Internal Assessment – The Scientific Investigation (SI)

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The internal assessment overview

As well as sitting the external assessments (Paper 1 and Paper 2) of the IB Diploma Physics curriculum, you will submit an internal assessment (IA) component, called the scientific investigation (SI). The IA has the same requirements for both SL and HL students and is mandatory.

The purpose of the SI is to give you a platform to engage your interests and display your application of the skills and knowledge you have gained throughout the course, without the stress or time limitation of the written exams. Your task is to formulate a research question, gather and analyse data, and produce a report on your investigation.

Your report will be internally assessed by your teacher and externally moderated by the IB at the end of the course. For both SL and HL courses, the scientific investigation has a maximum of 24 marks and is worth 20% of the final assessment. The time allocated to IA is 10 hours.

Your written report will be a maximum of 3000 words. The following items are not included in the word count for your report:

- charts and diagrams
- data tables
- equations, formulas, and calculations
- citations/references (whether parenthetical, numbered, footnotes, or endnotes)
- bibliography
- headers.

Even though a cover page or a contents page is not required for the report, you must include the following at the start of the report:

- the title of your investigation
- your IB candidate code (alphanumeric, for example, xyz123)
- the IB candidate codes for all group members (if applicable)
- the final word count.

For your SI, you can employ one or more of the following techniques for data collection and analysis:

- hands-on practical laboratory work
- fieldwork
- spreadsheets for analysis and modelling
- extraction and analysis of data from a database
- simulation.

Planning and guidance

The scientific investigation must be your own work. However, your teacher will help you during the planning stage and as you work. Your teacher will guide you on the requirements of the SI, the assessment criteria it will be moderated against and any experimental guidelines you need to follow when doing your investigation.

Initial proposal

It is important you reach out to your teacher about your SI ideas and your research question as the first step in the IA. Your teacher can then guide you on the materials available in your school's laboratory, suggest the use of equipment you may not have used before and advise you on safety procedures. Sharing your ideas with your teacher will enable your teacher to inform you about academic honesty at the very beginning of the IA procedure.

First draft

Once you collect your data, you should run a quick analysis (for example, averaging the dependent variable and calculating the uncertainty of trials) to see whether the data you collected is displaying a relationship between the dependent and independent variables. You may contact your teacher at this stage and decide together whether the data you collected suggests it is worth continuing with the analysis.

If your data is sufficient to continue with analysis, you can start the first draft of your report. Before you submit your first draft, try your best to complete all the components of your report. Your teacher can only read your scientific investigation report *once* and give advice on where to improve. This means if you submit a full draft report, the feedback you receive will be more comprehensive. Your teacher may give you verbal feedback or leave generalized guiding notes, such as 'be careful about the units in the tables', or 'include maximum and minimum gradients on your graph'. Try to follow your teacher's guiding notes to reach a higher mark on your final submission.

Final version

Once you submit your final report, you have finished your scientific investigation. It is your teacher's responsibility now to grade your report according to the level descriptors defined by the IB (see the tables in this section) and to check for the authenticity of your report.

Academic honesty and integrity

As stated on page 3 of the Academic Integrity Policy of the IBO: '**academic integrity** is the responsibility of the whole IB community … It is a guiding principle in education and a choice to act in a responsible way whereby others can have trust in us as individuals. It is the foundation for ethical decision-making and behaviour in the production of legitimate, authentic, and honest scholarly work.'[1]

The scientific investigation you submit must be your own work. Your teacher may use a web-based plagiarism detection service such as Turnitin to check your report's authenticity.

As you prepare your research question, keep in mind that this work will be your intellectual property. The design of your scientific investigation is a good opportunity to display your originality.

During your physics course, your teacher will guide you on how to write a scientific investigation through in-class work. They will have an idea of your writing style, based on your prior work, and so can judge the authenticity of the report you submit. As your teacher grades the report that you submit, they will also consider your initial proposal, your first draft, and your references.

Citing references

As part of academic integrity, you must recognize the work and ideas of others. Make sure you reference your sources properly, such as enclosing direct quotations from authors in quotation marks and following the proper rules for referencing.

The IB does not require a particular style of referencing since there are many disciplines, countries, languages and educational situations represented in the programme. However, you should choose and use one referencing style consistently throughout your work. The referencing systems suggested by the IB include MLA, APA and Chicago.

At the end of your report, all in-text citations should be stated in a bibliography, works cited, or references section. For online material used, the section heading or the number of the relevant paragraph can be stated, and the date of access should also be given.

