Diploma Programme

Physics

Contents

Internal assessment

Range and suitability of submissions

There was an interesting and wide range of topics, mostly in mechanics, waves, and temperature related topics, in particular viscosity. From simplistic to advanced, the vast majority of work submitted was suitable for assessment. It is the quality of an investigation and not the topic that determines the overall success. The most successful investigations had well-defined research questions, clearly identified variables and a suitable means to measure and relate the variables, plus an appropriate and known scientific background. Most importantly, the successful investigations were scientifically interesting and showed genuine student involvement.

Some interesting investigations included analysis of a bouncing Tic Tac, the Q-factor of coupled oscillations, Compton scattering via simulation, reflection of light and polarization, and the use of a satellite database to investigate Signac interference. Some popular investigations included viscosity and temperature, the singing wine glass, the catapult, the Gaussian gun, coefficient of restitution and ball pressure, solar panel angles, refractive index and temperature, refractive index and concentration, measuring the width of a human hair with a laser, and variations on projectile motion.

Candidate performance against each criterion

Personal Engagement

Students would often over-emphasize ‘personal significance’ by writing what seemed to be artificial comments about their general interests. Moreover, their background interest would not link to a specific research question. For example, the love of playing ball sports is not inherently related to an investigation into the coefficient of restitution of a bouncing ball. Teachers should encourage students to demonstrate their curiosity and insight in the investigation itself, in the nature of the research question, in the details of methodology and analysis, and in other contributions made by them to their individual investigation. When a student’s report demonstrates independent thinking, initiative or creativity, or when there is interest and curiosity relating to the research question, or when there is personal input in the design or implementation or presentation of the investigation, then and only then has the student addressed the criterion of personal engagement. Full marks for PE require addressing a number of the indicators. PE is assessed holistically, not in a section or paragraph with the heading ‘Personal Engagement’. It was encouraging to see that some students had modified a traditional investigation or designed their own, thus demonstrating independent and creative thinking. Performing an investigation with a standard method and standard analysis but in a thoughtful, detailed and competent way can earn full PE marks.

Exploration

Successful investigations always included a single and well-defined independent variable and a quantifiable dependent variable. Appropriate investigations made use of known scientific concepts and relevant equations, and they would establish a relationship or function between two variables or determine an important scientific constant. Issues of safety, ethical and environmental concerns were mentioned when appropriate. Occasionally students would select multiple independent variables, perhaps thinking this would enrich the investigation when in fact it inhibited it. Often the known context of a RQ was not addressed but would have been helpful to the student in order to focus and clarify their work. Historical background is not relevant. A research question like “How does the length of a wire affect its resistance?" is simplistic. Confirming a known relationship is acceptable for an IA but the research question should not be stated as an open ended question.

Analysis

Analysis includes the traditional scientific skills that concern data collection, data processing, appreciation of errors and uncertainties, the scope and limit of the data, as well as graphing and methodological issues. The majority of students demonstrated the ability to obtain and record data, including raw uncertainties. In most cases, data tables were clear and consistent with scientific notation. Processing was often detailed, with sample calculations of complex computations. Samples of simple calculations are not required. A spreadsheet can easily determine the average of a number of repeated measurements. Graphs were nicely presented often with uncertainty bars. There has been an increase in the use of Smartphone apps but without an appreciation of precision or accuracy.

Data table column headings should include the quantity, the units and the uncertainty. The terms 'proportional' and 'linear' were not always understood correctly. The construction of minimum and maximum gradients, when the gradient was meaningful, was often done in an unrealistic and extreme way. Students need to appreciate what their data does and does not reveal. Several times a student graphed relevant data where the data scatter suggested a curve and yet the student forced a linear fit. The linear fit was then used to establish an invalid conclusion. Often a forced linear fit would imply a meaningless or impossible physical result when extrapolated to an axis origin. There were occasional inconsistent expressions of significant figures.

Students should realize: (1) No calculation can improve precision. The result of addition and/or subtraction should be rounded off so that it has the same number of decimal places (to the right of the decimal point) as the quantity in the calculation having the least number of decimal places. That is to say, a sum or difference is not more precise than the least precise number. (2) Significant figures in the result of multiplication and/or division should be rounded off so that the answer has as many significant figures as the least precise quantity used in the calculation. A product or quotient has no more significant digits than the number with the least number of significant digits.

Occasionally students would fill pages with formal or purely mathematical error analysis without reference to the physical meaning of their data. The focus needs to be on physics. Correlation coefficients, for example, are often used to establish a statistical relationship between two variables. In physics, however, we already know many functions, so the coefficient value is not helpful. Data in a simple pendulum investigation might have a correlation between period and length of 0.993 while the correlation between the period and the square root of length (the known function) might be 0.997; a polynomial with powers of 5, 4, 3, 2 and 1 might fit the period to length graph with a perfect correlation of 1.000. In other words, correlation coefficients are not appropriate for physics analysis and do not prove anything.

