Physics 301
Modern Physics
Fall, 2023

Meets:
1:30 pm – 3:20 pm
Tuesday, Thursday
150 Meldrum Hall

Instructor:
Dr. Christopher Cline
278 Meldrum Hall
Chat/call me on Microsoft Teams
ccline@westminsteru.edu

Textbook: Readings will be made available to you as needed, including selected chapters from Knight's *Physics for Scientists and Engineers, Understanding Physics* by Cummings, Laws, Redish, and Cooney, and OpenStax *University Physics*.

Course Description: Physics 301 is a junior level course in modern physics – essentially it might be considered a bridge course between the introductory physics sequence, Physics 211 and Physics 212, and the senior level quantum physics course, Physics 425. Physics 301 covers topics in Special Relativity and Quantum Mechanics. It is intended as a first introduction to the dual revolutions in our thinking about the universe around us, which were caused by these two theories.

Special Relativity (SR) was initially motivated by a need to unify the electrodynamics of Maxwell, with Newtonian mechanics. It succeeded admirably in this regard (by specifying a radical change in mechanics!). Its impact on physics has propagated well beyond this initial motivation. Its statements about the nature of space and time, predictions about their interrelationship, and the unification of such previously independent concepts as conservation of energy and conservation of matter, rocked the physics community of the early 20th century. SR continues to provide the basic structure for the interpretation of high energy physics. SR also represents one of the first examples of a theory based upon a postulated symmetry (constancy of the measured speed of light, or Lorentz invariance) and provides a fine example of how theories can be constructed to be consistent with a known symmetry.

Quantum mechanics is often considered to be the theory of very small systems. However, as all things are eventually composed of very small items (atoms for example), in many regards quantum mechanics is our most serious theory for understanding ANYTHING (other than gravity)! While Newtonian physics provides a good description of the motion of matter (better when modified by concepts from special relativity), it is only with quantum physics that we begin to understand why matter as we know it is even stable! Quantum mechanics involves a new way of looking at the world. At this point, there are simply no examples where firm predictions of the theory are known to fail.

Both of these theories, SR and quantum mechanics, are necessary foundational material for understanding the forefront of physics research today. For example, the combination of special relativity with quantum mechanics in relativistic quantum field theory, is an essential tool in understanding modern nuclear and high energy physics. Similarly, issues in quantum 'entanglement' (having an amplitude to be in several states simultaneously) are at the heart of new areas like quantum computation.

Learning Goals: This list represents what we want you to be able to *do* at the end of the course:

Relativity

Demonstrate the ability to convert to natural units and use them in calculations.

Understand and use space-time diagrams.

Understand the importance of the invariance of the space-time interval, and other invariant quantities in Relativity.

Demonstrate the ability to manipulate 4-vectors.

Understand the origin of time dilation, and use appropriate Lorentz formula to compute the effect.

Understand the origin of length contraction, and use the appropriate Lorentz formula to compute the effect.

Demonstrate the ability to use the Forward and Reverse Lorentz transformation to convert space time intervals from one frame to another, and to resolve various relativistic paradoxes.

Understand the equivalence of Energy and Mass.

Demonstrate the ability to relate Energy and Momentum as the length of 4-vector and use this to compute energy and mass in particle collisions.

Quantum Mechanics

Explain the historical development of quantum mechanics and the major experiments leading to it.

Know and understand the mathematical expressions to describe traveling waves.

Know and understand the relationship between wavelength, frequency, and energy of massless particles (photons).

Know and understand the relationship of wavelength, frequency, and energy of rapidly moving particles that have mass (The de Broglie relations).

Know and understand the Bohr Model and its relationship to energy levels and spectrum of the Hydrogen Atom.

Demonstrate the use of the Bohr Model to do back-of-the-envelope calculations.

Know the uncertainty relation in its various forms and use them to do back-of-the-envelope calculations.

Know the one-dimensional Schrödinger equation.

Know the meaning of the components of the one-dimensional Schrödinger equation.

Know the definition of an operator.

Know the definition of an eigenvalue, and eigenfunction.

Know the definition of energy and momentum as operators.

Compute simple normalization constants and expectation values.

Qualitatively sketch a wavefunction given a potential.

Experimental Techniques

Know the meaning of and be able to compute the standard deviation, standard error, uncertainty, fractional uncertainty.

Know how to propagate uncertainty in an equation with many variables using the total differential.

Know how to use the weak-link rule to determine the variable that causes the most error.

Know how to use the weak-link rule to estimate the uncertainty in an equation of many variables.