Safety requirements and recommendations

Even though the guidelines for safety requirements may vary from country to country, a safe and healthy work environment is essential for completing practical work. Your teachers are responsible for preparing and implementing the safety protocols and protection of the environment policy. As *caring* learners of IB Physics, any action resulting in harm to the environment is unacceptable. As you are designing your SI, remember you are responsible for using the resources provided wisely and respectfully.

You should always wear protective clothing, such as safety goggles, protective gloves and lab coats, when you are doing experiments in the science laboratory. During data collection, you will be running the trials but your teacher or a lab technician will always be present in the lab. They will know how to react in case of fire, electrical overloading, a gas leak or injury. However, it is also your responsibility to report immediately whenever you notice a hazard taking place.

[1] 'Academic Integrity Policy/What is academic integrity' 2019. Sso.ibo.org. Accessed January 7, 2023. https://resources.ibo.org/ib/works/edu_11162-58121?lang=en&root=1.6.2.4.5.
IB Academic integrity policy updated 2023: https://www.ibo.org/globalassets/new-structure/programmes/shared-resources/pdfs/academic-integrity-policy-en.pdf

Assessment criteria

The assessment criteria (identical for SL and HL students) contain descriptors of specific achievement levels. Each criterion has a range of 0–6 marks. The work you submit will be assessed for each individual criterion, according to the criteria given in Table 1, rather than holistically.

Table 1: The Inquiry processes and the IA criteria details

Criterion	Inquiry process	Maximum number of marks available	Weighting (%)
Research design	Exploring and designing	6	25
Data analysis	Collecting and processing data	6	25
Conclusion	Concluding and evaluating	6	25
Evaluation		6	25
Total		24	100

Source: Physics for the IB Diploma Guide, page 72.

You need to become familiar with the assessment criteria for each component of the scientific investigation, as detailed in the tables in this section.

Inquiry skills and the IA

The inquiry process has three steps:

1. Exploring and designing
    - Exploring
    - Designing
    - Controlling variables
2. Collecting and processing data
    - Collecting data
    - Processing data
    - Interpreting results
3. Concluding and evaluating
    - Concluding
    - Evaluating

In time, as you progress through the course, you will improve your inquiry skills so that you can design your own experiment.

The four assessment criteria will now be discussed in more detail, together with the inquiry skills they involve.

Research design

This criterion assesses how well you communicate the methodology (purpose and practice) of your investigation.

When writing the report of the scientific investigation, presenting the research design is much like giving a 'recipe'. Keep in mind that if any stranger were to redo your experiments, your methodology should be easy to understand and repeat. The research design links with Inquiry 1.

Table 2 sets out the marking criteria for this section.

Table 2: Marks and level descriptors for Research design

Marks	Level descriptor
0	• The report does not reach the standard described by the descriptors below.
1–2	• The research question is stated without context. • Methodological considerations associated with collecting data relevant to the research question are stated. • The description of the methodology for collecting or selecting data lacks the detail to allow for the investigation to be reproduced.
3–4	• The research question is outlined within a broad context. • Methodological considerations associated with collecting relevant and sufficient data to answer the research question are described. • The description of the methodology for collecting or selecting data allows for the investigation to be reproduced with few ambiguities or omissions.
5–6	• The research question is described within a specific and appropriate context. • Methodological considerations associated with collecting relevant and sufficient data to answer the research question are explained. • The description of the methodology for collecting or selecting data allows for the investigation to be reproduced.

Source: Physics for the IB Diploma Guide, page 72

Inquiry 1: Exploring and designing

Exploring and designing is the preparation stage for the scientific investigation. Here, you do your preliminary research according to your interests, construct a research question, decide on your methodology and design a method to test your research question.

Exploring

Exploring is the introduction to your journey of scientific investigation. In this section, you should express your motivation – the trigger and the intuition – for choosing your research question.

Although it is traditional to state the research question in question form, you may also give it as a statement. Whether it is a question or a statement, your it should include your independent variable (the variable you manipulate, decided in advance) and the dependent variable (the variable you measure). Broaden your topic of research by stating your controlled variables (the variables you kept constant throughout the data collection).

For example, if you wanted to investigate the relationship between mass and acceleration, your research question might be: 'How will the acceleration ($m\ s^{-2}$) of an experiment cart change when the mass of the cart (kg) is increased under the conditions that the force applied (0.098 N) to move the cart and the friction coefficient of the horizontal track of length 50 cm are kept constant and the cart is always released 10 cm away from the motion sensor?' Notice that all the variables of the experiment are stated in this question with their units; the constant values of the controlled variables are also stated.

