Physics Extended Essay

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*For grade boundary information, please refer to **the Grade boundaries for Diploma programme coordinators** document available on the PRC.*

Physics Extended essay

The range and suitability of the work submitted

Generally, the work presented is suitable for an EE in physics with the majority based on an experimental investigation and with candidates developing a personalised theoretical model. There is often good work drawn from very basic physics principles. A few approaches are empirical in nature hence limiting the scope of the essay; however, some essays refer to reliable and appropriate source(s). Typically essays in astrophysics (for example dark matter and dark energy in relation to gravity in the universe) are data-based investigations hence face the challenges of a potentially broad topic. A good number of students report a lack of access to a suitable lab or equipment; however, they demonstrate determination, initiative, creativity and perseverance in improvising different approaches. A few candidates use simulations, not always with clarity, efficiency and completeness. The use of secondary sources and data to perform candidate's research instead of hands-on experiments, while necessary and permitted as an approach, will not be successful if the investigation only provides a summary of such sources without personal input and contribution.

Topics cover a good range of physics disciplines from mechanics (e.g. oscillation of pendulum in liquids, effect of temperature on coefficient of kinetic friction) , electricity (e.g. Joule's effect), oscillations and waves (e.g. sound from music instruments, transmission of radio waves), magnetism (e.g. force between magnets), atmospheric physics (e.g. data from meteorological balloons), applications of physics in sports, (e.g. in water rockets, airfoils), thermal conduction (e.g. house construction materials used in a given country) or electric power lost in high tension transmission lines in their country.

The work presented ranged generally from satisfactory to excellent. Some weak essays would probably have benefited from focused supervisory guidance in some cases. Typically poor essays usually include variables that could not be quantified in a meaningful way, or were based on peripheral topics.

Candidate performance against each criterion

Criterion A: focus and method

The introduction is naturally related to the research question hence it's sensible to include it. The research question is generally stated and focused, though at times lacks clarity and completeness. A few candidates stated research questions too broadly (typically with too many dependent and/or independent variables) to be treated effectively within the word limit. The significance or context of the investigation was often subjective rather than objective. Many candidates do not identify relevant physics principles or do so incompletely. For the "methodology" strand, it is good for candidates to explain their decisions in designing their research, e.g. the reason why an option is preferable to another.

Criterion B: knowledge and understanding

Candidates generally demonstrate a good and appropriate level of knowledge and understanding in relation to the theory related to their research through the selection of relevant sources of materials and correct use of scientific terminology. Many develop relevant and appropriate personalised theoretical models, however a few generate highly complex and obscure theoretical models involving many variables. In some purely empirical investigations, no connection is made between experimental results and relevant results taken from a reliable academic source, there is often a statistical approach with no or

very little theory. Physics definitions and symbols are not always fully and correctly described. Surprisingly non-SI units are used (no attempt to convert non-standard units) and fundamental constant given with inconsistent sf (significant figures) or sensible number of decimal points. There were several examples where scientific conventions are not obeyed, for example the writing of numerical values with unit and uncertainty. The use of annotated diagrams for set-up, theory and analysis is a useful tool of communication and should be part of the student's physics language, as part of this criterion B.

Criterion C: critical thinking

The quality of the research is mainly adequate to good. The analysis often does not take into account the measurement uncertainties and consists only of the graphical presentation of the data. Several essays do not show sample calculations. Some analyses are limited and incomplete, a few are superficial. A good majority of candidates are able to analyse the data and results effectively, ensuring they are critically relevant to the research question, and candidates are often able to use physics laws and principles in doing so. A clear tendency is to rely on statistical analysis alone to justify graph trends. The majority of students are able to develop a good reasoned argument with a valid conclusion or at least an adequate argument. Most do not refer to literary sources when relevant and available – or they do so in a limited manner. Generally, discussions and evaluations are qualitative. Candidates do identify key problems or limitations but their quantitative impact on results and conclusion is rarely considered and often estimated. In these situations, research has been evaluated, but this is only partially critical or not done in a critical way. Purely empirical investigations without supporting sources and substantiation tend to not do well. Conducting a critical review of one's own investigation is always challenging, however a number of candidates do produce very convincing essays, and these are enjoyable to read.

Criterion D: presentation

Structure and layout of essays is generally good. In a good number of cases one or more of the four required elements on the title page are missing. Moreover, much unwanted extra information is given on the title page – while this is not penalised, it often means that identifiable information that is not necessary is included needlessly. A few candidates used a very basic structure and layout and some include an abstract which is accepted. Regarding the structure of essay, the organisation of the essays is not always reader-friendly. For example, when an essay involves a number of independent variables the list of equipment including measuring instruments, experimental procedures, raw data and processed data, analysis etc. are presented independently and alternately without any attempt of integration. This generates repetition, confusion and lack of coherence in the presentation and understanding of the reasoning. Generally, it is much preferable to complete the first independent variable from start to finish, including initial information, raw data table, processed data table, graphs, analysis, discussion/evaluation and conclusions. Regarding the layout of essay, the most common oversights are 'cookbook recipe' style methodologies, excessive use of colour blocks for different purposes including to highlight tables and/or graphs (not required), changes of font size, lack of numbering of illustrative material (including key equations, diagrams, graphs), missing pagination (rare), often unreadable legends on diagrams and graphs, lack of proof-reading, excessive use of colloquial language. Key equations, diagrams, images and tables are not always referred to in the text. If a table is used to organise information (with no data) all words included in the table must be part of the total word count given on the title page. There were examples of issues with quality of graphs, incomplete or limited grid lines making it difficult to read coordinates, and pictures which should be annotated and in high resolution.

It is wise to take into account the presentation early in the investigation and not wait until the last moment to organise the essay since it is important and time consuming.

Criterion E: engagement

Many candidates communicate well with a moderate level of personal engagement with the research focus and process. They are generally able to discuss challenges faced and explain how they are resolved. They also make reference to the way in which their research, knowledge and understanding evolved and demonstrate an appropriate level of intellectual initiative. At times comments are general and lack practical examples illustrating specifically how progress is achieved and key learning acquired. In some cases, it is difficult to judge personal engagement and interest in the chosen topic from the comments on the RPPF. During the investigation it is a good idea for the student to take some notes related to key steps and decisions which are representative of the thinking involved.

Recommendations for the supervision of future candidates

It is important for students to read the physics EE chapter carefully. In it there is more information around e.g. choice of topic, using secondary data, collecting primary data, and the difference between the physics IA and EE. The choice of a topic is crucial for the student for different reasons, and proper guidance from the supervisor will help ensure that the student makes a valid, realistic, and inspiring choice that will generate enthusiasm and dedication.

A suggestion may be to give students access to some typical articles taken from e.g. *The Physics Teacher* or *Physics Education* or other relevant sources that model exemplary works. This way students will learn about how focused such articles are, the organisation and layout, the use of SI conventions. These articles or papers represent an efficient way to learn about the different facets of a scientific academic paper. They are often good examples of logical and simple structures that facilitate the reading of the content.

It is really important that students remember that all information that is central and crucial to their investigation must be present in the body of the essay – they cannot refer a reader to an appendix.

In data-based essays, the reliability and appropriateness of sources, and an appreciation of the uncertainties and limitations of techniques and apparatus for data collection should be included.