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IA 1	Determining the charge of an electron using a computer simulation	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	2	The student is clearly engaged with the investigation, demonstrating initiative and curiosity. Although restricted to a simulation, the student demonstrates insight and understanding in the use of appropriate methodology and presentation of data. Searching for the correct simulation alone demonstrates personal engagement. This work is an excellent example of a student owning their investigation.
Exploration (6 points)	6	The investigation is relevant and focused, and clearly described in detail. The extensive background and context are nicely explained and fully support the research questions. The student missed a good nature of science issue; however, as in the original Millikan experiment there were two conflicting interpretations of the results. The methodology is appropriate (if hardly original) for a simulation and relevant factors are appreciated. The only weakness is that the student attempts two research questions; either one alone would have made a good internal assessment report. The assessment cost of this is the lack of some important details under Analysis.
Analysis (6 points)	5	The selection and processing data was sufficient to establish the conclusions. The processing, however detailed as it may have been, did not propagate the uncertainties appropriately. The analysis only compared the experimental values with the accepted values (this is a false error analysis). This is a major weakness for this type of investigation. Although not a significant impact, this omission is one that the methodology should have addressed. The uncertainty on the graph of discrete charges would have been interesting. Also, the student knew ahead of time what quantity scale to graph, and this is unfair to the data. There were some inconsistent significant figures; units with quantities were assumed the same as the stated uncertainties.
Evaluation (6 points)	6	Both research questions were answered in detail and justified by the analysis. The two experimental values were compared to the accepted values, but an experimental uncertainty should have been used as well as a comparison to the accepted value. We do not know the number of significant figures used in various calculations. However, this weakness was assessed under Analysis and is not penalized again under Evaluation (although it would be helpful in establishing the validity of the conclusions). Weakness and strengths were addressed and an extension was mentioned. For this type of internal assessment, the evaluation is fully established.
Communication (4 points)	4	The presentation is clear but somewhat wordy; the single spaced text makes reading a little intense. The two research questions (instead of one) also effect a concise presentation. Graphs and table should have been labelled. The report is nonetheless interesting to read and is focused. Communication assessment is a weak 4.

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IA 2	Investigating properties of light-dependent resistors	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	1	Although the student makes an attempt at expressing his or her personal engagement, there is limited independent thinking and insight. Curiosity seems artificial. There is, however, some degree of initiative in the work. The design and implementation is standard for this well-known investigation. Personal engagement earns a solid 1 here.
Exploration (6 points)	6	The student has selected two research questions, involving two independent variables. A more focused internal assessment would have looked at one in more depth. The topic of the investigation is clearly identified and much of the discussion is relevant to the research questions. The methodology is standard, but appropriate and relevant factors have been considered, even safety issues.
Analysis (6 points)	5	The raw data is limited but sufficient for both investigations. Processing seems appropriate but is not easy to follow. There are a few arithmetic errors, and uncertainties are not always justified or explained. Units are missing in a number of places but the reader can figure this out. The uncertainty for 9016.2791 ohms is ±862.328286 ohms. The student often makes errors with significant figures. Nonetheless, the graphical analysis allows for a valid conclusion consistent with the data.
Evaluation (6 points)	4	Directly proportional is an entirely wrong description of an otherwise informative graph. Reliability is addressed, a range of uncertainty is appreciated, but there is too much thought put into describing the mathematical information and not enough evaluation of the procedure, method or data. The conclusion that a large surface area relates to more light absorption is trivial but true. The energy of photons is related to frequency and not to the numbers of photons, so the student is clearly confused. Some strengths and weaknesses are addressed, some being relevant and others not. No quantitative assessment of the sources of errors was attempted. Some realistic improvements were suggested. Overall, the insight and understanding demonstrated in the evaluation is satisfactory but limited. Assessment mark 4 is the best fit.
Communication (4 points)	4	The presentation of the investigation is clear, although minor errors and excessive information slow the reader down at times. The structure is good, the process and method are understandable. Irrelevant graphs and too many calculations, not to mention two research questions, all limit the communications somewhat. However, given the student's purpose, these faults do not interfere much with the quality of the report.

