to refer to the marking criteria and get advice from friends. The marking criteria, summarized below, is exactly the same for all of the sciences and applies to both SL and HL courses. We will take each of these step by step so you can maximize your grade! The fact that your teachers are not permitted to offer significant feedback on your work doesn't mean that you are all alone! In fact, reviewing your classmates' work is a great way to get feedback and is the key to understanding how best to improve.

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 writing a lab report you need to be able to think like a scientist during the planning, execution and writing stages. Even if you make mistakes during your experiment, the great thing is that as long as you evaluate what you did wrong, you can still be rewarded. Let's get started.


COMMUNICATION

Communication is worth almost one fifth of the total IA mark, which is why it is so important to leave some time to polish up your final document before you hand it in. Luckily, a lab report is not like writing a novel; you should aim to be as clear and concise as possible. Complex sentences and extravagant words hinder the reader's understanding. Therefore, keep your sentences and words as simple as possible. The only fancy words you need are the scientific and technical terms.

Unlike essays, lab reports have a recommended structure. I always start my lab reports by writing down the titles of each of the sections. That way, I never forget a section and it feels pretty good as I fill out each section, one at a time. Here is a list of the suggested sections for a lab report, each 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 investigation in particular?

Research question: Concise question, typically in the form: What is the effect of [independent variable] on [dependent variable]?

Hypothesis: What do you predict the answer to your research question will be?

Method: List of variables, apparatus, steps taken.

Raw data: The measurements you obtained, typically organized as a table.
Analysis: All calculations and final tables or graphs representing the results.

Evaluation: Conclusions describing how your analysis supports your hypothesis and your assessment of how your experiment could be improved and extended.

Bibliography: All the sources used for your background information and accepted values used for your comparison.

Here is what you should be aiming for in order to achieve top marks for the **communication** criterion:

> 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

info@lanternaeducation.com

CHOOSING THE RESEARCH QUESTION

Deciding upon your own research question is difficult. Aim to strike a balance between something too simple and unattainably original and complex. Your topic needs to satisfy two criteria:

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

There are two approaches you could take. The first would be to think about something you are passionate about and then to relate that to a scientific concept. For example, if I find surfing cool and I study physics, I could investigate water waves in different depths of water. The second method would be to start with the scientific concept that you find interesting and then choose an interesting angle from which investigate that topic. For example, if I am a biologist and I find plant biology and photosynthesis fascinating, I could plan an experiment where I investigated how plants grow under different colors of light.

Whilst it might be easy to just copy another's experiment, you will undoubtedly lose points for personal engagement. However, there is nothing to stop you using these experiments as inspiration. Try changing the independent variable or one of the controlled variables. For example, if you are looking at one experiment examining the boiling point of water, perhaps you could investigate the boiling point of cooking oils because you love to cook! The textbook experiment can be a great source of inspiration and advice on your methodology as well.

Once you have selected your topic, you should then craft this into a research question. Start with identifying the independent variable and the dependent variable. The independent variable is what we are changing (e.g. in the above example, the color of light). The dependent variable is what we are measuring (e.g. in the above example, how much the plant grows). The research question can then be phrased as, 'how does **(independent variable)** affect **(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 upon your topic you need to set out any necessary scientific background. Supply the reader with enough information to support their understanding of your research question and hypothesis. Think of it like a funnel. Start with the wide opening, the very basic fundamentals of your topic (e.g. what is an acid / what is an enzyme / 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 to introduce any formulae you will use here. Background information is not just about theories but also about how scientists have conducted experiments like yours before. Try to mention how your topic has been investigated so far. You should end up at your research question.

Explicitly state your research question! Then, state your hypothesis and use scientific explanations to justify why you think it is true. Always write a hypothesis before you do your experiment! It is still interesting to reveal that your hypothesis is wrong, as long as by the end of the report you have provided a scientific explanation. That is what experimentation is all about! You will not be marked down for an incorrect hypothesis! Once you have cited your research question, the whole rest of the lab report should be devoted to answering that question using the scientific principles that you have just provided.

