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

**“Effect of coil diameter on the performance of an electromagnet”**

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| **Research**  **Design 0 – 6** | **Data**  **Analysis 0 – 6** | **Conclusion**  **0 – 6** | **Evaluation**  **0 – 6** | **Total**  **0 – 24** |
| **3** | **3** | **2** | **2** | **10** |

#### GENERAL EXAMINER’S COMMENTS

This is a weak but focused investigation. Lacking a sound understanding, the student managed to go through the motions of selecting a research question based on a known equation, designing a basic method, collecting and processing data, and an attempt at a conclusion and evaluation. Unfortunately, the overall quality of this report is low. More teacher guidance would have helped the student focus on appropriate theory and analysis. If you are looking for an inverse function, why not graph this?

**Research design**

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

**Research Design Best-fit Assessment is Level 3**

**Research Design 1st Descriptor**

The **first descriptor** addresses the research question or topic, the aim of the study, as well as a specific and appropriate context.

At first reading, the student appears to have addressed all the assessment aspects in a neat and thoughtful way. The given equation is the Biot-Savart equation, and confirming a known function can be a legitimate research topic. The research purpose is clearly stated, and a context limited to the relevant equation is also stated. The hypothesis is simply a re-statement of the known equation—a confirmation of the inverse function, although we see under evaluation that only a qualitative conclusion can be made. However, a closer reading reveals many flaws from theory to conclusion and evaluation.

Consider the theory under the first descriptor. The student investigates a ‘solenoid’. Although the equation is not in the syllabus, solenoids are mentioned under D.2 Guidance. The quoted equation is not for a solenoid. The correct theory for a solenoid requires the length to be at least ten-times longer than it is wide. In such cases, the diameter does not appear in the solenoid equation. The appropriate solenoid equation involves the number of turns per unit length. The equation quoted by the student is for a single loop of wire or for multiple of turns, *N*, of wire (a coil) stacked together. Here, *N* would be the number of loops (where there is no extension or length for the loops as we find in a solenoid). The student’s equation assumes negligible length compared to the diameter, as the Hecht textbook states. The student failed to understand the textbook explanation (assuming they read it). It is no surprise that the experimental results are poor. The research topic is thus outlined in a confused context.

On the lesser problematic side, we find mixed units in the explanation of equation, but this does not make a difference in this investigation. The research question seeks to confirm the inverse function between diameter and magnetic field given all other constants. Independent, dependent, and controlled variables are addressed. The permeability of (free) space as a ‘controlled variable’ is clearly not understood by the student. A more relevant controlled variable would be to keep the 50 turns (an appropriate controlled variable) at a constant unit length. But that would imply a solenoid and the loop equation would not be appropriate. The importance of a constant current in all trials is implicit in the comments about a fixed voltage, a constant total length of wire, and no temperature change. We give the student benefit of doubt here (under the second descriptor), as they are thoughtful. There is a board context given. Mark band low 3.

**Research Design 2nd Descriptor**

The **second descriptor** addresses methodological considerations associated with collecting relevant and sufficient data to address the research question.

Most of the methodology is presented with specific details. Five different diameters with three measurements each is satisfactory. Just how was the Smartphone was held in a fixed position with the solenoid was not explained. This detail is important. The student emphasizes the control of voltage, but the key is a constant current. We can assume if the number of turns of wire are kept constant and the total length of the wire is kept constant, then the resistance or load is constant (hence a constant current). As the solenoid’s diameter increases, and the number of turns remains the same, then more wire is included in the coils and hence more magnetic field. This is not appreciated. The photograph of the solenoid causes serious question about quality control. Does the distance the first coils from the end of the tube always remain the same? And how would the number of turns per unit length affect the results? Do we have multiple independent variables? Again, a loop or coil of wire is not a solenoid. The assessment of the second descriptor here balances upon the difference between stated and described. The student does provide some details, so ‘described’ is the best assessment. Mark band level 3.

**Research Design 3rd Descriptor**

The **third descriptor** addresses the details needed to reproduce this investigation.

We are told enough to reproduce the experiment, but the omissions mentioned under the second descriptor must also be addressed. There is not the focus and understanding that one would expect. Mark band level 4.

#### Data analysis

#### 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 Best-fit Assessment is Level 3**

**Data Analysis 1st Descriptor**

The **first descriptor** addresses the communication of the recorded and processed data

The recorded data and processing are clear and easy to follow. The uncertainty in the diameter is questionable and the uncertainty in the raw data of magnetic field measurements is missing. It should be the least count in the data, and half the range in averaged data value. The illustration of a simple average falsifies the quality of data, as the student increases the precision to two decimal places. And yet we understand what they are doing. What is communicated is clear but not consistently precise. Mark band at a solid level 4.

