

Extended Essay. Comment and Assessment Rubric - Physics

Criterion A: Focus and method

This criterion focuses on the topic, the research question and the methodology. It assesses the explanation of the focus of the research (this includes the topic and the research question), how the research will be undertaken, and how the focus is maintained throughout the essay.

(Strands: Topic, Research question, Methodology)

The title of the essay should:

- reflect the essence of the investigation
- by itself clearly describe the topic or aim of the essay
- not be too long
- be clarified, if necessary, early in the essay
- be different from the research question
- usually be presented as a statement.

Early in the essay the student should also outline the area of the research and the purpose and focus of the essay to clearly establish the context of the research question. It is usually appropriate to identify the physics principles relevant to the research question.

For example, a brief description of the motion of a cylindrical magnet falling inside a copper pipe will include the application of the laws of electromagnetic induction as well as Newton's laws of motion.

For this, the student should write a qualitative description of the forces acting on the falling magnet, and their possible variations along its path. Their description could usefully include diagram(s) and perhaps a sketch graph.

A formal development of the theory relevant to the research question follows later on in the essay.

The research question must be centred on physics as a science. It must not focus on peripheral issues, such as the history of physics or social implications of discoveries in physics.

The way in which students plan their investigation will depend on the approach they choose. They must demonstrate that their chosen methods and materials do address the research question.

If the essay is data-based, students' planning should include:

- the relevant physics theory based on reliable and appropriate literature research
- an appreciation of the uncertainties and limitations of techniques and apparatus for data collection.

Students must explain clearly the rationale for choosing their particular experimental methods. However, preliminary work should not be part of the core of the essay.

If their study is based on the research of secondary data, students need to ensure that the selection of sources is sufficiently wide and reliable.

Criterion A: Focus and method. *The Assessment Criteria*

Level	Descriptor
0	The work does not reach a standard outlined by the descriptors below.
1–2	<p>The topic is communicated unclearly and incompletely</p> <ul style="list-style-type: none">- Identification and explanation of the topic is limited; the purpose and focus of the research is unclear, or does not lend itself to a systematic investigation in the subject for which it is registered. <p>The research question is stated but not clearly expressed or too broad</p> <ul style="list-style-type: none">- The research question is too broad in scope to be treated effectively within the word limit and requirements of the task, or does not lend itself to a systematic investigation in the subject for which it is registered.- The intent of the research question is understood but has not been clearly expressed and/or the discussion of the essay is not focused on the research question. <p>Methodology of the research is limited</p> <ul style="list-style-type: none">- The source(s) and/or method(s) to be used are limited in range given the topic and research question.- There is limited evidence that their selection was informed.
3–4	<p>The topic is communicated</p> <ul style="list-style-type: none">- Identification and explanation of the research topic is communicated; the purpose and focus of the research is adequately clear, but only partially appropriate. <p>The research question is clearly stated but only partially focused</p> <ul style="list-style-type: none">- The research question is clear but the discussion in the essay is only partially focused and connected to the research question. <p>Methodology of the research is mostly complete</p> <ul style="list-style-type: none">- Source(s) and/or method(s) to be used are generally relevant and appropriate given the topic and research question.- There is some evidence that their selection(s) was informed. <p>If the topic or research question is deemed inappropriate for the subject in which the essay is registered no more than four marks can be awarded for this criterion.</p>
5–6	<p>The topic is communicated accurately and effectively</p> <ul style="list-style-type: none">- Identification and explanation of the research topic is effectively communicated; the purpose and focus of the research is clear and appropriate. <p>The research question is clearly stated and focused</p> <ul style="list-style-type: none">- The research question is clear and addresses an issue of research that is appropriately connected to the discussion in the essay. <p>Methodology of the research is complete</p> <ul style="list-style-type: none">- An appropriate range of relevant source(s) and/or method(s) have been applied in relation to the topic and research question.- There is evidence of effective and informed selection of sources and/or methods.

Criterion B: Knowledge and understanding

This criterion assesses the extent to which the research relates to the subject area/discipline used to explore the research question, or in the case of the world studies extended essay, the issue addressed and the two disciplinary perspectives applied, and additionally the way in which this knowledge and understanding is demonstrated through the use of appropriate terminology and concepts.

(Strands: Context, Subject-specific terminology and concepts)

The essay must show clear evidence of understanding of the physics focused on in the essay.

It is not required to explain fundamental laws of physics or general knowledge that are applied in the investigation.

Sources relevant to the research question should be effectively referenced and incorporated into the body of the essay in a way that demonstrates the student's understanding.

