Spacetime and the Quantum World (PHYS 135) Fall 2025 v1.0

We should take comfort in two conjoined features of nature: first, that our world is incredibly strange and therefore supremely fascinating. . . second, that however bizarre and arcane our world might be, nature remains comprehensible to the human mind.
- Stephen Jay Gould

1. Introduction to Phys 135:

We'll explore special relativity and quantum theory, two foundational building blocks of the modern physical understanding of the world. Remarkably the subjects are conceptually rich and yet can be accurately studied without (the usual) complex mathematical machinery. Nevertheless we will use diagrams (geometry), simple numerical calculations, some use of trigonometry, and some algebra during the course. A quick look at the two texts and the first three chapters of *Flat and Curved Space-times* will give you an idea of the level of math that we will be using. I will not assume that you have had any instruction in physics. As there is no set material that we 'have to get through' I hope that your interests will help determine the path through the semester.

2. Instructor:

Seth Major (he/him) Feel free to call me "Seth". It is what I prefer.
email : smajor@hamilton.edu
web : academics.hamilton.edu/physics/smajor/index.html
phone : x4919
office : Sci G052

3. Office Hours:

After each class and Thursdays 1:30 - 5:00 PM in the tutorial area outside my office G052 (drop-in help sessions). Feel free to call or send an email about a homework problem, questions on the text, or any other issue you'd like to chat about.

4. Texts:

- D. Mermin, *It's About Time* (I denote this with "M".)
- D. Styer, *The Strange World of Quantum Mechanics* ("S")
- We'll also delve into the first three chapters of Ellis and Williams ("E&W"), *Flat and Curved Space-times*, 2nd edition, which will be available on course reserves (whole book) and Blackboard (only Chapter 3).

Shop around for the best prices on these books.

5. On learning physics:

Learning occurs, and the seed of understanding is planted, when we think about a subject. This thinking happens when we actively confront a situation or a problem in a new way. Often, full understanding occurs only after iterating this process several times! Such active engagement with the material is especially beneficial to learning physics. The course is structured to foster this active learning. In class we will have clicker and whiteboard questions that will hopefully jump start this thinking and discussions, giving you a chance to understand some of the complexity, beauty, and fun of working

with close observation of our world. Also, please be patient. These subjects are deeply counter-intuitive and take time to mull over to understanding.

6. Guides:

Normally on alternate weeks I will distribute a Guide which includes reading for up-coming classes, problems on material you have worked with before, and other aspects of the course. I strongly recommend that you look over the reading assignments before class. Guides normally will be posted on the 135 website by Wednesday morning. When you have solutions due, the deadline will be Thursday evening at 11:00 PM on gradescaope. The first assignment is due September 8. You can find the gradescope submissions page for the course through blackboard or directly using the code DJP7BN. Solutions will normally be graded one point per problem. There will be about 7 guides during the semester.

Extension policy: Solutions turned in later than the deadline have a reduction of 20% per day (24 hours). However you have 3 automatic extension tokens during the semester. The policy is as follows: To opt in for any reason at all (illness, busy, travel, etc.) write me an email *before* the beginning of class on Thursday. You then have the weekend to complete your solutions. You can submit them via email for a time stamp or by sliding written (or printed) solutions under my door *no later than 9 AM Monday morning*. After this weekend extension, the assignment score decreases by 20% per day (24 hours).

7. Grades:

The work for the course will consist of reading, attending classes, solving some problems or puzzles, a couple of quizzes and a final.

Your semester grade will be determined by the following scheme:

(1) Participation (attending classes, contributing to the discussions both in class and office hours) 15%
(2) Solutions, assigned every two weeks: 25%
(3) Reaction questions: 10%
(4) Quizzes: 20%
(5) Final exam (Friday, December 19 at 2 PM) : 30%

7.1. **Participation.** This is primarily graded on your level of participation during the scheduled class time, and in office hours.