**Data Analysis 2nd Descriptor**

The **second descriptor** addresses the appropriate processing of data and the consideration of uncertainties.

Assuming the minimal uncertainty in the diameter measurements, the student correctly calculated and stated that the uncertainties were negligible. But does ±0.056% really make sense? The precision of the tube diameter is simply the least count of the digital calliper, but the student should have measured several diameters at different orientations of the tube, and given the slight flexibility of the carboard tube, the uncertainty is most likely significantly more. The diameter percentages claimed by the student are unrealistic. However, it is usually the dependent variable uncertainty that is important. The student correctly averages the repeated magnetic measurements but increases the precision significantly (two decimal places) and does not attempt to appreciate the uncertainty here. This is a major weakness. The student is wrong to say repeated measures cancel out the uncertainty. The examiner determined that the magnetic field uncertainty varied from 2 to 8 *μ*T. As percentages, this proves to be insignificant, a range from 2% down to 0.2%. There are serious omissions and inconsistencies. Mark band 3.

**Data Analysis 3rd Descriptor**

The **third descriptor looks** at the data analysis as to how it supports the research aim

The processing and presentation of the data is directed to the research question, but the issue of uncertainties is faulty. Although the graph does address the qualitative statement of the hypothesis, any formal function is not correctly understood. The correlation (based on the best fit equation) is meaningless here. The logarithmic expression is mathematical only. Given the student’s understanding of the equation in the research topic, one would expect a graph of magnetic field against the reciprocal of diameter. Indeed, that is what the student wants to confirm. And yet the student fails to try such a graph. Instead, the given graph reveals only a qualitative relationship. Under the assessment of the Conclusion below, we find that the student’s best fit equation yields negative values of magnetism for diameters of 10 cm and more. The 3rd descriptor is at level 3.

#### Conclusion

#### 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 a best fit at Level 2 with some benefit of doubt.**

**Conclusion 1st Descriptor**

The **first descriptor** addresses the conclusion and how well the interpretation and analysis of the data supports the conclusion.

The conclusion of a qualitative hypothesis is confirmed (not proved), but the claim of an “inversely proportional” function (which is the correct theory) is not justified (or even addressed). Even the best fit graph is meaningless. The student finds an equation for their data, an equation using logarithms (which can be useful but are not understood here). Taking the student’s best fit equation on the graph, and then extending the scale for diameter, you would find that at and beyond 10 cm the magnetic field (according to the equation) reveals negative values and increases at the diameter increases. Does this mean the magnetic field reverses? Can an increasing diameter increase the magnetic field? That would be the opposite of the known theory! The student does not attempt to explain the meaning of their equation other than an obvious qualitative statement of the general trend of the given data. More is expected at the IB level. The correlation values are qualitative information only, and do not support the quantitative result.

The examiner graphed the student’s data of field against the reciprocal of the diameter, as shown here, and given a best-fit linear line but the result is still inconclusive. An inverse function is not justified.

Magnetic Field vs. Reciprocal of Diameter (examiner’s graph)

Chart, scatter chart

Description automatically generated

Although a zero origin seems reasonable if we had uncertainty bars, the implied curve suggested by the data points form a nonlinear best fit. A graph of residues would establish this, but using residual is not expected at the IB level. (And yet the above graph clearly reveals a non-linear function.) Still, with appropriate uncertainty bars such a graph would have been expected. Perhaps with minimum and maximum gradients an inverse linear function would be justified. Although the student ignored the magnetic field uncertainties the examiner determined them by the taking one half the range of the repeated values. This resulted in values ranging from 1.5 to 8.0 *μ*T and an average of 3.3 *μ*T. Looking at the worst case, ± 8 *μ*T, this was then graphed by the examiner in an appropriate graph. As shown below, a small section of that graph reveals that even the worst uncertainty is insignificantly small.

Close up of Origin (examiner’s graph)

Chart, line chart

Description automatically generated

On the inverse diameter graph, the first four data points (ignoring the 1.8 cm diameter, an obvious outlier when looking for a linear function) suggests a linear line with zero magnetism at 0.0738 cm–1 or a diameter of about 13.6 cm. Is there where the assumption that the length is much more than any diameter affect theory? It is more likely that the data is not good due to multiple problems. The quality of data is in doubt here. The examiner’s experience using the magnetic field sensor is that it continually jumps about much more than the student recorded. At first thought, the assessment level could be zero. With some appreciation of what the student is trying to say, we can award level 3 for the first descriptor (the student attempts to describe, not just state, a conclusion.