A theoretical dimension must be part of any empirical investigation. For this purpose, students should develop their own model or use material from acknowledged sources in a relevant and appropriate way.

Students must demonstrate the ability to apply their method and selected sources effectively in support of their argument.

The relative weight given to literature sources will depend on the approach chosen by the student.

Students should make sure definitions are clearly stated if the material being discussed lies outside the IB physics course. Students must make sure that all steps in their reasoning are clearly understood. Students need to demonstrate that they fully understand what they are doing.

Physics terminology relevant to the research question should be used appropriately and explained to show understanding.

The essential quality of the language relates to exactness and precision, and typical expressions, such as “function of” or “proportional to”, carry specific meanings. A curve on a graph cannot be qualified as “exponential” or “quadratic” without prior proper analysis.

Any symbols used must be clearly and fully identified in the context of the situation and must be applied consistently throughout the essay. For example, writing “t for time” would not be sufficient but writing “t for time during which the magnetic force is applied” would be precise and helpful.

Appropriate and precise physics terminology includes units.

Only SI standards must be applied to numerical expressions associated with uncertainty and units.

The use of annotated diagrams for set-up, theory and analysis is an efficient and highly useful tool of communication in physics. It should be part of the student's physics language and properly integrated.

Criterion B: Knowledge and understanding. *The Assessment Criteria*

Level	Descriptor
0	The work does not reach a standard outlined by the descriptors below.
1–2	<p>Knowledge and understanding is limited.</p> <ul style="list-style-type: none">- The selection of source material has limited relevance and is only partially appropriate to the research question.- Knowledge of the topic/discipline(s)/issue is anecdotal, unstructured and mostly descriptive with sources not effectively being used. <p>Use of terminology and concepts is unclear and limited.</p> <ul style="list-style-type: none">- Subject-specific terminology and/or concepts are either missing or inaccurate, demonstrating limited knowledge and understanding.
3–4	<p>Knowledge and understanding is good.</p> <ul style="list-style-type: none">- The selection of source material is mostly relevant and appropriate to the research question.- Knowledge of the topic/discipline(s)/issue is clear; there is an understanding of the sources used but their application is only partially effective. <p>Use of terminology and concepts is adequate.</p> <ul style="list-style-type: none">- The use of subject-specific terminology and concepts is mostly accurate, demonstrating an appropriate level of knowledge and understanding. <p>If the topic or research question is deemed inappropriate for the subject in which the essay is registered no more than four marks can be awarded for this criterion.</p>
5–6	<p>Knowledge and understanding is excellent.</p> <ul style="list-style-type: none">- The selection of source materials is clearly relevant and appropriate to the research question.- Knowledge of the topic/discipline(s)/issue is clear and coherent and sources are used effectively and with understanding. <p>Use of terminology and concepts is good.</p> <ul style="list-style-type: none">- The use of subject-specific terminology and concepts is accurate and consistent, demonstrating effective knowledge and understanding.

Criterion C: Critical thinking

This criterion assesses the extent to which critical-thinking skills have been used to analyse and evaluate the research undertaken.

(Strands: Research, Analysis and Discussion and evaluation)

The research sources and collected data in an investigation must be essentially and consistently relevant to, and focused on, the research question.

Students should use mathematics as a tool without it replacing the relevant physics or becoming the goal itself. For example, in data analysis the student should show an understanding of the statistics and mathematical relationships produced automatically by software programs and pay attention to uncertainties and significant digits of quoted fit parameters.

Any automatic software curve-fitting and parameter estimation, eg polynomials of degree n , must be justified within a meaningful physics model or theory.

Statistics should not override physics. A purely empirical approach will not achieve the highest band of this criterion.

Students should be able to manipulate properly significant digits and uncertainties, especially uncertainty in the mean and in graphs. They should also understand propagation of errors, where appropriate.

Students need to demonstrate understanding of the intrinsic limitations of an investigation, and their implications for the conclusions reached. They should demonstrate how a given proposed limitation impacts the final results and conclusion, such as where experimental results are compared with standard values.

Students must evaluate the validity and reliability of data and information from sources. They should comment on the quality, balance and quantity of the sources and data used.

Throughout the essay, students should present a clear, coherent and focused argument based on the research question. Personal views should not simply be stated but must be supported by reasoned argument to persuade the reader of their validity.

Straightforward descriptive or narrative accounts that lack analysis do not usually advance an argument and should be avoided.

The level of insight and depth of understanding are most likely to be demonstrated as a consequence of detailed research, reflection that is thorough and well informed and reasoned argument that consistently and effectively addresses the research question.

A well-organized and well-presented essay will enhance the clarity of an argument.