Personal Engagement:

Outline what it was that sparked your initial interest in your topic. Another way to show personal engagement is by commenting on the previous experiments you found. Do you like their method? Is there a way to make a previous experiment work better 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 significant theories and formulae I will use in answering my question?
- Did I mention how scientists have previously conducted experiments within 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 it is that 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 far too ambitious at the start. It is best to have a manageable research question that actually allows you to collect appropriate data than it is to have a super cool research question that you are unable to even come close to answering.

It's time to list your variables! Firstly, look directly at your research question. Explicitly state your independent and dependent variable. When possible, make sure you will be able to quantify these variables — provide numerical values to represent your data. Sometimes you will have to work with qualitative (observational) data, but it is always best if you can figure out a way to measure your variables. If not, there is an opportunity to mention improvements and weaknessees during your evaluation at the end of your lab report. Next, you need to figure out your controlled variables. What other things could change the results? Things like apparatus and room temperature are normally applicable but you will need to think a little deeper to consider what aspects are important to control in your experiment.

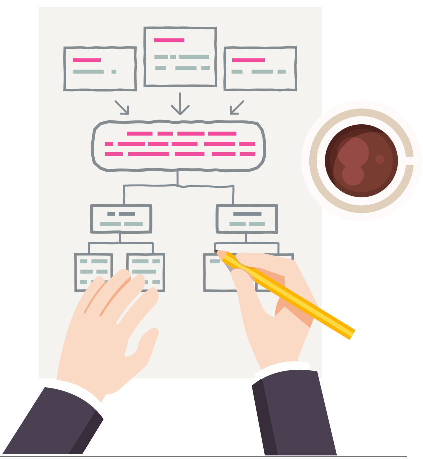
Now you get to list all the apparatus you will use! You can also add a picture of the apparatus setup, in addition to the list. You might even choose to draw it yourself and insert a scan. Make sure you label all the apparatus in the picture! Don't forget to mention important details, such as the exact size of beakers and measuring cylinders. Your method needs to be repeatable. This apparatus list is also useful on the day of the experiment, so before you do anything make sure you have everything to hand. 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, presenting the apparatus list in a columnar format can save you crucial space!

The last step is the method. You will likely have written this as a set of instructions before you did the experiment. It is important to realize that your final lab report must present the method not just as a general set of instructions but a specific account of the steps that you must take to conduct the experiment exactly as you intend. Later, in your analysis and evaluation you have the opportunity to discuss the intricacies of your own experiment (strange trials etc.) One thing never to forget is to include how you will keep track of your controlled variables! It is not enough to list them above. On the day of the experiment you need to be constantly checking that your controlled variables aren't changing! Finally, never forget to conduct multiple trials! We cannot trust that our results from just one trial are accurate so always conduct at least three!

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 considerations normally encompass how you will dispose of the chemicals. Finally, ethical considerations need to be present if you use animal or human subjects (see the biology section later on).

Checklist 4: research design!

- Dependent and independent variables are listed, in a quantitative format where possible
- All controlled variables are listed and explicitly mentioned in the method
- Apparatus is fully listed
- Method is highly detailed
    - Details how independent variable is changed
    - Details how dependent variable is measured
    - Details how controlled variables are kept constant
- Number of trials
- Safety, ethical, and environmental considerations



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

The evidence of personal engagement within the exploration is clear with demonstration of 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 under the criterion of **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, relevant** and enhances the understanding of the context of the investigation.

The **methodology of the investigation choseen 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

