**Grading Rubric**

***Lab 3 – Magnetic Field of Solenoids and Coils***

***( /54)***

Recall that your goal is to teach them through inquiry-based teaching, and therefore you should encourage discussions, and make them understand the concepts (and achieve the best marks possible) as opposed to strictly evaluating them. You should try and assess their understanding in the last 30 mins of the lab session, or before they leave.

Points are distributed in four parts: **Pre-lab**, **Log book structure**, **Session A** and **Session B**. For the latter two, there’s always a **Conceptual questions and Critical thinking** and sometimes **bonus points**. Only during Session B will there be a **Data presentation** subsection.

**Pre-lab (/2)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Unsatisfactory (0) | Minimally satisfactory (1) | Satisfactory (2) | Exceeding Expectations (3) |
| Pre-lab Activity | Did not attempt any of them | Gave an answer to all of them. Made some mistakes. | Gave an answer to all of them. Made no mistakes | - |

**Log book Structure (/4)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Unsatisfactory (0) | Minimally satisfactory (1) | Satisfactory (2) | Exceeding Expectations (3) |
| Session a | Did not write any introduction or conclusion | Introduction and conclusion sections are present. Made no effort in evaluating their sources of error, and potential follow-up. | Introduction and conclusion sections are present. Made some effort in evaluating their sources of error, and potential follow-up. | Introduction and conclusion sections are present. Put in a lot of effort in evaluating their sources of error, and potential follow-up. |
| Session b | Did not write any introduction or conclusion | Introduction and conclusion sections are present. Made no effort in evaluating their sources of error, and potential follow-up. | Introduction and conclusion sections are present. Made some effort in evaluating their sources of error, and potential follow-up. | Introduction and conclusion sections are present. Put in a lot of effort in evaluating their sources of error, and potential follow-up. |

**Session A**

**Conceptual questions and Critical thinking (/16)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Unsatisfactory (0) | Minimally satisfactory (1) | Satisfactory (2) | Exceeding Expectations (3) |
| Drew magnetic field lines | Did not draw the field lines. | Field lines do not have the correct orientation and/or magnitude in a significant way that obscures the physics. | Field lines are drawn correctly: the orientation and magnitudes are correct. | - |
|  | Unsatisfactory (0) | Minimally satisfactory (N/A) | Satisfactory (1) | Exceeding Expectations (N/A) |
| Understanding the field lines inside the solenoid | Did not understand what happens inside a solenoid. | - | Understood that the magnitude is roughly constant and has one direction. | - |
| Swapping the connections of the solenoid | Does not understand what happens. | - | Understood that this flips the orientation of the field. | - |
| Connected the field lines of a solenoid to a magnet | Did not make the connection. | - | Made the connection | - |
| Gave a hypothesis of possible parameters affecting the magnetic field strength | Listed less than 3 parameters. | - | Gave at least 3 parameters that could affect the magnetic field. | - |
|  | Unsatisfactory (0) | Minimally satisfactory (2) | Satisfactory (4) | Exceeding Expectations (6) |
| Found that scales linearly with the current . | Did not observe this. | Observed it but their data was not good (poor and/or error bars)\*. | Observed it with good data. | - |
| Found the dependence on such that one can observe a fit. | Did not offer an explanation. | Offered an incorrect explanation. | Found that depended , the radius of the solenoid. | Found the exact dependence between and : with centered along the solenoid, they found  where are the two ends of the solenoid. |
|  | Unsatisfactory (0) | Minimally satisfactory (1) | Satisfactory (2) | Exceeding Expectations (5) |
| Offered a discussion about the behavior. | Did not offer a discussion. | Only noticed one of the aspects mentioned in the “Satisfactory” condition. | Pointed out that the intermediate and near behavior cannot be modelled by due to “interreference” of the two ends of the solenoid. Furthermore, the intermediate regime does not allow for the approximation (), which simplified to the behavior. | Noticed both conditions for “Satisfactory”. Further connected to the field emitted by an electron (), and that of an infinite plane/capacitor () and an infinite line (). Related it to lab 1. Attempted a discussion about dipole moments. |

\*Note that they are not to produce detailed analysis of their data, however you should point out to them when they are clearly misreading their data.

**Bonus points:**

For the following, they should try to understand these geometrically based on their intuition. Of course you can verify these by computing the limits with the equation.

* Discussed the limit **(+2)**.
  + This is the center of the solenoid. The B field receives equal contribution from both sides of the solenoid via the Pythagoras theorem.
* Discussed either or limits **(+2)**.
  + For , we have , and for , we obtain a constant also, but for different reasons. For the former, the radius is large such that the field does not reach the central axis. For the second case, geometrically, no field can be produced.
* Discussed either or limits **(+2)**.
  + For , we have a circular ring. For , we have a constant field for all : we are always inside the solenoid, and always far away from the sides of the solenoid.

**Session B**

**Conceptual questions and Critical thinking (/16)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Unsatisfactory (0) | Minimally satisfactory (2) | Satisfactory (4) | Exceeding Expectations (6) |
| Explained how the frequency is related to the torque . | Did not attempt to answer the question | Incorrectly explained the relation: does not know the definition of torque. | Correctly explained that torque is a **rotational force**, thus it naturally generates a frequency of rotation. | Further offered a discussion about angular momentum. |
| Found that the frequency is linearly dependent on the current . | Did not observe this. | Observed this, but obtained unconvincing data. | Observed this, and had good data. | - |
| Found that the frequency is linearly dependent on the magnetic field . | Did not observe this. | Observed this, but obtained unconvincing data. | Observed this, and had good data. | - |
| Offered other parameters that could affect the frequency of rotation. | Did not list other parameters. | Listed some parameters, but the latter cannot affect the frequency of rotation. | Correctly listed some parameters that could affect the frequency. We expect them to at least consider the number of turns of coil and its size (radius). | See “Satisfactory” conditions. Noticed however that it shouldn’t simply be the radius, but actually the area. |

**Data presentation (/16)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Unsatisfactory (0) | Minimally satisfactory (1) | Satisfactory (2) |
| Appropriate algebra (includes appropriate error propagation calculations) | Overwhelming number of mistakes | Made mistakes but it did not affect the overall understanding of the physical concepts. | Most calculations are correct. |
| Units (results and graphs) | Missing | Incorrectly used | Correctly used |
| Standard deviation  and significant figures | Missing | Incorrectly used | Correctly used |
| Title (figures and tables) | Missing | Incorrectly used | Correctly used |
| Axes labels | Missing | Incorrectly used | Correctly used |
| Error bars on graphs | Missing | Incorrectly used | Correctly used |
| Fit equation for graphs | Missing | Incorrectly used | Correctly used |
| value for graphs | Missing | Incorrectly used | Correctly used |

**Bonus points:**

* Discuss the effect of the back EMF **(+2).**