The conclusion(s) should be consistent and develop clearly out of the argument. It should not introduce new evidence or extraneous matter. It should be personal to the student and present a new synthesis in light of the discussion.

The analysis and conclusion(s) should reveal the impact on the investigation of the limitations inherent in theoretical models, in the experimental data collected and in the experimental design. When the original research question is not fully answered, students may briefly suggest how these unanswered aspects might be further investigated.

Criterion C: Critical thinking. *The Assessment Criteria*

Level	Descriptor
0	The work does not reach a standard outlined by the descriptors below.
1–3	<p>The research is limited.</p> <ul style="list-style-type: none">- The research presented is limited and its application is not clearly relevant to the RQ. <p>Analysis is limited.</p> <ul style="list-style-type: none">- There is limited analysis.- Where there are conclusions to individual points of analysis these are limited and not consistent with the evidence. <p>Discussion/evaluation is limited.</p> <ul style="list-style-type: none">- An argument is outlined but this is limited, incomplete, descriptive or narrative in nature.- The construction of an argument is unclear and/or incoherent in structure hindering understanding.- Where there is a final conclusion, it is limited and not consistent with the arguments/evidence presented.- There is an attempt to evaluate the research, but this is superficial. <p>If the topic or research question is deemed inappropriate for the subject in which the essay is registered no more than three marks can be awarded for this criterion.</p>
4–6	<p>The research is adequate.</p> <ul style="list-style-type: none">- Some research presented is appropriate and its application is partially relevant to the Research question. <p>Analysis is adequate.</p> <ul style="list-style-type: none">- There is analysis but this is only partially relevant to the research question; the inclusion of irrelevant research detracts from the quality of the argument.- Any conclusions to individual points of analysis are only partially supported by the evidence. <p>Discussion/evaluation is adequate.</p> <ul style="list-style-type: none">- An argument explains the research but the reasoning contains inconsistencies.- The argument may lack clarity and coherence but this does not significantly hinder understanding.- Where there is a final or summative conclusion, this is only partially consistent with the arguments/evidence presented.- The research has been evaluated but not critically.

7-9	<p>The research is good.</p> <ul style="list-style-type: none"> - The majority of the research is appropriate and its application is clearly relevant to the research question. <p>Analysis is good.</p> <ul style="list-style-type: none"> - The research is analysed in a way that is clearly relevant to the research question; the inclusion of less relevant research rarely detracts from the quality of the overall analysis. - Conclusions to individual points of analysis are supported by the evidence but there are some minor inconsistencies. <p>Discussion/evaluation is good.</p> <ul style="list-style-type: none"> - An effective reasoned argument is developed from the research, with a conclusion supported by the evidence presented. - This reasoned argument is clearly structured and coherent and supported by a final or summative conclusion; minor inconsistencies may hinder the strength of the overall argument. - The research has been evaluated, and this is partially critical.
10-12	<p>The research is excellent.</p> <ul style="list-style-type: none"> - The research is appropriate to the research question and its application is consistently relevant. <p>Analysis is excellent.</p> <ul style="list-style-type: none"> - The research is analysed effectively and clearly focused on the research question; the inclusion of less relevant research does not significantly detract from the quality of the overall analysis. - Conclusions to individual points of analysis are effectively supported by the evidence. <p>Discussion/evaluation is excellent.</p> <ul style="list-style-type: none"> - An effective and focused reasoned argument is developed from the research with a conclusion reflective of the evidence presented. - This reasoned argument is well structured and coherent; any minor inconsistencies do not hinder the strength of the overall argument or the final or summative conclusion. - The research has been critically evaluated.

Criterion D: Presentation

This criterion assesses the extent to which the presentation follows the standard format expected for academic writing and the extent to which this aids effective communication.

(Strands: Structure, Layout)

This criterion relates to the extent to which the essay conforms to current academic standards regarding the way in which research papers should be presented. It also relates to how well these elements support the reading, understanding and evaluation of the essay.

Students must provide a section and subsection structure to their essays, with appropriate informative headings.

In experimental investigations, a scientific annotated diagram can efficiently introduce key elements of the set-up. Only relevant details of key equipment should be given and exhaustive lists of equipment avoided. A summary of the essential procedural steps in a scientific paper style is expected rather than a cookbook recipe approach.

Any graphs, figures or tables generated by students or taken from literature sources included in the essay must be carefully selected and labelled. They should only be used if they are directly relevant to the research question, contribute towards the understanding of the argument and are of a good graphic quality. Clarity in tables and graphs is important and students should not use unnecessary over-formatting that may detract from communication.