Use a variety of sources (webpages, books and articles) to find and choose appropriate sources of information to support your research topic. Use the information you have gathered in your research to support your hypothesis, based on scientific reasoning and understanding.

Designing

When the exploration phase of the scientific investigation is complete, you can state the methodology you will use to collect sufficient data. Are you planning to collect your data by designing a hands-on investigation or by using a simulation? Perhaps extracting data from a database is more convenient for your research question. Once you decide on your methodology, design a method to collect sufficient data to test your research question. Rather than repeating a ready-made design, you are encouraged to demonstrate your creativity by designing your experiment or an investigation using databases, simulations, or modelling.

As you are designing your method, you should specify the range of measurements of the independent variable, the number of trials you will have for the dependent variable, and the pre-set or constant values of the controlled variables, supported by scientific reasoning. The procedure of the experiment should be given clearly, step-by-step, so that anyone replicating your work can understand and repeat the method.

Controlling variables

To have valid measurements, the controlled variables should be determined once the independent and dependent variables are decided. Any fluctuation in the fixed values of the controlled variables will result in anomalous values in the set of raw data collected.

When controlling variables, you are expected to:

- calibrate the measuring apparatus – for example, resetting a force sensor
- maintain constant environmental conditions of systems – for example, keeping the temperature, pressure, humidity or light intensity the same
- insulate against heat loss or gain – for example, using a calorimeter for insulation
- reduce electrical resistance – for example, using the least number of low-resistance connection wires possible
- reduce the effects of friction – for example, using low friction pulleys and tracks
- take background radiation into account – for example measuring the background radiation before bringing the radioactive source to where the measurements will be taken.

Checklist for research design

Use this checklist to ensure you have included everything for the research design.

- ☐ An introduction with the reason(s) for choosing your topic of investigation
- ☐ Background information with sources (aim for 3–5), including any necessary equations
- ☐ A research question including all the variables of an experiment, with their units and their constant values
- ☐ A stated hypothesis with relevant supportive scientific reasoning
- ☐ A table of the variables of the experiment including:
    - the method for manipulating the independent variable with the range of data
    - the method for measuring the dependent variable with the number of repeats
    - reasoning and methods for keeping the controlled variables constant with their fixed values
- ☐ A labelled clear drawing or photograph of the setup for hands-on experiments
- ☐ A stated database or a model or a simulation for the sampling of data (if not a hands-on experiment)
- ☐ A list of materials with their quantities (e.g. number of items used and their sizes)
- ☐ Safety precautions and ethical and environmental considerations
- ☐ A clear, step-by-step methodology that can be repeated by anyone

Data analysis

In this criterion, you will be assessed on recording, processing and presenting your data. You have designed your methodology, so it's now time to apply it. You should provide evidence of how you performed in your scientific investigation. The data analysis portion of the scientific investigation links with Inquiry 2.

Table 3 sets out the marking criteria for this section.

Table 3: Marks and level descriptors for Data analysis

Marks	Level descriptor
0	• The report does not reach a standard described by the descriptors below.
1–2	• The recording and processing of the data is communicated but is neither clear nor precise. • The recording and processing of data shows limited evidence of the consideration of uncertainties. • Some processing of data relevant to addressing the research question is carried out but with major omissions, inaccuracies or inconsistencies.
3–4	• The communication of the recording and processing of the data is either clear or precise. • The recording and processing of data shows evidence of a consideration of uncertainties but with some significant omissions or inaccuracies. • The processing of data relevant to addressing the research question is carried out but with some significant omissions, inaccuracies or inconsistencies.
5–6	• The communication of the recording and processing of the data is both clear and precise. • The recording and processing of data shows evidence of an appropriate consideration of uncertainties. • The processing of data relevant to addressing the research question is carried out appropriately and accurately.

Source: Physics for the IB Diploma Guide, page 73

Inquiry 2: Collecting and processing data

Now you are ready to collect raw data, and then process and analyse it. This part of the report is where you can display the skills you have gained by using the Tools that are integrated throughout your course, especially Tool 3 (for more information on the Tools, see the Physics Tools and Inquiries reference guide, available at https://www.hoddereducation.co.uk/ib-extras).

You are expected to apply technology for data collection, such as using sensors, and for processing data, such as using spreadsheets or scientific calculators for computing, and graphing software for interpretating processed data. Processing data also requires general mathematics, using units, symbols, numerical values, and the processing of uncertainties.