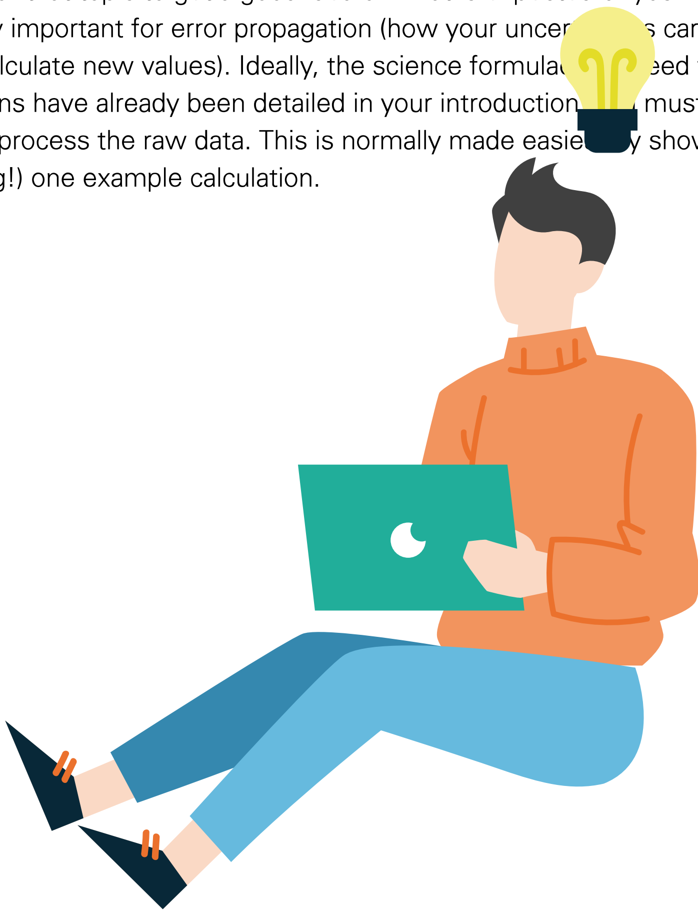
The first thing to include is the raw data! Raw data means the quantitative data you receive prior to any calculations! It includes the data from all of your trials, including any that you think have failed! It is normally best to organize this in table form, although some experiments best output in the form of graphical raw data. You will be awarded marks for translating your results accurately into a graphical format, so you can always put large tables into an appendix if there is not much space. Check out the table and graph checklist to make sure you do not forget anything, as this is the easiest place to lose communication points! There are a couple of things you should not forget in your raw data. The first is your controlled variables. If you actively attempted to control your controlled variables you likely measured something, therefore mention those measurements (e.g. room temperature 21°C). Secondly, any qualitative observations should be included. Qualitative data includes any observations — you saw and felt (e.g. was the beaker hot?) These observations show that you were engaged and if there is an outlier often you can see what was strange about that trial from the requisite qualitative data. Thirdly, uncertainties, uncertainties, uncertainties! There is no way that you are measuring something completely precisely, and therefore every number you quote should come with an uncertainty. Remember — the uncertainty is ± half of the smallest increment measured. So, if a measuring cylinder has $0.1cm^3$ markings its uncertainty is $\pm 0.05cm^3$. For digital measurements, like most scales, as we zero the scale and then take the measurement we do not half the increment! So, if the scale can measure 0.1g, its uncertainty is ±0.1g.

Checklist 5: raw data

- All data organized in a concise manner (table!)
- Results given for each trial
- Uncertainties detailed for all observations
- Qualitative observations
- Measurements for the controlled variables

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

Now it's time for the calculations themselves! 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 a graph or table that can essentially summarize your whole lab report! The calculations that need to be done vary immensely with each topic. Each scientific subject has its own data processing topic as part of its syllabus. Therefore, refresh your memory of that topic to get a good idea of what is expected of you. This is especially important for error propagation (how your uncer s carry over as you calculate new values). Ideally, the science formula eed for your calculations have already been detailed in your introduction must show how you process the raw data. This is normally made easie y showing (and explaining!) one example calculation.



Checklist 6: data processing

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

Checklist 7: tables

- Title
- Units given 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 (independent variable on x axis, dependent on y axis)
- Gridlines are visible, so that values can be easily read off the graph

Here is what we should be aiming for under the **analysis** criterion 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.

info@lanternaeducation.com

EVALUATION

We are on the home stretch! Now we just have to talk in depth about all the science that we just did. While doing the evaluation, have your research question by your side. It is so easy to go off on tangents and waste precious space! We are going to break this down step by step…

Step 1: Through your analysis did you find evidence to help answer your research question? The evidence you collect can **support your hypothesis** or **not support your hypothesis.** Either is fine.

