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| **IB Physics Internal Assessment**  **Comments on Student Script “C”**  Research Design, Data Analysis, Conclusion, Evaluation | SafariScreenSnapz001.tif |

**“Exploring the physics behind a pulley system”**

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| **Research**  **Design 0 – 6** | **Data**  **Analysis 0 – 6** | **Conclusion**  **0 – 6** | **Evaluation**  **0 – 6** | **Total**  **0 – 24** |
| **6** | **4** | **5** | **2** | **17** |

#### Research design assesses the extent to which the student effectively communicates the methodology (purpose and practice) used to address the research question

**Research Design Assessment** is well within the top mark band. A low-level **Level 6** here does not mean perfection but what can be achieved by a high school student. An explanation of the scope and range of data would have been helpful. And yet the work here demonstrates high achievement.

**Research Design 1st Descriptor**

The research question is described with a theoretical derivation. This derivation can be seen as a specific context, and clearly directs the processing of data. Appropriate variables are identified. The hypothesis is qualitative only, and obvious. The relevant equation articulates the function. The brief comment about pulleys is not helpful. The definition is rather ill-sounding. A better approach would have been to talk about ‘systems’ in mechanics. Details about the system (trolley mass and hanging mass) need a little more clarity (although we figure it out sooner than later). The student does not demonstrate a deep understanding here but does reflect a consistent and an acceptable approach to this investigation. And the derivation is sound.

**Research Design 2nd Descriptor**

The method is explained, including obtaining reasonable data. Five sets of mass values are the minimal range (but acceptable). Repeated measurements are made. Controlled variables are nicely explained. Sufficient attention is given to the quality of data. The method is a standard method to confirm Newton’s second law; normally, the reciprocal of acceleration is graphed against the reciprocal of the hanging mass; then, the data would form a linear line with a *y*-intercept representing the reciprocal of free fall gravity. But here, the student measures time and squares it, but time-squared and acceleration are clearly related.

**Research Design 3rd Descriptor**

The theory and the method of the investigation are easily reproduced.

#### Data analysis assesses the extent to which the student’s report provides evidence that the student has recorded, processed and presented the data in ways that are relevant to the research question.

**Data Analysis Assessment** is in the 3–4 mark band. With a little teacher guidance, a draft of this report could have been directed into a higher mark band of assessment. **Level 4** is a best fit.

**Data Analysis 1st Descriptor**

The recording of raw and processed data is clear but there are too many inconsistences (e.g., the values for mass and its uncertainty) and missing units to say it is also precise. See the comments under the second and third descriptors. None the less, the tables and nicely presented and the graphs are appropriate but hard to read (Missing units on Graph 2.). Why calculate uncertainty as a percentage? The student claims a stopwatch uncertainty of 0.05 seconds and yet in the data column uses one-half the range (which is slightly smaller but assumes precision). See descriptor 2.

**Data Analysis 2nd Descriptor**

Although the student addresses uncertainties in most aspects of the report there are some mistakes, ambiguities, and inconsistencies in processing. See, for example, page 4 Table 1, where the absolute uncertainty in the mass is one-tenth the least count. The percentages are thus wrong: 0.20% should be 2%. No explanation of why 0.050 kg mass is also claimed to be 0.0497 kg. The absolute and percentages of uncertainty for average times are correct. No uncertainty for the raw data is given. The uncertainty in the *y*-intercept (page 6, under Graph 2) is incorrect. The student should have written: (0.71 – **0.23**)/2 = ±0.24 s2 and not ±0.15 (without units). At the end of page 6 the experimental equation for time-square has the incorrect uncertainty of the *y*-intercept. This mistake is carried through the report.

**Data Analysis 3rd Descriptor**

The processing of data is guided by the correct theory and the research question. The focus is appropriate, the method is standard IB method, but the issue of accuracy is wanting. There are numerous examples of incorrect significant figure comments. For example, 0.04 is said to have three significant figures. Values for the reciprocal of mass (Table 2) are inconsistent. The percentage and absolute values of uncertainty here is also wrong as carried forward from Table 1. The time squared uncertainties are correctly processed. Units are missing in many places, see Graph 2 and Table 2. Graph 1 implies that the mass is the hanging (vertical) mass. The outlier mentioned about Graph 2 should be removed if it is a justified outlier (but it is not). The examiner removed this point and found that the remaining four points line up perfectly, almost too good.

#### Conclusion assesses the extent to which the student successfully answers their research question with regard to their analysis and the accepted scientific context.

**Conclusion Assessment** is in the on the 4/5 borderline, but level 4 would be too critical. **Level 5** is the best fit for Conclusion assessment. The student gives attention to the key issues.

**Conclusion 1st Descriptor**

The conclusion (both qualitative and numerical) is fully consistent with the analysis and confirms the obvious hypothesis relating an increase in hanging mass with decrease in falling time. Slight variation off a linear line and a systematic shift may well all be within experimental error. But there are more subtle details that need appreciation. Stating a “clear linear line” just describes the linear line that the student fit to the scattered data. Other comments are repetitive or general and vague. The real conclusion is how well the experimental model aligns with the theoretical. This is addressed to an extent. The student’s formal approach lacks precision but does confirm the general theory. However, the *y*-intercept being negative is a serious concern. On Graph 2, the *y*-axis intercept resents the time-squared when there is zero tension in the string, that is, when the hanging mass is free falling the fixed distance and accelerating at the rate of gravity. In this experiment, that free fall time should be 0.44 s, so this squared would be 0.19 s2. The student must not expect a zero-zero origin as that would mean an instantaneous drop time (physically impossible). Using correct theory, the *y*-intercept on Graph 2 must be positive, above the zero origin. Clearly, there is a major systematic error in the student’s data. The student’s work reveals this but does not demonstrate a focused understanding. Some serious thought about the systematic shift would be interesting.

**Conclusion 2nd Descriptor**

On Graph 2 the R2 correlation value of 0.9948 is inappropriate. There is not enough data to treat statistically. The correlation value for Graph 1 was 0.997 (higher than graph 2). Here is where the student gets a little lost. Graph 1 had an automatic best fit equation with mass to the power of –0.564. This in turn would make ‘time” to the power of 1.77 and the student reads this as “time squared” or time to the power 2.00 (a significant difference). The student has imposed the squared power and then concluded a square power. It is true that in theory time squared to related to the reciprocal of mass, but the student’s analysis was not insightful and contains some mistakes. The theory directing the investigation is an adequate context to accepted theory. However, this type of lab is easily found online, and the student could have compared their results with another.

#### Evaluation assesses the extent to which the student’s report provides evidence of evaluation of the investigation methodology and has suggested improvements.

**Evaluation Assessment** is in the 1–2 mark band considering what could have been discussed. A few issues were stated. The best fit is **Level 2**.

**Evaluation 1st Descriptor**

The student’s attempt at a thoughtful conclusion and evaluation lacks the focus of the earlier parts of the report. Claiming “no major problems” reveals a lack of in-depth understanding. However, the examiner appreciates that it is not easy to imagine weaknesses in this basic and standard lab. The difficulty of measuring time was appreciated. Lowering the “speed” (that is, implying a smaller hanging masses) is only part of a solution. No more thought is given to how to improve the method here, such as using a Smart Pulley, a motion sensor, or video analysis.

**Evaluation 2nd Descriptor**

Comments addressing the indicators here are covered in the first descriptor assessment. It is not uncommon for students to apply themselves under analysis but then make little effort at an evaluation, especially and evaluation of the overall methodology (as well as procedural steps).

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23 August 2024