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IA 3	How does the density of water affect single-silt diffraction patterns of waves?	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	2	The student demonstrates curiosity in the formulation of the investigation, and within the confines of the course, he or she demonstrates initiative in the design and implementation of the experiment. Comments about an interest in photography add nothing to the research question. Overall, personal engagement is on the 1–2 borderline but the moderator feels the student is genuinely involved.
Exploration (6 points)	4	The topic of the investigation is identified but the research question is not highly focused. Why not investigate how the salt concentration affects wave speed (or wavelength)? The theory of diffraction and gap size is well known. The background information is superficial and limited at best. The scientific reasoning of the student is somewhat bogus. The methodology is highly appropriate and detailed, except for how to measure the length of a moving wave. The student is careful about relevant factors, and even too detailed about procedure. We do not need to know that the method includes gathering materials, setting up the equipment, and so on.
Analysis (6 points)	5	The limited data range is acceptable given the complex method. An appropriate conclusion is possible. Processing seems authentic, but is confusing at times and significant figures are inconsistent. There is a clear appreciation of uncertainties. Benefit of doubt is given when the student claims the diffraction angle is good to ±1°. The quality of the graphed data is amazing, but the student claims an inverse relationship when in fact a linear (with negative slope) one is demonstrated. This is not penalized under Analysis.
Evaluation (6 points)	3	A clear and concise conclusion is stated, a conclusion based on the data. However, the results are contracted by a reference (McCowen) and the student does not follow this up. Moreover, the inverse function identified is really a linear one (for the limited range) with negative slope. Justification is missing. Superficial comments address some procedure but not methodology. There are few improvements based on evidence, and extension is only briefly mentioned (sound, laser) without any explanations. Evaluation is in the 3–4-markband.
Communication (4 points)	3	The presentation is clear, and the occasional minor digressions are well intended. The report structure is excellent, but too much detail is given. A methodology with 24 steps is overkill, and distracting. The quality of the graphs is poor but benefit of doubt is given here (due to poor scanning). There are occasionally confusions in notation and significant figures, but the overall relevance and focus are maintained. Terminology is mostly correct. A careful reading of a draft by the teacher could have directed the student to improve this report.

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IA 4	Determining the circumstellar habitable zones of five stars	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	2	There is ample evidence of personal engagement and curiosity, and good use of research to select appropriate methodology and an online database. Personal input is evident in the design, implementation and presentation (even where flawed in part) of the investigation.
Exploration (6 points)	5	The research question clearly describes the aim of this investigation. The background information is entirely relevant, detailed, and helps explain the methodology, which is initially well laid out. The selection of stars is limited (there are no O, B, A, F stars), and given the "hypothesis" in Section 1, a wider range would have been appropriate. Some explanation of the values for inner and outer range would also have been helpful. More common details, like the AU, are explained.
Analysis (6 points)	5	The data is properly selected (from a wide variety of options) despite using only three star types. The processing is done correctly and follows the Morris method for calculating CHZ. The bar graph, for some unknown reasons, is incorrect (although the values are correct); the graph does not show the CHZ region. The habitable zone for our Sun is given as 0.95 to 1.37, and this should have been on the graph. There is a genuine attempt to consider and propagate uncertainties although the data source is somewhat limited. Error analysis is consistent but is not a main issue in this type of investigation. There is no citation for the log 10 error but it is handled correctly. Finally, the interpretation is correct despite the major error on the graph.
Evaluation (6 points)	5	The conclusion is appropriate and justified by the data analysis. Although there may be no accepted values for the selected stars, there are similar CHZ boundaries and that Tau Ceti is Sun-like in its extensive CHZ range. The student outlines strengths and weakness, and highlights areas of concern for data sources. The student notes that there are several methods to construct CHZ boundaries, and these calculations do not show that liquid water may be present. There is a valid and appropriate extension suggested. The use of a spreadsheet would have enabled much more data to be processed and included in this investigation, but the student acknowledges this.
Communication (4 points)	3	Communication is generally good and the text is clear but errors such as the graph (which expresses the purpose of the investigation) is a major fault. Some of the calculations are dense but the presentation and organization of the report is nicely structured. Communication, then, is not as concise or focused as required for a mark 4. Terminology is correct.