Develop a hierarchical and flexible plan for the course of an experiment.

Develop the skills to operationally understand the use a new piece of experimental apparatus and use it to perform an experiment.

Keep a record of your thoughts, measurements, and explanations in such a way that you can come back to your notes in 5 years and understand what you did.

Understand the concept that Physics is an experimental science.

Understand the concept that all measurements have uncertainty.

My goal is to have minimal lecturing and lots of discussion from your readings. We'll do hands-on explorations of physical systems as appropriate. Also, I hope to have lots of problem solving. I'll do some in class; you'll do lots in class; you'll do lots more at home.

Conditions of enrollment: Physics 212 (Physics for Scientists & Engineers II) is a prerequisites for all students enrolled in this course.

How to get help: My *office hours* are MW 1:00 pm – 4:00 pm, TTh 10:00 am – 12:00 pm, and TTh 4:00 pm – 5:00 pm. If you can't come during any of these hours, I will be happy to make an appointment with you for another time. For me, *the* most enjoyable aspect of teaching is working with students one-on-one. *Please, please* come see me often—*especially* if you run into difficulties with concepts.

Class Attendance and Participation: Class meetings are TTh 1:30pm-3:20pm. Preparation for class, attendance, and participation will be rewarded.

Course Requirements

Grading: Your overall "Course Score" will be calculated using the following relative weights:

Reading Memos	15%
Homework and Labs	25%
Final Paper	15%
Exams	45% total

Reading Memos: It is nearly useless to read a physics text as you would a novel. "Studying" such a text requires that you be an *active* reader, that you remain engaged in a virtual and *appropriately skeptical* conversation with the author. You should, for example: (1) reserve doubt about everything the text says until it thoroughly convinces you, (2) think about situations to which the author's arguments might not apply, (3) make notes in the margins, (4) draw your own sketches and graphs to help visualize situations and functional behaviors, and *especially* (5) fill in all of the missing steps in any mathematical arguments. Indeed it is *all* too tempting to simply take the author's word for everything including the results of any calculation; after all, he or she wouldn't consciously *lie* to you, right? Well, yes; probably. But if you get into that habit, you will become a *passive* reader. Your mind forms no permanent "hooks" on which to store the information being presented. The time spent in the process may well be reduced, but will also have been essentially wasted.

Perhaps mathematician Paul R. Halmos gave the best advice about how to study: "*Study actively. Don't just read the text; fight it! Ask your own questions, look for your own examples, discover your own proofs.*" (*I Want to Be a Mathematician*, New York: Springer-Verlag, 1985). Similarly, Kate Wilson describes a critical reader as:

> "They **ask questions**; they **relate the text to other sources**; they think of examples to **corroborate** or **challenge** the text; they **play with the ideas**, extending or elaborating on them; they **relate** the text to their **own purposes or experience**. Furthermore, they "**criticize**" the text in the more traditional sense of the word, looking for **bias**, for poorly developed logic, for hidden assumptions. They locate the **author's position** through active "listening", relate this to their own ideas or experience, and **reshape their own understandings** in the light of the text."

Accordingly, to help you form or hone these important good study habits, I will ask you to produce and turn in a "Reading Reflection" for the week's reading. Your reflection should be presented as paragraphs, using complete sentences. You will submit your reflection by emailing it to me, either as a PDF document (typed or scan of your handwritten notes) or a media file (audio or video). Generally, an appropriate length would be at least one full page handwritten, half a page typed, or 2 minutes of spoken word.

The following questions may guide your reflection; you are *not* limited to these questions, nor do you need to answer them all each time. I am most interested in hearing your response to the reading.

> Which parts of the reading were the most difficult or challenging? Was anything surprising? Did you make a connection between this reading and previous course material? Can you speculate on what further applications one could do with these concepts? Which parts were most confusing – did you eventually figure them out, and if so, how? Did you mentally poke some holes in the author's argument? Did you try an example problem yourself – if so, how did it go? Did you have an "Aha!" moment of realization at some point? Do you have any questions of the material?

Beyond their effectiveness at helping you to stay engaged as you study, your Reading Reflections will also help me to understand those items and topics that may require more attention in class. Reading reflections for the entire week's readings are due by class time each Tuesday before Spring Break and Thursdays after Spring Break. Your Reading Memos will be given full (3 pts) or partial credit (1 or 2 pts) *purely* on the basis of whether or not it appears that your good faith effort was involved and *not at all* on the basis of format, sophistication, vocabulary, correctness, etc. A full-credit reflection is composed of *your* insights, not just a summary/notes/transcription of the text. It includes specific details that convince me that you have thoughtfully engaged with the reading. Late submissions will be accepted up to 48 hours late for a -1 point penalty. To allow for extraordinary circumstances (*including* absence for *any* reason), I will throw out your lowest two scores.