A representative sample of raw data collected in large amounts by the student must be included in the core of the essay in a data table including uncertainties and units. The rest of the raw data should be in the appendix where they should be carefully labelled. Tables of processed data in the core of the essay should be designed to clearly display the information in the most appropriate form.

Graphs drawn from the analysed data should be selected to highlight only the most pertinent aspects related to the argument. Too many graphs and data tables will detract from the overall quality of the communication and interrupt the development of the argument.

Only processed data, graphs, diagrams or images that are central to the argument of the essay should be included in the body of the essay, as close as possible to its first reference in the text.

Data tables should enhance a written explanation; they should not themselves include significant bodies of text. If they do, then these words will be included in the word count.

The use of a summary table and the combination of multiple graphs into one graph (family of curves) will avoid unnecessary repetitions. Equations referred to in the text should be numbered.

Any material that is not original must be carefully acknowledged, with specific attention paid to the acknowledgment and referencing of quotes and ideas. This acknowledgment and referencing is applicable to audiovisual material, text, graphs and data published in print and electronic sources. If the referencing does not meet the minimum standard as indicated in the guide (name of author, date of publication, title of source and page numbers as applicable), and is not consistently applied, work will be considered as a case of possible academic misconduct.

A bibliography is essential and has to be presented in a standard format. Title page, table of contents, page numbers, etc must contribute to the quality of presentation.

The essay must not exceed 4,000 words of narrative. Students should be aware that examiners will not read beyond the 4,000-word limit, nor assess any material presented thereafter.

Criterion D: Presentation. *The Assessment Criteria*

Level	Descriptor
0	The work does not reach a standard outlined by the descriptors below.
1–2	<p>Presentation is acceptable.</p> <ul style="list-style-type: none">- The structure of the essay is generally appropriate in terms of the expected conventions for the topic, argument and subject in which the essay is registered.- Some layout considerations may be missing or applied incorrectly.- Weaknesses in the structure and/or layout do not significantly impact the reading, understanding or evaluation of the extended essay.
3–4	<p>Presentation is good.</p> <ul style="list-style-type: none">- The structure of the essay clearly is appropriate in terms of the expected conventions for the topic, the argument and subject in which the essay is registered.- Layout considerations are present and applied correctly.- The structure and layout support the reading, understanding and evaluation of the extended essay.

Criterion E: Engagement

This criterion assesses the student's engagement with their research focus and the research process. It will be applied by the examiner at the end of the assessment of the essay, after considering the student's *Reflections on planning and progress form*.

(Strands: Reflections on planning and progress)

This criterion assesses the student's engagement with their research focus and the research process. It will be applied by the examiner at the end of the assessment of the essay, and is based solely on the candidate's reflections as detailed on the RPPF, with the supervisory comments and extended essay itself as context.

Students are expected to provide reflections on the decision-making and planning process undertaken in completing the essay. Students must demonstrate how they arrived at a topic as well as the methods and approach used. This criterion assesses the extent to which a student has evidenced the rationale for decisions made throughout the planning process and the skills and understandings developed.

For example, students may reflect on:

- the approach and strategies they chose, and their relative success
- the *Approaches to learning* skills they have developed and their effect on the student as a learner
- how their conceptual understandings have developed or changed as a result of their research
- challenges they faced in their research and how they overcame these
- questions that emerged as a result of their research
- what they would do differently if they were to undertake the research again.

Effective reflection highlights the journey the student has engaged in through the EE process. Students must show evidence of critical and reflective thinking that goes beyond simply describing the procedures that have been followed.

The reflections must provide the examiner with an insight into student thinking, creativity and originality within the research process. The student voice must be clearly present and demonstrate the learning that has taken place.

Criterion E: Engagement. *The Assessment Criteria*

Level	Descriptor
0	The work does not reach a standard outlined by the descriptors below.
1–2	Engagement is limited. <ul style="list-style-type: none">- Reflections on decision-making and planning are mostly descriptive.- These reflections communicate a limited degree of personal engagement with the research focus and/or research process.
3–4	Engagement is good. <ul style="list-style-type: none">- Reflections on decision-making and planning are analytical and include reference to conceptual understanding and skill development.- These reflections communicate a moderate degree of personal engagement with the research focus and process of research, demonstrating some intellectual initiative.
5–6	Engagement is excellent. <ul style="list-style-type: none">- Reflections on decision-making and planning are evaluative and include reference to the student’s capacity to consider actions and ideas in response to setbacks experienced in the research process.- These reflections communicate a high degree of intellectual and personal engagement with the research focus and process of research, demonstrating authenticity, intellectual initiative and/or creative approach in the student voice.