Collecting data

Your primary aim is to collect sufficient data to address your research question and for later analysis. However, to have reliable data, your first step should be defining and/or measuring the values of the controlled variables. You can either give the values of the controlled variables as a list or, you can mention them in the title of the raw data table in your report.

Make sure you select equal intervals of change for your independent variable. For instance, in our example research question on page 5, you would ensure there are equal increases for the mass of the experiment cart, such as by increasing the mass of the cart by 200 g for each new value of the independent variable (mass).

Remember, one measurement is never enough to give precise data. You should repeat the same measurement at least five times with the same value of the independent variable to have a reliable measurement for your dependent variable.

As you are collecting your raw data, be careful to avoid random errors that may occur during the measurements. Before moving on to a new value of the independent variable, review the collected data for any anomalous measurement and, if necessary, repeat that measurement to reduce the uncertainty.

Record your collected quantitative data (data with numbers) in a table with the appropriate names for all the quantities, their units, and the device uncertainties and their units. This raw data table should be given a number and a name. The table name should refer to the variables in the table and include the constant values of the controlled variables.

You also need to record relevant qualitative observations (the descriptive information related to the characteristics of the experiment). You can state the changes in shape, colour or the behaviour of the system, such as in the system in the example research question: 'As the mass on the experiment cart is increased, it became harder to initiate its motion.' Here you are explaining to the reader how the system behaved when you made the changes to the independent variable.

Unfortunately, sometimes the data collection may not be very smooth and easy. In our example, perhaps the inclination of the track causes the experiment cart to accelerate without the application of an external force, which you only notice as you are taking your third measurement. In such a case, you must stop taking your measurements, check the horizontal level of your track using a spirit level and start again. If a problem arises during your data collection, and you notice and correct the issue, this is something you should include in your report.

Processing data

Once the raw data is collected, you can start its processing using relevant physical and mathematical equations, such as averages, reciprocals, and trigonometric functions. As you are writing your report, bear in mind it will be checked by an external moderator who knows nothing about you or your knowledge of physics and has no idea of what challenges you had during this process. Therefore, explain fully any calculation you make to process your data. This can easily be done by giving a sample calculation for each type of calculation you make. Use a formula editor (often included in word processing software) and remember to write the unit of each calculated quantity.

Once you have completed your calculations, give your processed results in appropriate tables. Processed data tables should have appropriate names, just like your raw data table(s), with units and uncertainties included. Give your results to the appropriate number of significant figures. If your measuring device is capable of measuring one digit following the decimal point, do not include two digits following the decimal point; your calculations *cannot* be more precise than your measurements.

Interpreting results

Now that you have processed the raw data, you should present and interpret your processed data using diagrams, charts and graphs. For most physics experiments, processed data is displayed by an appropriate graph (including error bars) with the processed dependent variable on the vertical axis and the independent variable on the horizontal axis. The graph should be linearized where appropriate, including the maximum and the minimum gradient lines. Your graphs are preparing the reader for the results, the conclusion and the evaluation of your experimental procedure. Any trends in the graph will help you to identify the relationships between your variables, and any outliers in the measurements. For more on constructing graphs, see page 16 in the Physics Tools and Inquiries reference guide at https://www.hoddereducation.co.uk/ib-extras.

Checklist for Data analysis

Use this checklist to ensure you have included everything for the data analysis.

General

- ☐ All tables are numbered and have a caption describing their content.
- ☐ The tables are easy to understand and neatly organized.
- ☐ All table headings include the name or the symbol of the measured variables with units in parentheses.
- ☐ The measurements, relevant device uncertainties, and processed data are written to the correct number of significant figures.

Collecting data

- ☐ The collected data agrees with the variables defined in the research question of the investigation.
- ☐ Quantitative observations (raw data) are given in an appropriate table.
- ☐ Qualitative observations are given as a paragraph.

Processing data

- ☐ A sample calculation is given for each of the operations.
- ☐ Sample calculations are written using a formula editor.
- ☐ The units of the results of calculations are given.

Interpreting data

- ☐ All graphs are numbered and have a title and a caption.
- ☐ All graphs have the independent variable on the horizontal axis and the dependent variable on the vertical axis.
- ☐ The linearization of the graphs is made using necessary mathematical operations.
- ☐ The maximum and minimum gradients of the linearized data are drawn.
- ☐ The uncertainty of the gradient of the best-fit line is calculated.
- ☐ Any anomalous or outlying data is stated and removed with justification.