Homework: I will make regular Homework Assignments due at intervals of approximately a week and a half to two weeks at the beginning of a specified class meeting.

As you surely know by now, the primary purpose of assigned problems in physics is ***absolutely not*** to see if you can get the right answer. Rather, it is for you to practice and then demonstrate that you have learned 1) how to determine the fundamental physical principles that are involved in a described situation and 2) how to apply those principles in a disciplined and orderly fashion. Of course, if you have learned how to do these things, you should expect to get the right answer too, but that is - really - of secondary importance. You will find - indeed, you probably have found - that, given time, an open book, lots of worked examples, and knowledge of the correct answer, it is very often possible to "get the answer" without the slightest understanding of what you are doing. Please guard against this; it is a complete waste of your time because it does not prepare you for, and it obviously will not work on, exams.

Accordingly, we are not - and you should not be - satisfied with problem "solutions" that simply consist of a series of mathematical manipulations leading to a result. Instead, the problem solutions you submit are to be "presented." By this we mean that they should be readable by someone who does not have access to the problem statement; should include written explanations and thoughtful comments about what you are doing and, especially, why; should use well-defined and consistent notation (employing unique and meaningful subscripts and superscripts as necessary); should be accompanied by neatly drawn and carefully labeled diagrams; and should flow in a logical and orderly progression down the page. They should use more space for the written explanatory information than for the mathematics! They should ***not*** include lengthy, multiple-step, purely mathematical manipulations because it only serves to obscure the physics. Do this kind of work on scratch paper and simply say something like "Solving equations 1, 2, and 3 for x, y, and z, we obtain ..." and give the result.

By class time on the day it is due, you will email me a PDF copy of your homework. At the beginning of class, I will answer remaining questions and I am willing to go over some problems if the class requests it. After class, you will be responsible for reviewing the solutions (available on the class homework page), annotating your written assignment in a **different color of pen**, and assigning yourself a score based on the rubric below.

Score (Out of 10 Points)	**Descriptive Qualities**
10	All problems are completed, correct, and well explained. Minor mathematical errors are okay.
8.5	All problems have been seriously attempted, but some contained major errors in setup or completion. Some problems may be incomplete.
7	All problems were started but the majority did not get very far. – or – Some problems were seriously attempted/completed but other problems were not really attempted.
0	Nothing turned in. (You do not need to submit a self-assessment in this case; however I encourage you to review the solutions for your own learning.)

Write your score and a 1-3 sentence justification at the top of your assignment, then resubmit your annotated homework to me by email. Self-Assessments are due at the same time as the next homework assignment due date, or the next exam time, whichever comes first. However, I encourage you to complete your assessment within a few days of the original assignment due date. Assignments with no self-assessments will be awarded 6/10 points. You are expected to be truthful with your scores, and I will check scores to assure that they are accurate reflections of your work. I do not accept late Homework Assignments, but to allow for extraordinary circumstances (*including* absence for *any* reason), I will throw out your two lowest scores.

I *strongly* encourage you to form study groups and to discuss with others your readings, questions that come up in and out of class, and how to go about solving problems. The work ***you*** turn in, however, must be ***yours***, based on the understanding ***you*** have acquired. When faced with two write-ups that show any signs of copying, I conclude that at least one person hasn't done the work. In such cases both papers will receive no credit and both students will be reported to the Dean of Students. You are not allowed to post your problem to the internet to be solved and are not permitted to solicit answers to assignment problems from any source outside of our class. It is against class policy and copyright law to use any "answer sharing website" such as Chegg to search for the resolutions to your homework problems.

Final Paper: You will choose one topic related to special relativity or quantum mechanics for further investigation outside of class. A list of possible topics will be provided separately. I encourage you to be creative, but also caution that it is best to restrict the scope to well-thought-out investigation than a rehash of a general discourse in a library book. The essay will be approximately 2 to 5 pages long (single spaced). I will offer suggestions for improvement to any student who turns in a draft of their paper at least one week before the due date.

Exams: There will be two exams, either in-class or take home. The materials that you may use for each exam will be announced ahead of time. You may not work with or gain assistance from anyone except members of the Westminster physics faculty. Of course, I trust you will do all your own work on the exams. If you are caught cheating on an exam you will receive an F for the exam for the first offense; for a second offense, you will receive an F for the entire course.

