- This lab report is 'AI-Prep': Midshipmen may use AI to assist them in gathering information and organizing materials while preparing to complete an assignment. However, for the actual submitted assignment, midshipmen are required to produce original work on their own without using any form of AI.
- Two (or if needed three) authors per report.
- The writing should be in your own words. Any image that you didn't make should be cited.

Due October 2, 2026

Abstract: The abstract should be in the range of 150-250 words. It should be written as a single paragraph and should be fully self-contained (don't cite or reference any other works in the abstract). It should succinctly state what you did. It should then state the primary results. It is worth noting that the abstract is in some ways a stand-alone summary. If a person were to read the abstract alone they should be able to understand what you did. And if they read the article alone (skipping the abstract) it should make sense. So it is fine if the abstract seems repetitive with the rest of the article.

Introduction: The first section of the body of the article is the introduction. It is a paragraph or so describing previous work on the topic. It should start with one or two sentences simply stating what the Zeeman effect is.

Theory: This sections lays out any theoretical basis needed for your report. For this lab the theory section should mostly be energy level diagrams for both the green and blue lines. These diagrams can be hand-drawn but should be neat and relatively to scale. (By scale I mean that the energy splittings in the upper and lower states should be roughly proportional to the g-factor for the state. It is inevitable that the energy splittings under field will be greatly exaggerated in comparison to the overall energy difference between the upper an lower states.)

For your paper the Theory section really won't need much in the way of calculations. In particular, there is no reason to repeat the formula for Landé g-factor in your paper: this is a well-known formula that is in every textbook so you don't need to repeat it. Your energy level schematic should have the term symbol (such as $^3S_1$) and g-factor for each state but you shouldn't actually detail the calculation of the g-factor.

Experiment: Your experiment section will be the bulk of your paper. It will explain what you did and show the results. You should start with a description of your magnetic field calibration measurement. You should include a picture (photo or a drawing) of the experimental apparatus. Then show a figure that has the magnetic field as a function of current. You can state that you fit the data to a parabola and then give the fit parameters in the text.

Then you should describe your data taking. You should mention that we used Fabry-Perot etalons (and mention their free spectral ranges) but you shouldn't include formulas about constructive interference in etalons - again, that is information that a reader can look up if they don't already know it. At this point I would suggest showing your zero-field 'effective frequency' vs. position graphs fit to parabolas for both the green and blue lines. Then describe and show the bulk of your data: Intensity v Δf plots at 45°, 0° and 90° polarizer angles for both the green and blue lines and then a description of the field-dependent data taken on the green line a plot of Δf vs. current.

Analysis: The analysis section should detail what your results tell us. You should use your results to determine what ΔM_J is for transitions that emit light polarized parallel to the magnetic field (horizontal or 90° for us) and what ΔM_J is for transitions that emit light polarized perpendicular to the magnetic field (vertical or 0° for us). Then you should describe and show the graph of $|\Delta f|$ vs magnetic field fit to a line with zero intercept. State the slope and its uncertainty and then state your experimentally measured value of μ_B and its uncertainty. Then briefly compare your measured value to the expected value. Here you need to be accurate in converting the slope to a value of μ_B but you don't need to explain how you did it - at this point you are experienced enough that a reader should be able to trust you. As always, I suggest keeping one significant figure in the uncertainty (unless that digit is a 1, then keep a second sig. fig.) and enough digits in the value so that its last digit and the last digit in the uncertainty match. This could be written, for example, as $\mu_B = (9.37 \pm 0.05) \times 10^{-24}$ J/T. Uncertainty is also sometimes written with the uncertainty in parentheses at the end where the last digit in the uncertainty lines up with the last digit in the value, as in $\mu_B = 9.37(5) \times 10^{-24}$ J/T.

A final word about the tone that you should be going for. You will wind up with an experimentally determined value for μ_B and you will compare it to the current accepted value (*https://pml.nist.gov/cuu/Constants/*). But you should not use this to declare your experiment a success or a failure. Instead you should remember that the Bohr magneton is an empirically measured constant: its accepted value is determined by doing a weighted average of many measurements by physicists all over the world. You should think of yourself as one of them and that your measurement should lead us to (at least theoretically) adjust our prior opinions on the value of this constant. Now I'll admit that our error bars will be way, way larger than those of world-class experiments and for this reason our results are not going to have any real effect on the accepted values. But this should be your vibe: you should write your lab report as if you were a physicist participating in the scientific process in order to best determine this value.

