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

**“Investigation of the effect of heat on the coefficient of restitution”**

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| **Research**  **Design 0 – 6** | **Data**  **Analysis 0 – 6** | **Conclusion**  **0 – 6** | **Evaluation**  **0 – 6** | **Total**  **0 – 24** |
| **3** | **3** | **1** | **2** | **9** |

#### 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 best fit at level 3.**

This is a standard and well-known investigation. The Yoshitaka Tamiya reference is a published IB student lab report from the International School Bangkok on the identical topic. This resource is acknowledged but too much of the background theory as well as analysis and conclusion are clearly taken from this 2010 article. All the conceptual issues, the hysteresis information, even the understanding of the graph (and the forced polynomial), are copied from the more authentic report by Tamiya. There was too much paraphrasing and lack of a sound understanding. However, the student did perform an investigation, processed data, and made an effort at an evaluation, so plagiarism is not an issue. The student did not understand much of what they copied.

**Research Design 1st Descriptor level 3**

The research question is briefly outlined in a seemingly relevant context (there is an attempt for this context to be ‘described’ but the text does not communicate a sound understanding). There seems to be a fluid relationship between the numerous technical terms in this report: elastic collisions, elasticity modulus, Young’s modulus, hysteresis, coefficient of restitution, all relating to a bouncing rubber ball. There are equivocations and ambiguities when attempting to use these terms. For example, the student’s hysteresis diagram is identical to the on in the Tamiya article, but the student’s discussion does not relate the impact and rebound lines to the energy lost (but uses the terms found in Tamiya’s IA report). Quote: “…the force given to compress the ball multiplied by how much it compresses is the energy used during the compression.” This is not the energy lost on impact. Hysteresis is not understood. One could have said that the area between the impact and rebound lines represents the energy lost. There is only the vaguest reference to how temperature affects the rebound (and the equation not mentioned is for the kelvin scale). One insightful phase was that “the COR quantifies a collision’s elasticity.” Then they attempt to clarify this by saying that the COR is the amount of energy conserved after a collision. The student also claims that the COR ‘shows the change in potential energies’ in a collision, when in fact COR is the square root of the ratio of an energy-function before and after the impact. The COR can be used to calculate lost energy, but the COR is a ratio. Under Variables, the student says they will calculate the COR “by the reciprocal of the square root of that height”. Fortunately, the student does not do this and instead calculates the COR ratio correctly.

**Research Design 2nd Descriptor** **level 3**

The methodology is basic and neatly outlined (more details are required to say the method was described), and more details of how the height was measured are expected. The infrared thermometer was a good idea. The student is correct to appreciate how quickly the ball cools down, but knowing this, a larger uncertainty should have been established. The least count (± one degree) is too small here. The photograph suggests the metre rule is not strictly vertical. How well-defined are the video images of the rebound height? More detail would have helped. There is a limited range of temperatures (perhaps realistic for the classroom) but a wider range is needed (this will impact the conclusion), and lower temperatures (between room temperature and freezing) could have easily been obtained. The title mentioned the effect of heat on the ball, but the student investigates temperature. Predicting a logarithmic correlation only means forcing a linear line on a log graph (which is not done). Comments seem to be paraphrased from the Tamiya article (with less depth and less understanding). The hypothesis (item 1.3) is vague and lacks depth and clarity. There are many sloppy expressions. The method and research question, the variables and procedures are appropriate to a limited degree. The range is also limited but acceptable for high school.

**Research Design 3rd Descriptor level 3**

As this is a well-known and established investigation we can easily read between the lines and, using the student’s methodological approach, we could reproduce this investigation. Much is missing in the details of determining the rebound height and a few other procedural issues, but using a camera is a start even with the ambiguities.

#### 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 level 3.**

**Data Analysis 1st Descriptor level 3**

Raw and processed data are easy to follow and clear but contain a number of inconsistent significant figures and unrealistic uncertainty values. The uncertainty in individual rebound heights is clearly wrong as are the uncertainties in the average COR values. More explanation is needed here. The uncertainty in the ruler measurements are much more than 0.0005 (assuming units of metres). A video is being made of the bouncing ball, and the images are not well-defined. What about parallax, and is the ruler truly perpendicular, and how about the resolution of a moving ball in the video analysis? The data then is clear but not precise.

**Data Analysis 2nd Descriptor level 3**

Although uncertainties are mentioned and apparently dealt with, a clear and sound understanding is missing. The student considers uncertainties in places (going through the motions of relevant skills) but there are significant omissions, inaccuracies and inconsistencies.