7.2. **Solutions.** Please leave time to stop by during office hours to ask questions if you have difficulty. When preparing your solutions, work in a logical, easy-to-read manner. A common best practice is to copy over your solutions and hand in a readable final copy. Please do consult with your fellow students when you are solving these problems, but write up your own solutions. Whenever ideas are not 100% yours please cite your sources, including discussions with friends, and all online materials. When writing up your work always follow the Hamilton Honor Code.

7.3. **Reaction Questions.** These will be moments for feedback. These will be quick a sentence or two reacting to the state of your knowledge (or uncertainty!) concerning special relativity and quantum mechanics. I will use these reactions to help plan upcoming classes and the path of the course. A most useful reaction is a specific question: for example, "What does it mean to say that an electron does not have a position?" Other possible reactions would be indications of general interest ("I'd like to learn more about black holes.") or general questions about course material. They are not graded. You will need to submit questions for 80% of the reaction moments for full credit. (Thanks to Dan Styer for this aspect of the course.)

7.4. **Final and Quizzes.** : We'll have a couple of in-class quizzes and a final. The first quiz will be October 9. The final will be during the scheduled time: Friday, December 19 at 2 PM. Please arrange your travel so that you are on campus for the final. The quizzes and exam include material in both the reading and the classes. Historical material will not be on any of the tests.

8. Accommodations:

I, with support of the college, will make reasonable accommodations for students with documented disabilities. If you are eligible to receive an accommodation(s) and would like to make a formal request for this course, please discuss it with me at the beginning of the semester. You will need to provide Allen Harrison, Assistant Dean for Accessibility Resources (aharriso@hamilton.edu) with appropriate documentation.

9. Learning goals:

Through your work in this course, you will[1] :

- work with spacetime diagrams to answer questions of causal order and the nature of spacetime;
- acquire an understanding of the consequences of the relativity principle and the constancy of the speed of light including, the relativity of simultaneity, time dilation, length contraction, and what is means to "see";
- acquire a basic yet firm understanding of quantization, interference, and entanglement;
- apply logic and quantitative reasoning, partly through mathematics;
- understand that science involves reasoning about nature from observations and experiments; appreciate the character and limitations of science; and begin to appreciate the beauty, elegance, and economy of nature and scientific explanations.

10. An Approximation to the Weekly Schedule

Decoding: "SR: means special relativity. "Q" means quantum. "M" is for Mermin's book. "E&W" is for Ellis and Williams. "S" is for Styer's text.
What follows is preliminary!

Enjoy!

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[1]Thanks to Dan Styer for some of these!

Week	Date	Topic	Reading
1	28 August	SR: Observing motion & reference frames	M Ch 1
		Collisions & SR: Momentum conservation	M Ch 1 & 2
2	4 September	SR: c, the speed of light & principles of SR	M Ch 3
		ST diagrams & SR: The slip in simultaneity	E&W Ch 3 (M Ch 5)
3	11 September	SR: Length contraction & time dilation	E&W Ch 3 (M Ch 6 & 13)
4	18 September	SR: Velocity addition	M Ch 4
5	25 September	SR: The whole package	E&W Ch 3
6	2 October	SR: Seeing swiftly moving objects	M Ch 7
7	9 October	SR: The invariant	**Quiz** M Ch 8 (E&W 4.2)
Fall break starts October 14			
8	23 October	SR: $E = mc^2$	E&W Ch 3 (M Ch 11)
9	30 October	Q: Black holes	Extra
10	6 November	Q: Magnets and spin	S Ch 1 & 2
11	13 November	Q: Stern-Gerlach variations	S Ch 3 - 5
12	20 November	Q: Bell's inequalities & variations	**Quiz** S Ch 6 - 8
Thanksgiving break			
13	4 December	Q: Quantum amplitudes	Ch 9 - 12
14	13 December	Spacetime and the Quantum world	...
Final Friday December 19 @ 2 - 5 PM			