Conclusion: Finally, you repeat you primary findings in a final paragraph. In some ways the conclusion is fairly similar to the abstract. But I'd say that the conclusion section should have less focus on procedure and be laser-focused on what you actually measured. I'd guess that the biggest difference is that you write the conclusion assuming that the reader has already read the paper (where that is not true for the abstract).

Writing tips: The entire focus of the paper should be on what measurements you performed and what information these measurements provide about the physical world. The paper is <u>not about you</u>. In particular the paper should <u>not</u> be about your experience of doing the lab. You should not declare your experiment to be a success or a failure.You should not describe what you learned from doing the lab. Scientific papers are often written in a passive voice (writing "The magnetic field was measured." instead of "We measured the magnetic field."). I won't require that, but generally if you find that your writing has a large number of first-person pronouns ('We' or 'I') then that is a clue that you are overemphasizing your experience instead of putting the focus on the experiments. Similarly, the use of words that indicate the passage of time like 'First', 'Next', or 'Afterwards' is a hint that you are focusing on process over results (the exception here would be if the experimental results depend crucially on the order of various steps).

Equations should be treated as part of the text even when they need to be separated into their own line. By this I mean that having a separated list of equations is not acceptable. You could also consider that equations are nouns and these nouns belong in sentences that are grammatically correct with verbs, etc. A series of equations showing each step in a calculation is likewise inappropriate. You can assume that the readers of a scientific paper will be a trained physicist - they should be able to understand and repeat your calculations without every step written out. If a calculation is important enough to detail its derivation then each step needs to be described in words. But for this lab report I don't think that there will be any need to detail derivations: just show your results.

If you need to use this lab report to fulfill the capstone requirement:

- Write the standard lab report with one or two classmates. You may then build upon that, but mention your co-author in an acknowledgment at the end.
- The background section should be enlarged. You should give a more in-depth description of the history of the Zeeman effect. You should describe when and how the Zeeman effect was discovered. You should also put the Zeeman effect into an appropriate scientific context by mentioning important uses. You should describe the difference between the normal and anomalous Zeeman effect. You should describe the difference between the low field and the high-field Zeeman effect (the latter is also called the Paschen-Back effect).
- In the theory section, add a table where you show the energy shift of each new line ($+\mu_B B$ or similar) and match that to the ΔM_J for that transition.
- Have at least three citations that cite original peer-reviewed work.

Citations: Each capstone paper should have at least three citations to previous work. Note that this should be in different places: don't just cite 3 papers by Zeeman to serve the same point. Where to find these works? Honestly, the references at the bottom of the wikipedia page (https://en.wikipedia.org/wiki/Zeeman_effect) are a fine place to start. There are five paper by Zeeman from 1896-1897 listed there and three of them are in English. You can click on those papers and then try to find papers that cite them, etc.

In order to cite a paper you add [#] (where # is 1 for the first paper cited, 2 for the second, etc) right after the sentence where this information is relevant. This is usually at the end of the sentence (whether the citation number goes before or after the period is actually a contentious issue whose norms vary from journal to journal) but can also be in the middle of a long sentence after the part of the sentence that mentions this previous work. Then, at the end of the paper, you have a list of references in order with each reference on its own line. The line starts with [#]. This is followed by a list of the authors (usually with initials instead of first names). Multiple authors are separated with a comma. If the list of authors is particularly long you can write only the name of the first author followed by *et al.* (short for et alia, Latin for and others). The last author (or the *et al.*) is followed by a comma, after which you write the journal name in italics. Many journal names will have standard abbreviations: *Phys. Rev. Lett.* for *Physical Review Letters*. After the journal name you place the volume number in bold type. The volume number is followed by a comma and then the page numbers of the article (either the page range or just the first page). Finally, the page number is followed by the publication year in parentheses and then a period. Here is an example paragraph with two citations and the citations from the end of the paper:

> Frustrated quantum spin systems — where no collinear magnetic order can simultaneously satisfy all interactions in the spin Hamiltonian due to the geometry of the lattice, disorder, or competing interactions — will often feature highly degenerate ground-state manifolds with unusual spin correlations and excitations [1]. Subtle perturbations can lead to very different physics in similar systems by selecting between nearly degenerate possible ground states. Multiferroic materials, with coexisting magnetic and electric order parameters [2], offer technological promise but are relatively rare in part because ferroelectric order requires a noncentrosymmetric space group that breaks inversion symmetry while magnetic order instead breaks time reversal symmetry.
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> [1] L. Balents, *Nature* **464**, 199–208 (2010).
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> [2] S.-W. Cheong, M. Mostovoy, *Nat. Mater.* **6**, 13–20 (2007).