**Data Analysis 3rd Descriptor level 2**

Although the graph addresses the RQ, there are some serious flaws. The student’s temperature range was from 20 to 60 °C. This may be acceptable for a high school lab (as assessed under RD) but the range in the article guiding the student’s work was from –50 °C (well below freezing) to +70°C. Given the student’s data, the graph should have been linear with only a slightly positive gradient (or not at all with propagated uncertainties in the ‘*e’* values). Many online articles on the same RQ show a linear line with a small positive gradient for the given range. The student’s equation (mirroring the article) of an “inverse exponential logarithmic” function is not justified. The student copied the general form of the graph from –60 to +80 onto their scatter data from only +20 to +60. The curve only starts around 30 to 40 degrees below zero. An approximate zero value for the COR is near 80° below zero, not as the student suggests (a zero COR at about 0°C for the student). Note the small gradient (0.0016) on the best fit line for the student’s data constructed by the examiner (below).

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| Moderator’s graph of  student’s data.  There is no suggestion  of a complex polynomial  seen in the scatter of data. So, where did the student’s equation “COR = A\*ln(Bx)”  come from? | A graph with a line and a black dotted line  Description automatically generated |

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| A closer look at the student’s data with more realistic uncertainty bars for COR.  Here, on the student’s data, at zero degrees Celsius, the COR is extrapolated to be about 0.768 |  |

The student’s analysis attempts to be relevant and addresses some of the descriptors but is very much incomplete (even wrong). The assumed function applied to the student’s own data will affect the ability to address assessment under Conclusion.

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| This is the graph from the Yoshitaka Tamiya article. Note the much wider range of temperatures (starting from well below freezing). The student seems to have ‘seen’ the same function shape in their own data. The student’s temperature range as seen on the Tamiya data reveals a nearly flat best fit (the last three data points on the right). |  |

#### 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 level 1.**

**Conclusion 1st Descriptor level 1**

If there is a positive correlation revealed in the data (not the referenced article) then the student’s claim is not justified; the student imposes such a function on a linear scatter. The “inverse exponential (logarithmic) function” is stated in the referenced article, but in no way is supported by the data or analyses in the student’s work. The student’s conclusion (as far as assessment goes) is meaningless. Only the qualitative observation that the COR value increases with temperature might be considered justified. The student’s comments are assessed in the 1-2 mark band.

**Conclusion 2nd Descriptor level 1**

Because the unjustified conclusion does restate the known theory, the second descriptor is hard to assess. As there is no comparison as such, just a restatement, mark band 1-2 is again appropriate. There are many online articles on this topic that demonstrate a small increase in the COR value for an increase in temperature. The student should have used some of these to justify the linear aspect of their data. The student then puts words on the strange equation, which seem plausible, but this is at best a superficial comment. Again, the conclusion tends to be a description of the data and the imposed (incorrect) function on the graph, following the words of the referenced article. Think of extrapolation: why would the student’s data suggest an approach to near freezing for a COR value of zero? The obvious linear trend is not this way. The student is not thinking about their experimental results. Although the claimed conclusion is justified with known theory, it is not the conclusion appropriate for the given investigation, the experimental data. Because the student’s conclusion is just a restatement from the Tamiya article, we must say that the second descriptor under Conclusion is superficial at best.

#### 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 a best fit at level 2.**

**Evaluation Assessment 1st and 2nd Descriptors: levels 1 and 3**

Although a section on Sufficiency is interesting, the range of the 5 trials is not addressed. And are five data points enough to construct a curve? More data points between the given range and more repeated trials would not improve things as much as a larger range and more realistic COR uncertainty values. It is correct to say there is no textbook value for the given ball types, but there is a known trend as the referenced article mentions and other places for the limited range the student considers. That “the complex curve line nearly passing through all the data points” is not a systematic error. Other comments about the polynomial are irrelevant and again the student fails to see the obvious. The correlation of 0.945 is meaningless as a near infinite number of polynomials could fit the data (and pass through the data points). It is not a strength to reuse the once heated ball for consecutive drops. The student is aware that the temperature rapidly changes. It was wise to recheck the temperature after the rebound as there were several degrees reduction. None of these comments address the methodology but rather are for procedural issues. Yes, precision and accuracy of the camera are important, but there were no insightful comments relating this to the data or analysis. Attention to the difficulty (quantifying precision as the impact of a weakness) of making measurements from a video would have been appropriate, and then relevant improvements could follow. A comment about the temperature on different surface points of the ball was interesting and appropriate. The table describing weaknesses, explanations and improvements was often relevant (and demonstrated serious thought). The first descriptor is level 1 while the second descriptor (with some BOD) is level 3; best fit overall assessment is level 2.

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