Step 2: Compare your conclusion to an accepted answer. Find a literature value for your experiment, or use the closest thing you can find. 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 or not you obtain perfect results, but in how you analyse and evaluate the data you do obtain! Ensure you cite where you found the accepted scientific answer. If your results are quantitative, compare your conclusion with percentage error! The percentage error can be calculated by subtracting your result by the accepted value and dividing the answer by the accepted value! 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 concerning precision (how large your uncertainties are).

Step 3: Does everything so far make scientific sense? Relate the scientific background that you explained at the very beginning to your results. Refer to graphs and raw data and comment on whether it makes scientific sense.

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

This brings us to the final step in the evaluation: errors and improvements. Your method is usually the key place to search for improvements. Was there a particular apparatus that was very imprecise (e.g. a cylinder that could only measure volume to the nearest 10cm3?). The IB loves it when you are able to 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 the error 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 (made your accuracy lower than expected)
    - Error in equipment calibration (e.g. did you forget to zero the scale?)
    - Apparatus didn't work properly (if so, note the specific trial!)
    - User read/used apparatus incorrectly
    - A step in the method where heat/energy/light/etc was lost
- Random (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, as 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 to show some more 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 the supporting science to explain my results?
- Have I commented on my precision/uncertainties?
- Have I identified sources of systematic errors? In which direction do they influence my results? 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 under the **evaluation** criterion to get top marks:

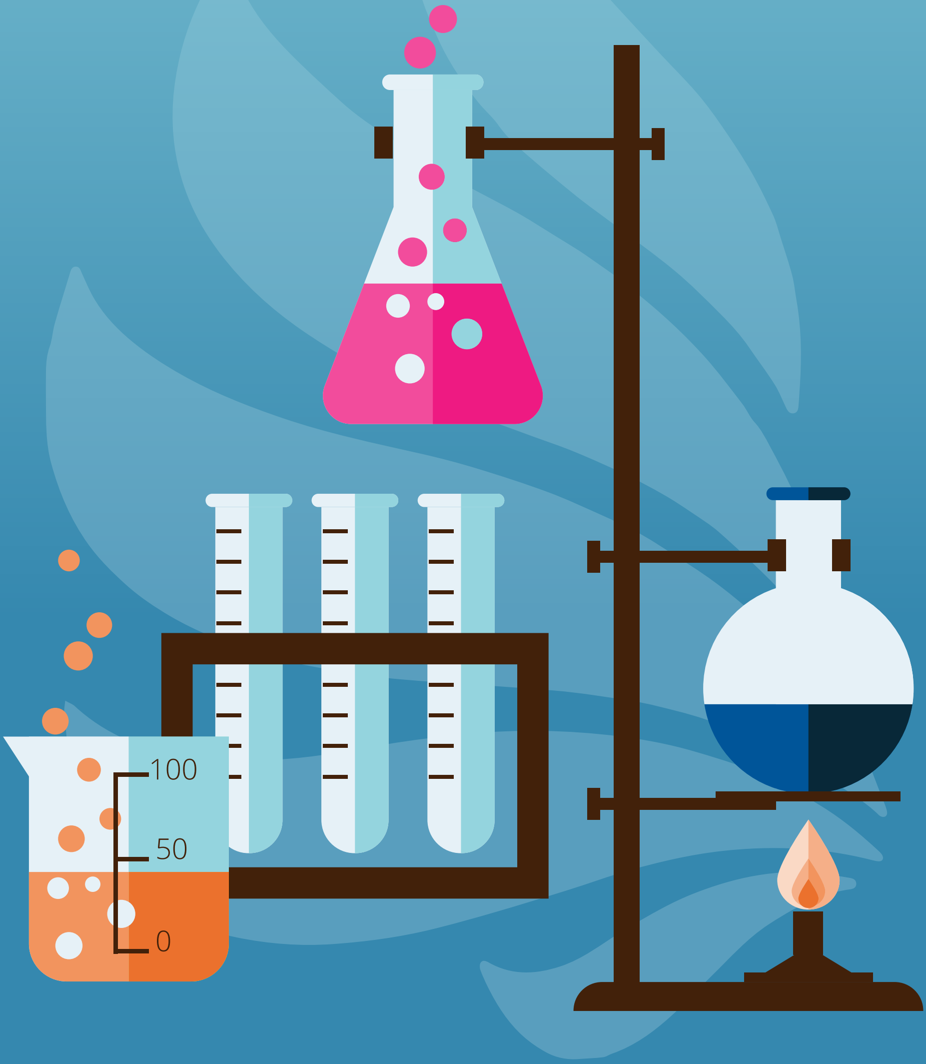
A detailed **conclusion** is described and justified which is entirely **relevant to the research question** and fully **supported by the data presented.**

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.