Conclusion

So far you have recorded and analysed your data, and given your interpretations of your results. Now it's time to draw conclusions from your results. In this criterion, you will be assessed on how successfully you answer your research question, with reference to your analysis and the accepted scientific context. The conclusion portion of the scientific investigation links with the first part of Inquiry 3.

Table 4 sets out the marking criteria for this section.

Table 4: Marks and level descriptors for Conclusion

Marks	Level descriptor
0	• The report does not reach a standard described by the descriptors below.
1–2	• A conclusion is stated that is relevant to the research question but is not supported by the analysis presented. • The conclusion makes superficial comparison to the accepted scientific context.
3–4	• A conclusion is described that is relevant to the research question but is not fully consistent with the analysis presented. • A conclusion is described that makes some relevant comparison to the accepted scientific context.
5–6	• A conclusion is justified that is relevant to the research question and fully consistent with the analysis presented. • A conclusion is justified through relevant comparison to the accepted scientific context.

Source: Physics for the IB Diploma Guide, page 74

Inquiry 3: Concluding and evaluating

This is the part of the scientific investigation where you reply to your research question. Your conclusion should be built on your processed data and your graphs drawn as an interpretation of the data, rather than describing a general case.

Concluding

In the conclusion part of the report, use your processed data and analysis to justify your conclusions. You should also compare the outcomes of your investigation to the accepted scientific context. You can refer to the background information from the beginning of your report and use the necessary physical and mathematical concepts. If you can find literature values or results of pre-existing research related to your investigation, you can relate those outcomes to your own stated research question or hypothesis. If possible, carry out an error analysis to compare your results with the literature values (calculating percentage error is covered in Tool 3 Mathematics). If you cannot calculate the percentage error, state the trends of the raw and processed data, and discuss the impact of the associated uncertainties on the results of your investigation.

Checklist for Conclusion

Use this checklist to ensure you have included everything for the conclusion.

- ☐ The research question is answered in relation to the outcomes of your investigation.
- ☐ The outcomes of your investigation are compared to the appropriate scientific context.
- ☐ The reliability of the raw data and the suitability of the processed data are explained.
- ☐ The impacts of the associated uncertainties of the processed data are discussed.
- ☐ If possible, an error analysis for the literature value is included.
- ☐ An appropriate citation of the published materials for the literature value is given.

Evaluation

Following your conclusion, you will evaluate your investigation. This is the section where you evaluate your methodology and suggest improvements. The evaluation portion of the scientific investigation links with the second part of Inquiry 3.

Table 5 sets out the marking criteria for this section.

Table 5: Marks and level descriptors for Evaluation

Marks	Level descriptor
0	• The report does not reach a standard described by the descriptors below.
1–2	• The report states generic methodological weaknesses or limitations. • Realistic improvements to the investigation are stated.
3–4	• The report describes specific methodological weaknesses or limitations. • Realistic improvements to the investigation that are relevant to the identified weaknesses or limitations, are described.
5–6	• The report explains the relative impact of specific methodological weaknesses or limitations. • Realistic improvements to the investigation, that are relevant to the identified weaknesses or limitations, are explained.

Source: Physics for the IB Diploma Guide, page 74

The second part of the third step of the inquiry process is assessed under this criterion.

Inquiry 3: Concluding and evaluating

The evaluation is your reflection on your investigation. It should be specific to the investigation you carried out, rather than including the methods for similar research questions from the literature.

Evaluating

For this part of your report, start with an evaluation of your hypothesis. Briefly restate your hypothesis and state whether your analysed data supports it. Here you will also identify and discuss sources and impacts of random and systematic errors on your investigation. Scrutinize the weaknesses of your methodology in terms of control of the variables, the precision of your measurements and deviations of data in the measurements. What were the consequences of any methodological weaknesses? Were there any limitations to your setup due to the range of the data you collected? Did you make any assumptions? Remember to suggest and explain reasonable improvements to your investigation that you could make.

Checklist for Evaluation

Use this checklist to ensure you have included everything for the conclusion.

- ☐ You state whether the hypothesis is supported.
- ☐ Any sources of random and systematic errors are identified and discussed.
- ☐ The impacts of random and systematic errors on the results are discussed.
- ☐ Any methodological weaknesses are reviewed.
- ☐ The limitations of the conclusion are discussed.
- ☐ Reasonable and appropriate improvements to the investigation are suggested.