Online LAB: Measuring e/m

***Learning Goals**:*

1. *Reconstruct the famous experiment by J. J. Thomson to measure e/m of an electron.*
2. *Learn how each assumption translates directly into your mathematical model.*

Measure the charge to mass ratio of an electron (Application experiment)

The Task: Measure the charge to mass ratio of the electron (e/m_e) using a method similar to that used by J. J. Thomson in 1897, and compare it to the accepted value.

Watch the video for this lab: https://www.youtube.com/watch?v=CyEMzKbWqjo

Before taking any data, watch the first ~3 minutes of the video carefully and discuss the following questions in your group.

1. In order to create a near-uniform magnetic field in the region between the coils, should the current in the 2 coils be going in the same direction, or in opposite directions? Draw a diagram to justify your answer.

2. In the apparatus on the video, is the current in the coils going clock-wise or counter-clockwise when viewed from the front?
   Hint – if you're not sure how to answer this question, watch the video again carefully .

3. Based on how the electron beam curves when the magnetic field is turned on, determine the charge of the electrons. Justify your answer by drawing a sketch of the apparatus including direction of current in coils and direction of B-field, and a free-body diagram for the electron. Is that consistent with what you know about the sign of the electron charge?

Now watch the video again, and take the data that you need to do the experiment.

A proper experiment will have the elements below.

- Mathematical model (from prelab)
- Identification of assumptions made in the mathematical model.
- Determination of the effects of each assumption.
- Properly recorded and analyzed data, including uncertainties.
- Comparison of your result to accepted value $1.758\,820\,01076(53) \times 10^{11}$ C/kg.
- Description of how discrepancies could be explained by assumptions you made.

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Grading rubrics*

Scientific Ability	0	1	2	3
G4: Is able to record and represent data in a meaningful way	Data are either absent or incomprehensible.	Some important data are absent or incomprehensible. They are not organized in tables or the tables are not labeled properly.	All important data are present, but recorded in a way that requires some effort to comprehend. The tables are labeled but labels are confusing.	All important data are present, organized, and recorded clearly. The tables are labeled and placed in a logical order.
D7: Is able to choose a productive mathematical model for the experiment.	Mathematical model is either missing, or the equations written down are irrelevant to the design	A mathematical model is provided, but is incorrect or incomplete, due to which the final answer cannot be calculated.	Correct and complete mathematical model is provided, but an error is made in the calculations.	The mathematical model is fully consistent with the design, all quantities are calculated correctly. Final answer is meaningful.
D8: Is able identify the assumptions made in a mathematical model.	No attempt is made to identify any assumptions.	An attempt is made to identify assumptions, but the assumptions are irrelevant or incorrect for the situations.	Relevant assumptions are identified but are not significant for solving the problem.	All relevant assumptions are correctly identified.
D9: Is able to determine specifically the way in which assumptions might affect the results.	No attempt is made to determine the effects of assumptions	The effects of assumptions are mentioned but are described vaguely.	The effects of assumptions are determined, but some are missing and/or there are some minor errors.	The effects of the assumptions are correctly determined.
G5: Is able to analyze data appropriately.	No attempt is made to analyze the data.	An attempt is made to analyze the data, but it is either seriously flawed or inappropriate, and/or uncertainty analysis is missing.	The analysis is appropriate, but it contains minor errors or omissions.	The analysis is appropriate, complete including uncertainty analysis, and correct.

* ISLE scientific abilities rubrics https://sites.google.com/site/scientificabilities/

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PreLab Problems for "Measuring e/m"

1. For the Helmholtz coil described in the video, what is the I-*to*-B conversion factor, in units of Tesla/Amp (T/A)? That is, if you write a mathematical model, $B = \mathrm{k}I$ where k is a constant, what is the numerical value of k?
   For more info on Helmholtz coils: https://en.wikipedia.org/wiki/Helmholtz_coil

2. An electron of mass m_e and charge e is accelerated through a potential difference V_{acc}. What is the final speed v of the electron?

3. The same particle moves perpendicularly through a uniform magnetic field of strength *B*. What is the radius r of the particle's path?

4. Combine your answers from questions 1-3 to get a mathematical expression for the electron's charge to mass ratio e/m_e in terms of the accelerating voltage V_{acc}, the current through the Helmholtz coil I, and the radius of the circular path of the electron beam, r.

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