CHEMISTRY



Writing lab reports in chemistry is great! Most of the units covered in IB have reasonable experiments that you can carry out in a school environment. The one caution when designing an experiment is make sure you have access to the chemicals before you get too invested in planning!

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

Here are some ideas:

- Titrations are very popular! But be creative! 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! In which case, your independent variable could be the type of fruit or even the 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.


BIOLOGY

For biology there is a very wide range of research questions to choose from. A good piece of advice is to skim through the option section of your textbook. There are some cool things you could investigate in there, as well as plenty in your core curriculum. If you are not inspired by the topics you have covered so far, there is always plenty of inspiration in your textbook, especially within the higher level material and the options!

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

Yes, human: make sure you have all participants sign consent forms before collecting data.

Yes, human and involving bodily fluids such as blood samples: you cannot do this experiment…transmission of bloodborne diseases is of too high risk!

Yes, animal: make sure you discuss your design with your teacher to ensure that it meets the IB animal experimentation policy…no experiment should harm any animal subjects.

No: you still need to consider safety implications — how will your experiment affect yourself and those around you?

Some ideas:

- Investigate how plants grow in different light environments. Get creative! You could investigate 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 for which you have sufficient data. Can you determine if the trait is recessive or dominant?
- Determine whether an enzyme inhibitor is competitive or non-competitive.

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 a wide array of 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 inspiration, but be creative!

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

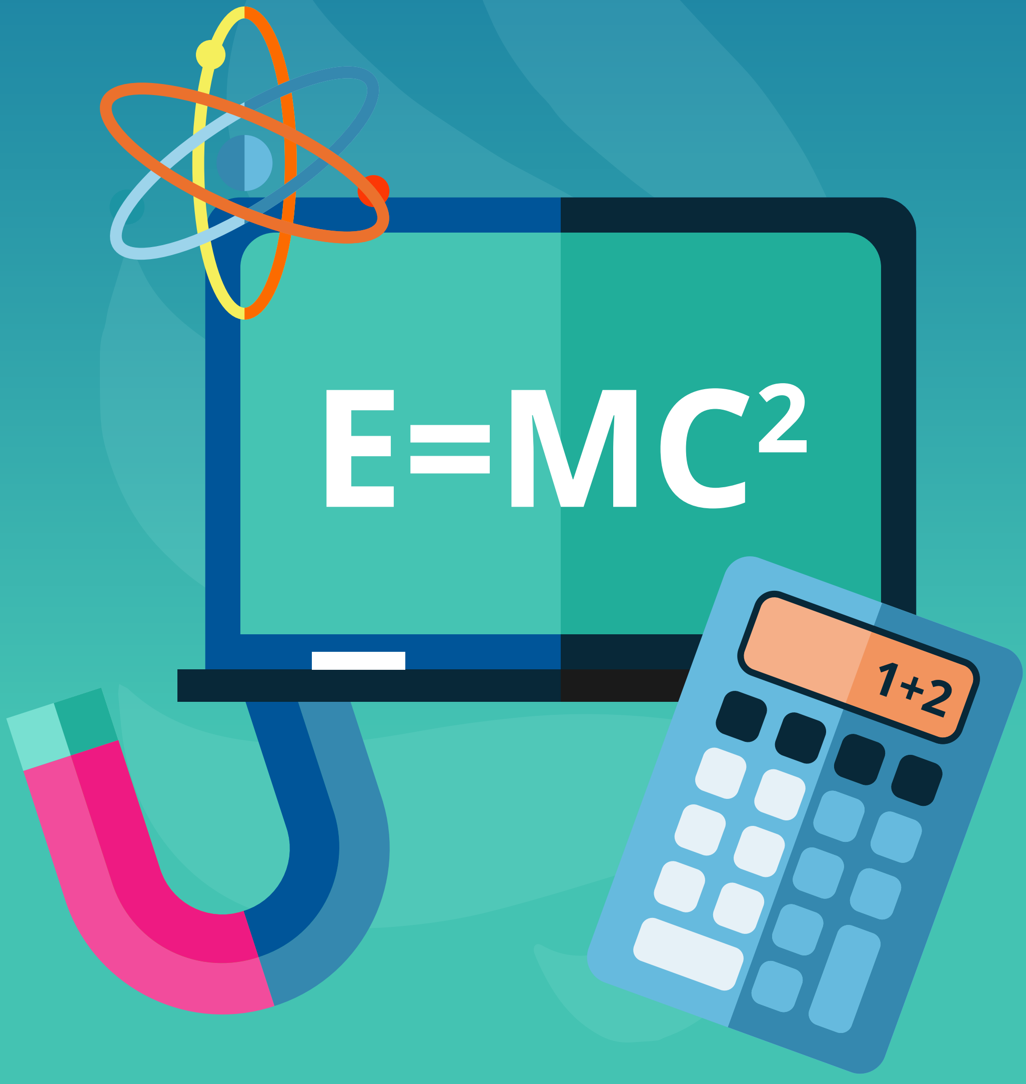
The only thing to keep in mind is that whatever your method of choice is, it must answer your research question, and you must be able to effectively collect and analyse data using the resources you have available. Keep in mind that if you plan to do experiments involving human behaviour or animal studies, you need to fulfill the conditions for these kinds of IA (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.).
- You could conduct an IA in which 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.