Evaluation

The evaluation criterion remains one of the most demanding. Students should describe in detail and justify a conclusion for their investigation based on the original research question and their data analysis. Focus is the key here. Appreciation of the quality and range of data should be included. The propagation of uncertainties is relevant. When there is a known scientific context or accepted value, then students need to compare their result with the accepted value. For example, using a simple pendulum, a student determined that the free-fall acceleration of gravity was 16 m s–2. They never considered the viability of their result. When there is no known or reasonable value then an interpretation of the accepted scientific context should be given. Another difficult component of the evaluation criterion is an appreciation of the strengths and weaknesses of the methodology involved in the investigation. The more successful student reports showed an appreciation of the scope, limit and the assumptions of their methodology. Finally, students need to suggest realistic and relevant improvements as well as possible extensions of their investigation. These need to be specific and based on an evaluation and appreciation of the weaknesses or limits. Significant improvements can be understood as an extension.

An appreciation of the scope and limit, the methodology and any theoretical assumptions, should be addressed when evaluating a conclusion. Too often students made general and qualitative comments only. Something more than a qualitative statement (such as Y increases as X increases) is expected. Often students would construct a meaningless polynomial equation to fit their data and then assert a conclusion described by the equation, without giving any physical meaning to the results. Or, if the data scatter appears to follow a curve, the student would force-fit a linear line. Students need to appreciate the physical meaning of the quantities under investigation. There is more to a graph than a simple equation. Finally, evaluations were often superficial, blaming human error or friction, or systematic error without details of specifics.

Communications

Communications, like Personal Engagement, is assessed holistically. This means that the overall clarity, flow and focus of the report are assessed. The best reports made it clear in the first paragraph or two what the specific investigation was about, how it was conducted and what results were found. The best reports stayed focused on the research question and related physics and did not ramble on with generalities about the student's interest or brief autobiography, historical background or unnecessary pedantic details. The best reports had descriptive titles, like "How temperature affects the refractive index of water" and not titles like "Bending light". The majority of reports used correct and relevant scientific notation, equations and units. Word processors often have a built-in equation editor, and students are expected to present equations properly. The majority of reports were within the 12-page expectation. It has become clear that ten or so pages are a reasonable length for a focused and concise IA report. Occasionally, however, an extended report flowed well and wasted no space, was clearly presented, and as such, for example, a 16-page report was not penalized under Communications. Reasonable margins, spacing, appropriate scales of graphs and data tables, all help the communications criterion. Most students provided references to their cited work (in a variety of consistent and acceptable ways). Although the moderator needs to know how the student performed the investigation, they do not need comments like: "Set up the equipment, turn on the computer….." Often students include photographs when a clear sketch would have been better. Photographs of a metre stick, stop watch and other basic equipment can contribute little. Often images taken from books or the internet were not referenced. Communications does not penalize for lack of references but rather when this occurs it becomes a serious IB issue of academic honesty and possible plagiarism. Simply listing a few texts or websites at the end of the report without using them is not proper referencing. Some students padded their investigations with artificial research references that were never used. Finally, some technical terms were not always used correctly. There are important distinctions in the notions of resistance and resistivity, speed and velocity, projectile range and path, efficiency, viscosity, concentration. Students sometimes claimed their graph "proved" a hypothesis. When a student writes the units of speed as "ms^{-1}" they are actually denoting "per millisecond". There should be a half-space between non-italic m and s, for the correct units of metres per second, $\mathrm{m\,s^{-1}}$.

Recommendations and guidance for the teaching of future candidates

- It is important that teachers provide guidance during the entire IA investigation process, and not only when they read a draft. Some of the weaknesses that teachers could have corrected during the student's design stage included multiple independent variables, unquantifiable variables, multiple investigations, and unrealistic experimental expectations.
- Students need to have a sound knowledge of the assessment criteria. Teachers can discuss extensions to class investigations or ideas relating to topics studied throughout the teaching of the course, so when students are expected to come up with their own research topic, their minds are full of exciting possibilities.
- Teachers should not allow students to copy existing IA samples found in the teacher support material or other places online.
- Extensive bibliographies that are not referenced within the text should not be included at the end of the report.

Further comments

- Teacher should realize that issues of uncertainty and error analysis appear under the Exploration, Analysis and the Evaluation criteria. However, each time the issues are addressed from a different perspective. In Exploration, students should take into consideration significant factors that may influence the quality of work. Under Analysis, students need to appreciate the impact of uncertainties, and this is a quantitative appreciation. Under Evaluation, students should discuss the limitations of the data, as well as the sources of errors and uncertainties.
- Under the criterion of Evaluation, procedural and methodological issues are distinguished. Procedural issues (mark band 1-2) are a fixed set of steps, not a generalization. They are a subset of methodological issues. For example, taking more data, or extending the range of data, are both procedural issues. In mark bands 3-4 and 5-6, methodological issues are mentioned, and these issues address the assumptions in the method, and may include suggestions on new ways to measure the quantities or alternative approaches to the research question.