Academic Integrity: Please make sure that you have read and fully understood Westminster's Policy on Academic Honesty (and Dishonesty) (as listed in the 2023-2024 *Westminster Academic Catalog*). My sincere desire is to act as facilitator—not an enforcer—for your studies in physics. Accordingly, I operate on the assumption that all of our interactions are based on openness, honesty, and good faith. I expect all of us to be honest and to treat each other fairly and with respect. Because our trust in each other is absolutely *crucial* to the effectiveness of our relationship, I take an uncompromising stance, as should you, on the necessity for sanctions when it is violated. The first occurrence of academic dishonesty will result in a score of zero on that assignment or exam; the second occurrence will result in failure of the course.

Your rights under federal law

Section 504 of Rehabilitation Act of 1973/ADA: Westminster University is committed to providing equal access in higher education and to creating a learning environment that meets the needs of its diverse student body. If you are a student with a disability, or you think you may have a disability, we encourage you to meet with the office of Student Disability Services, which you can reach at disabilityservices@westminsteru.edu or 801-832-2272. You can find more information, including how to request accommodations, at the Student Disability Services website.

Title IX: Westminster University is committed to providing a safe learning environment for all students that is free of all forms of discrimination and sexual harassment. This includes discrimination based on sexual orientation, gender identity and gender expression. If you (or someone you know) has experienced or experiences any of these incidents, know you are not alone. Westminster University has staff members trained to support you in navigating campus life, accessing health and counseling service, providing academic and housing accommodations, and more.

Please be aware all Westminster University faculty members are “mandatory reporters” which means if you tell me about a situation involving sexual harassment or gender discrimination, **I must report that information with the Title IX Coordinator.** Although I have to make the notification, you will control how your case will be handled, including whether or not you wish to pursue a formal complaint. Our goal is to make sure you are aware of the range of options available to you and have access to the resources you need.

If you wish to speak to someone, you can contact any of the following on-campus resources. These resources are confidential:

- Counseling Center (egibson@westminsteru.edu or 801-832-2237)
- Student Health Services (801-832-2239)
- Victim’s Advocate – Stephanie Nolasco (advocate@westminsteru.edu)

If you wish to make a report directly to the Title IX Office, please complete the online reporting form located on the Title IX website or contact Mary Edmonds at 801-832-2496 or medmonds@westminsteru.edu. The Title IX website contains more information about resources, rights, policy and procedures, and updated information regarding our Title IX program at Westminster University.

Student Care: Westminster is committed to providing a safe and non-discriminatory environment for all members of the University community, including those whose gender identity and/or expression differs from the sex assigned to them at birth. Harassment and discrimination based on gender identity or expression is prohibited by the University and will not be tolerated. This includes refusal to address an individual by the gender they identify with. If you experience or witness prohibited conduct, or any form of discrimination or harassment, you should contact the Director of Student Care and Conduct listed below.

- Mary Edmonds (801-832-2496) or medmonds@westminsteru.edu

As a professor, just as with Title IX, I am required to report any information I obtain regarding discrimination or harassment to the Equal Opportunity Officer for further review.

Wellness Statement at Westminster University

Westminster University's integrated approach to wellness empowers students to live a healthy life and to develop self-efficacy toward their own wellness coupled with self-efficacy in the communities and social groups with which they are engaged. Through prevention and intervention programs/services students learn how a holistic approach to well-being can help them discover health, contentment, purpose, and connection. Integrated Wellness at Westminster encompasses social, intellectual, emotional, spiritual, physical, environmental, and financial aspects.

Westminster faculty care deeply about both your academic success and personal wellbeing. The University, and its faculty and staff, are all committed to advancing the mental health and wellbeing students, while acknowledging that a variety of issues, such as strained relationships, increased anxiety, alcohol/drug problems, and depression can directly affect students' academic performance. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, contact the Counseling Center at (801) 832-2465 for more information or to schedule an appointment. The Counseling Center is located on the lower level of Shaw Student Center.

Bias Statement at Westminster University

A bias occurrence involves words and/or actions directed toward a person, group, or property, motivated by a bias against an aspect of one's identity or lived experience, which impacts participation in the campus community. The bias incident reporting process helps to create an inclusive campus community by providing resources and support to address student issues and concerns that may not rise to a student policy violation. If you believe that you have experienced or witnessed bias in the classroom, residence hall, or at a university-associated event or activity, you are encouraged to report it. To submit a bias incident report, go to the Bias Report Form. Bias incident reports may be submitted anonymously.