- 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.

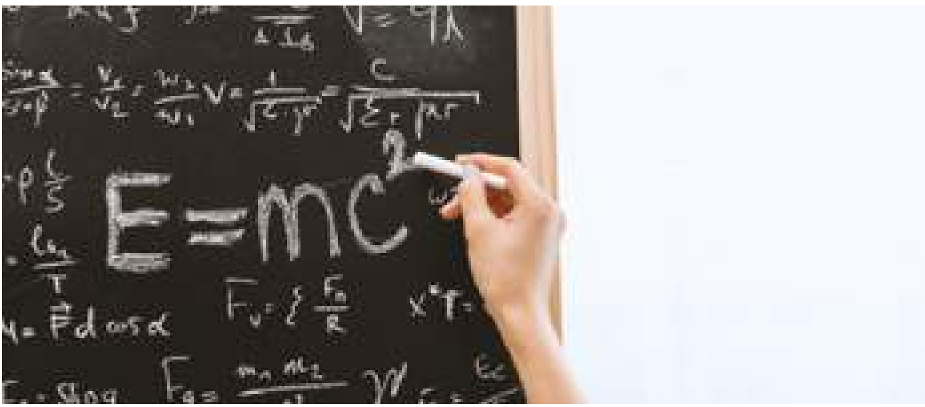
PHYSICS



So much of the physics syllabus provides inspiration for different types of investigation that you could conduct! Unfortunately, some of the modern physics that we learn such as nuclear physics and astrophysics is out of reasonable scope for a secondary student lab report but there are still plenty of cool experiments available!

- 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 using simple harmonic motion!
- Investigate how springs in parallel or series affect the total force. (Hint: extend Hooke's law!)
- Determine the resistivity of pencil lead.
- Investigate how temperature affects refractive index.
- Determine the latent heat of fusion of your favorite substance. (Hint: 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 to do at least 4 trials for a physics IA to get more precise results. You learned all the error propagation in unit 1, so make sure that you use this skill when writing your lab report!



Online Private Tuition

Receive one-on-one support from the comfort of your own home. Support whenever and wherever you need!

FOR MORE SUPPORT

head to lanternaeducation.com

Revision Courses

A helping hand when it matters the most to boost your grades! Held stategically during the Winter and Easter break before you final exam, our courses help ensure you reach you full potential!

Summer Courses

Whenever you are about to start your first or final year of the IB, use the summer to get ahead and on top of your IB subjects!

Questions? Email us at info@lanternaeducation.com