**Conclusion 2nd Descriptor**

The **second descriptor** addresses the justification for the conclusion within accepted scientific knowledge.

There is no attempt to relate the results to the known theory other than impose the given equation to the data. The student has forgotten the physics of the investigation. If we read the *“conclusion makes superficial comparison to the accepted scientific context”* from the Research and Design aspect of the student’s report, we can image that there is a recognition of the correct theory (even if only qualitative). At best, assessment level 1.

#### Evaluation

#### 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 in the lowest mark band, low but at level 2.**

**Evaluation 1st Descriptor**

The **first descriptor** addresses the evaluation of the methodology and explains the impact of methodological and procedural weaknesses and limitations.

The “specific trend” and the range chosen does not yield “an accurate and correct trend line”. (Quotes from student text.) The “imposed trend line” does not answer the research question, despite what the student says. A base 10 logarithm forced equation was not the original research question. The RQ was to confirm the inverse function between magnetic field and diameter. The examiner does not agree that a precision uncertainty of 0.056% indicates the conclusion is ‘justified’. An accurate and correct trend was not established, just a strange equation that fits the scatter. No outliers suggest the selected range was appropriate or perhaps just too limited. The ‘correct’ trend was mistaken. Yes, the graph was easy to see but as criticized above, the inverse function should have been graphed. There is little methodological reflection here.

Under the student’s Strengths section, the prevision of a strength measured with *Phyphox* was indeed precise, but what is needed here is an appreciation of the consistent location of the sensor to the solenoid and the quality of the solenoid (always the same length?). Comments about the suitability of wire only vaguely related back to a strength. Finally, the ‘guarantee” of the controlled variables needs more serious attention.

Under a weakness, the student announces that five diameters were not enough because the graph was “flattening out”. This is inconsistent with the conclusion statement. We are also told the data trend ‘curved’ but this also contradicts the student’s conclusion. Random and systematic issues were not clearly understood. The insulation on the wire does not change the wires resistance. By not realizing what the student’s data reveals, the student is unable to identify serious faults, weaknesses, or even proper strengths in their investigation. The overall approach (the equation and theory) was flawed and should have been addressed.

Some generic systematic issues were mentioned, but little evidence was given as this might relate to the method or understanding of the results. Electrical insulation does not add to the resistance of a wire. Although random errors are mentioned, the comments are at best generic (the lowest mark band). The only legitimate observation concerns a reliable location of the sensor to the solenoid but ignore the quality of the solenoid. Best assessment is in level 1 (some might argue zero).

**Evaluation 2nd Descriptor**

The **second descriptor** addresses the possible improvements to the issues explained in the first descriptor

Most comments were generic and superficial. The student claims a gauss meter could have been used but that would give only one decimal place precision (and yet the student’s raw data has no decimal place precision). The limited range was justified. The secure and fixed position of the Smartphone was mentioned (student addressed this under Method) but failed to mention the end coils being consistently at the end. They did suggest commercial solenoids would help (but details are missing). An interesting comment about the wire heating and changing current was made. The dubious quality of handmade coils was mentioned. Again, the photo reveals serious problems with the coil construction. Suggesting commercial solenoids is a realistic improvement (but other issues would need to be controlled) but just what would be improved is not mentioned. The only legitimate observation concerns (again) a reliable location of the sensor to the solenoid. The student’s suggestion for a stand was appropriate. The student’s last paragraph alone earns mark band 1-2. A few other generic comments (hinting at improvements) were addressed under the first descriptor.

The overall assessment of Evaluation second indicator is difficult as the focus was not on the method. The improvements can be assessed at level 2. The two Evaluation descriptors tend to be addressed together in the student’s report.

**Note**

The correct equation for a **solenoid** does not include the radius; rather, it includes the number of turns, the overall length, permeability constant, and the current:

<https://www.google.com/search?client=safari&rls=en&q=equation+for+a+solenoid&ie=UTF-8&oe=UTF-8>

The correct equation for the **loop** includes the radius, the axial distance from the coil center as well as current, the permeability constant, and the number of turns:

<https://physics.nyu.edu/~physlab/GenPhysI_PhysII/Intro_experimental_physicsII_write_ups/Magnetic-field-circular-coil_01_30_2017.pdf>

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06 August 2024