Physics 301
Modern Physics
Fall, 2020

Meets:
2:00 pm – 3:50 pm
Tuesday, Thursday
150 Meldrum Hall

Instructor:
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278 Meldrum Hall
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Textbook: Readings will be made available to you as needed, including selected chapters from Knight's *Physics for Scientists and Engineers*. Other readings can be completed *either* with OpenStax *University Physics* or *Understanding Physics* by Cummings, Laws, Redish, and Cooney (the textbook used in Physics 211/212).

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 Quantum Mechanics and Special Relativity. 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 M 3:00 pm – 5:00 pm, W 1:00 pm – 4:00 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 2:00pm-3:50pm. Preparation for class, attendance, and participation will be rewarded.

Course Requirements

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)

Accordingly, in order to help you form or hone these important good study habits, I will ask you to produce and turn in a "Reading Memo" at the beginning of each day for which there is assigned reading. A "Reading Memo" is an informal running collection of thoughts about and reactions to the material in the text. As you study, keep a pencil in hand and note any questions that occur to you; any surprises, insights, or connections to other things you know about; anything you think may be wrong or incomplete and why you think so; anything you think could be said more clearly and your proposed revision; etc. Beyond their effectiveness at helping you to stay engaged as you study, your Reading Memos will also help me to understand those items and topics that may require more attention in class.

Your Reading Memos will be given full (3 pts) or partial credit (1 or 2 pt) *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. In order to allow for extraordinary circumstances (*including* absence for *any* reason), I will throw out up to three "missing" Reading Memos.

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.

I will not "check" your homework solutions in any in-depth fashion; it is up to *you* to check them against the solutions that I will hand out and to get answers—from me or others in the class—to any remaining questions you have. I will look over your work only casually and assign a holistic score of 5 to 10. See the Homework Rubric for more information, but briefly: a 9 or 10 point assignment work shows a correct understanding of the concepts and explains them clearly to a new learner. A 7 or 8 point assignment is generally correct but not clearly explained, or contains misunderstandings but is clearly written. A 5 or 6 point assignment demonstrates little understanding of the concepts or is so poorly written (or absent) that the reader can't understand. Unsubmitted problems or problems submitted with minimal development will receive a 0.

Problems that receive a score of 5-8 may be redone and resubmitted within 5 calendar days from the return of the original work. All resubmitted problems must include a thoughtful reflection on your original work and mistakes. The final score will be the average of the score on the original work and the score on the resubmitted work.

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 will conclude that at least one person hasn't done the work. In such cases both papers will receive no credit.

I do not accept late Homework Assignments, but, in order to allow for extraordinary circumstances (*including* absence for *any* reason), I will throw out your two lowest scores.

Subjective Bonus: A small portion of your grade is also determined by my own overall subjective evaluation of your work in the class. Although it is subjective, my policy is that it will *not* be less than the average of your Reading Memo and Homework scores. It allows me *only* to *reward* students who make contributions to the class that may not be fully recognized, who make particularly effective use of office hours, or who, in any other way, seem to deserve a bit of *additional* credit.

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.

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

Reading Memos	15%
Homework	25%
Subjective Bonus	10%
Exams	50% total

Academic Integrity: Please make sure that you have read and fully understood Westminster's Policy on Academic Honesty (and Dishonesty) (as listed in the 2020-2021 *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.

Face Covering Requirement: The College's Policy 521 on Complying with COVID-19 Guidance governs all students, faculty, staff, and campus visitors in all College-owned, leased, or operated facilities. Face coverings MUST be properly worn at ALL times in ALL classrooms, both indoor and outdoor. Accordingly, no consumption of any food will be allowed in classrooms, both indoor and outdoor.

As the instructor of this course, I shall comply fully with Westminster College's policy. Students who attempt to enter a classroom without face coverings will be asked by the instructor to wear face coverings prior to entry, and will not be admitted into the classroom without a face covering. Students who remove their face coverings at any time during a class session will be asked by the instructor to resume wearing their face coverings.

Students who do not comply with a request by a Westminster College instructor to wear a face covering in accordance with the College's Policy may be subject to disciplinary actions per the rules, regulations, and policies of Westminster College, including but not limited to the Student Handbook.

Non-compliance with this policy may result in disciplinary action, up to and including any of the following:

- dismissal from the course(s)
- removal from campus housing (if applicable)
- dismissal from the College

To immediately protect the health and well-being of all students, instructors, and staff, instructors reserve the right to cancel or terminate any class session at which any student fails to comply with faculty or staff request to wear a mask in accordance with College policy.

Students are strongly encouraged to identify to their instructor any student or instructor not in compliance. Non-compliance may be anonymously reported via the Incident Reporting Form (*https://westminstercollege.edu/about/risk-management/coronavirus-covid-19-resources/covid-19-comments-questions-and-incident-reporting*)

Your rights under federal laws:

Section 504 of Rehabilitation Act of 1973/ADA: Westminster college is committed to provide equal access in higher education. If you need disability-related accommodations in this class, have emergency medical information you wish to share with me, or need special arrangements in case the building must be evacuated, please inform me immediately. Please see me privately after class or in my office. Disability Services authorizes disability-related academic accommodations in cooperation with the students themselves and their instructors. Students who need academic accommodations or have questions about their eligibility should contact Jody Katz, Director of Disability Services & Testing Center, in the basement of Giovale Library (801-832-2272) or email *disabilityservices@westminstercollege.edu*.

Title IX: Westminster College 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 College 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 College faculty members are "mandated reporters," meaning **if you tell me about a situation involving sexual harassment or gender discrimination, I must share 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 privately, you can contact any of the following on-campus resources:

- Counseling Center (*egibson@westminstercollege.edu* or 801-832-2237)
- Student Health Services (801-832-2239)
- Victim's Advocate (*advocate@westminstercollege.edu*)

If you wish to make a report directly to the Title IX Office, please complete the online reporting form located on *www.westminstercollege.edu/titleix* or call 801-832-2262. The Title IX website contains more information about resources, rights, policy and procedures, and updated information regarding our Title IX program at Westminster College.

Equal Opportunity: Title VI of the Civil Rights Act of 1964 prohibits discrimination based on race, color, or national origin in any program or activity receiving federal financial assistance. In addition to these, Westminster's Equal Opportunity policy prohibits discrimination or harassment based on ethnicity, age, religion, military status, or genetic information in any of its programs or activities. If you encounter this type of discrimination or harassment, or feel that you have been retaliated against for reporting prohibited conduct or participating in any related proceeding, you should contact an Equal Opportunity Representative listed below.

Julie Freestone (801-832-2573 or *jfreestone@westminstercollege.edu*)
Kat Thomas (801-832-2262 or *kthomas@westminstercollege.edu*)

The equal opportunity policy and procedures can be accessed from the Student Life webpage.

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