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IA 5	The relationship between suspension length and period of disk rotation	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	2	Attention to detail and precision, and the overall competence in this otherwise straightforward investigation, earns full marks for personal engagement. The student clearly shows initiative and interest, and to confirm a known equation for a subject of interest one might say that the student also shows curiosity.
Exploration (6 points)	6	The topic is nicely identified, and the text is relevant and focused. Because the theory is well known, the research question could have been rephrased as an investigation to confirm the limits of the theory. The background is entirely appropriate. The methodology could not be improved, but the theory shows a horizontal mass while the method shows a vertical mass. There is an issue of the centre of mass to consider. The range of data is acceptable given the detail to each set of measurements. It would be interesting to test extreme lengths. All the other factors are clearly identified.
Analysis (6 points)	6	There is sufficient data, but the range could have been larger. The processing and accuracy are most appropriate. There is almost too much detail, but the analysis is sound. The impact of uncertainties is appreciated and the analysis allows for a consistent conclusion based on the data. However, the major systematic shift of the nicely linearized line needs some attention in the conclusion and evaluation section. One might argue that the gradient uncertainty should nonetheless be determined, either using the time-squared error bars. Nonetheless, the student addresses this issue with the sometimes-dubious correlation coefficient.
Evaluation (6 points)	5	The student addresses the important issue of systematic shift, but their comments are misguided. The issue of air resistance is exaggerated due to the vertical placement of the mass. There are more than enough sufficient details in the quantitative analysis evaluation to earn a good mark. However, the methodology is not seriously approached. An extended range could count as an extension of the investigation. Evaluation is someplace on the 4-5 borderlines, but given the overall competence (a best-fit assessment) a 5 is awarded.
Communication (4 points)	4	The student has produced an interesting report. The presentation is clear, the text is nicely structured, and the focus is always on the experiment. The only criticism is that sometimes there is too much detail, but it is acceptable. The text remains focused and relevant. Terminology and conventions are appropriate. The few ambiguities do not keep the student from earning top marks for this criterion.

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IA 6	An investigation of measuring the permeability of free space constant using simple solenoids and a magnetic field probe	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	2	Teacher's comments suggest that the student spent a lot of time performing this investigation. There is evidence of personal interest and curiosity, but the design and method are standard, and the work shows little independent thinking or insight.
Exploration (6 points)	5	The research question and its purpose are defined and focused. However, the student means relative permeability and not permeability of free space, a distinction that should have been recognized. Also, permeability is a defined quantity, and only the permittivity is an experimental value. There is sufficient background information although some points are missing, and the safety issue of high current was recognized (up to 10 A is enough for the high school laboratory). The methodology is standard but appropriate.
Analysis (6 points)	4	Sufficient data was collected. The current range was justified. Appreciation of the Earth's magnetic field was nicely stated. Significant figures, however, were mixed and inconsistent, demonstrating a lack of appreciation for precision. Often units were missing from tables and calculations. A calculator, spreadsheet or website can do standard deviation, and details need not be shown. The major offset of a zero-zero origin required more attention. Results are indeed linear but not proportional.
Evaluation (6 points)	4	The results were compared to the accepted value but the experimental value should have been expressed with an uncertainty. The "slight error" of the conclusion misses the point of the investigation. Precision and not accuracy is relevant in this investigation. The issue of the Earth's magnetic field could have been dealt with in a more appropriate way. Although the comments of evaluation are general, they are not based on critical analysis. Improvements are rather simplistic. The methodology was not sufficiently addressed.
Communication (4 points)	4	The report is clear and easy to follow. The focus is never lost, and the information is presented in a coherent way. The few errors or mistakes do not hamper the understanding. Communication can earn top marks even with the mistakes mentioned under the other criteria. It is a pleasure to read a concise report.

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IA 7	Calculating Wien's constant and evaluating the accuracy of a simulation	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	1	Although this is an acceptable investigation, and the student is aware that he or she is accessing the simulation and not performing a real experiment, the research question and the method are straightforward and obvious. There is nothing unique here. Another student could have done an identical investigation. Personal engagement earns a solid 1 but lacks creativity, personal input, or independent thinking needed to earn a level 2.
Exploration (6 points)	5	The scientific context and the research question are focused and appropriate. Significant background information is relevant. The student is clearly in the 5–6 markband. However, the "actual constant" is an experimental measure and so the student should have quoted the best estimate of this with an established uncertainty. Also, the methodology should have tried a linear graph, and not the curves used. These two weaknesses put the student's exploration in the lower end of the top mark band.
Analysis (6 points)	4	The student recorded an appropriate amount of raw data. One wonders why he or she recorded the peak intensity, however. There was the suggestion that repeated measurements were not needed but this could have been tested. The student claims that the peak wavelength was not analogue, but a quick review of the simulation shows that it is determined on an analogue scale. Is this an error of communication or a lack of understanding? Then the student says an analogue scale would not allow an estimate of uncertainty. The student's data shows an uncertainty of ±0.05 μm, so the confusion is rectified. Perhaps the student confuses the terms digital with analogue. The temperature (a digital scale) should have an uncertainty of the least count, ±1 K. While it would be insignificant, it should have been addressed. A linear graph would have been more appropriate but what the student did for analysis works. The achievement level is between 4 and 5, and the moderator decided on 4 for the student's analysis.
Evaluation (6 points)	4	The well-defined and rather basic research question somewhat limits the expectation of an evaluation for this investigation. The question was just how accurate the computer's value of the Wien's law constant is when compared to the accepted scientific value. The first fault here is taking an online source (from Hyperphysics, quoted only as $2.898*10^{-3}$). Besides incorrect notation and units in italics, the student quoted only four significant figures. The accepted value with uncertainty for the constant is $2.8977729(17)\times10^{-3}$m K. No doubt the student's accuracy and hence conclusion is based only on the rounding error of using four significant digits. Nonetheless, the student takes his or her result seriously and goes through appropriate motions (propagating the analogue uncertainty), hence addressing assessment in the 3–4 markband. Overall the student is aware of what he or she is trying to do despite the obvious mistakes and limitations of not being able to rewrite the simulation software. The second research question about learning how simulations work is not addressed and for assessment this is not taken seriously.
Communication (4 points)	3	The writing style occasionally lacks the focus that the rest of the report demonstrates. There is the confusion over analogue and digital, but more

		importantly there are too many graphs when one or two would have been best, and a linear graph too. At time the text feels like it lacks focus, but the overall intent is communicated well. The communication criterion is clearly in the 3–4 markband. The moderator gave this a 3.

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IA 8	What is the best mathematical model we can use to describe the expansion of the universe?	
Topic	**Grade**	**Moderator Comments**
Personal Engagement (2 points)	1	The student is clearly interested in this contemporary issue. The student demonstrates curiosity in that he or she considers three interpretations of the same data. However, these interpretations are not original and there is little evidence of initiative in the design or implementation of the investigation, as all the details for the method and data analysis come from established sources.
Exploration (6 points)	5	The topic is identified and the research question is described—the best mathematical model for a set of data. The second part of the research question, the implications for using the models for establishing the future of the universe, is interesting but far from being established in the confines of an internal assessment. This investigation is not your typical internal assessment, and perhaps should have been limited to the first question. The method of analysis is entirely appropriate (as it came from a university website), but the selection of data limits the possible trend lines. The student should have looked at official Hubble-like data to consider the possible graph lines and their corresponding uncertainties. Most of the appropriate factors were considered (given the student's approach), and the student demonstrates some insightful understanding. The student's hypothesis that less gravitational force causes increased velocity is wrong-headed, and neglects general relativity, space-time itself expanding and other issues. The hypothesis should have been left out.
Analysis (6 points)	4	The limited data can be seen to beg the question, as appropriate data goes up to 130 Mpc. The limited range can have a number of best-fit lines, as the student shows. The processing is appropriate and errors are appreciated. The three interpretations are understood in great mathematical details (not as much physical detail, though). The R-squared value is a meaningless quantity for this type of investigation. The issue of a correct interpretation is not fully addressed by the different line fits.
Evaluation (6 points)	5	The student appreciates the three interpretations in both mathematical and physical terms. The research question has been answered with the established linear model, and the student's thoughts here are genuine and impressive. There is no attempt, however, to connect the results with the accepted theory (meaning why Hubble's constant is linear, albeit changing gradient with time). It is a fact that any finite data set has an infinite number of best-fit lines, polynomials and all. Again, the R-squared factors are meaningless in this study. More reflection of the selected data would help. Nonetheless, the student has done a splendid job here. Could it be that the student has confused the standard textbook graph of the radius of the universe against time, where the open, flat and closed lines tells us the fate of the universe?
Communication (4 points)	4	The report is clear and minor errors in unit style or missing units do not hamper the intent of the study. The structure is focused but there is some repetition and some material that is not needed, which makes the length of the report too long. This alone would put the communication mark at level 3 but because the overall structure is focused and the language is concise, the student earns a 4 here. Subject terminology is correct. Graphs are clear and

		easy to understand.

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