PHYSICS 61 – Mechanics and Special Relativity

Course Syllabus, Autumn Quarter 2024

Instructor: Prof. Patricia (Pat) Burchat – burchat@stanford.edu

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Class meetings:

PHYSICS 61 meets in Lathrop 016 for all 80-minutes on Monday, Wednesday and Friday.

Enroll in the section that best fits your schedule; however, if you *can* enroll in Sec 02, *please do so.* (Sec 01 enrollment is currently over the capacity of the room.)

- Sec 01 – 1:30 to 2:50pm, MWF, Lathrop 016
- Sec 02 – 3:00 to 4:20pm, MWF, Lathrop 016

Pre-requisites: IMPORTANT – PLEASE READ!

If you were advised to enroll in PHYSICS 41 or 41E when you took the Physics Placement Diagnostic (and you have *not* completed PHYSICS 41), you will not be prepared to succeed in PHYSICS 61, in terms of both *content* and *pace*. You should instead follow the advice you received and enroll in PHYSICS 41 or 41E and then PHYSICS 43 so that you are ready to succeed in PHYSICS 61 next year. See section below for more details on pre/co-requisites.

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Group Study Hours (GSH):

An opportunity to work with other PHYSICS 61 students guided by one of the Teaching Assistants (TAs) or Prof. Burchat. For more details on how to take full advantage of GSHs, see section at the end of this document on *"What are Group Study Hours?"*

Schedule of Group Study Hours: *TBD*

One-on-one meetings with Prof. Burchat for pre-major advising, study skills coaching, etc., can also be scheduled on request.

Problem Sets: New problem sets will be posted online each Tuesday or Wednesday and will *generally* be due (on Gradescope) by 9pm the following Tuesday with a number of exceptions – for example, near the start or end of the quarter or to allow you to prepare for a particular Learning Assessment. In particular, Problem Set "0" is due Thursday, Sept 26, at 9pm.

Schedule of Learning Assessments (LA):

1. LA#1: Wed **Oct 16**, 7:30 - 9:00pm (week 4)
   - Lessons 1-6, Problem Sets 1, 2, part of 3.
2. LA#2: Thurs **Oct 31**, 7:30 - 9:00pm (week 6)
   - Lessons 7-13, Problem Sets 3, 4.
3. LA#3: Thurs **Nov 14**, 7:30 - 9:00pm (week 8)
   - Lessons 14-19, Problem Sets 5, 6.

4. LA#4: Mon **Dec 9**, 12:15 - 3:15pm (Final Exam week)
    - Lessons 20-28, Problem Sets 7, 8, 9.

Learning Assessments:

There will be four Learning Assessments (LA) throughout the quarter to allow you to synthesize the material you are learning, to allow the teaching team to assess how well you are each understanding the concepts, and to provide you with an opportunity to learn any concepts you missed. Solutions will be posted shortly after each LA. You will submit Reflections & Revisions to correct any errors, for all but the final Learning Assessment.

The first LA will cover the kinematics portion of special relativity. The remaining LAs will emphasize the material covered since the most recent LA. The fourth and final LA will be administered during the end-quarter exam week, on Mon Dec 9, 12:15 to 3:15pm.

There will generally be no "make-up" Learning Assessments.

Added 9/18/24: This course is participating in the proctoring pilot overseen by the Academic Integrity Working Group (AIWG). The purpose of this pilot is to determine the efficacy of proctoring and develop effective practices for proctoring in-person exams at Stanford. To find more details on the pilot or the working group, please visit the AIWG's webpage.

Grading scheme:

PHYSICS 61 is a 4-unit course with a Satisfactory / No Credit (S/NC) grading basis [1]. Our goal is to provide you with a very strong foundation on which to build your future studies in the physical or natural sciences, or engineering. We do this through deep engaged learning in class, weekly problem sets, interactive Group Study Hours, frequent Learning Assessments, and Reflections & Revisions that allow you to learn any concepts you miss on your first attempt. Full engagement in all these elements of the course is *necessary* to stay on top of the material and pass the final Learning Assessment.

An internal grade will be based on three elements of the course:

- Ten problem sets (0 through 9): 45%
- Four Learning Assessments: 45%
- Engagement with materials in class: 10%

Our goal is to provide every student in the class with the opportunity to develop a deep understanding of the material (so that the majority of the class would have received a letter grade of A!) and that each student takes advantage of that opportunity!

Course management website – Canvas:

All materials and announcements for the course are hosted on the PHYSICS 61 Canvas website.

- All lecture notes, activities, problem sets and solutions, miscellaneous handouts, and the syllabus and learning goals will be available (at appropriate times) in the Canvas Modules.

[1] Effective Autumn 2022, courses that are *not* offered with a letter grade option (such as PHYSICS 61) will count towards Ways requirements.

- The lecture notes and activities for each lesson will appear in a separate Lesson Module shortly before each class. Solution versions will be posted soon after Sec 02 (after ~5pm).
- The textbook sections corresponding to each lesson will be listed in the Module name.

Required textbooks:

1. *Special Relativity for the Enthusiastic Beginner* (2017), David Morin. Available on Amazon for ~$20. Kindle version is ~$7 and is free with the paperback version on Amazon. The first chapter of this book, all appendices, corrections / typos / errata / clarifications, and other materials can be found on the author's website here: https://scholar.harvard.edu/david-morin/special-relativity
2. *An Introduction to Mechanics* (2nd ed. 2014), D. Kleppner and R. Kolenkow ("K&K" for short). Available online, new or used. Kindle version ~$41. Amazon link.

Textbooks are also available to rent or buy through the Stanford Bookstore.

Although special relativity is covered in the later chapters of K&K, there are a few "shortcomings" in the presentations that are not uncommon in undergraduate textbooks on this topic. Therefore, we will instead be using the excellent textbook by David Morin, described above, as well as providing many of our own materials on this intriguing topic.

Where to start:

If you would like to **start reading or reviewing material** before the start of the Autumn quarter, here are some recommendations:

- Read these two very useful appendices in Morin's Special Relativity textbook: Appendix F (Problem-solving strategies) and G (Taylor series). The appendices are linked to the textbook webpage here. We will be emphasizing these important techniques throughout the quarter.
- Review the following sections on vectors in Kleppner & Kolenkow Chapter 1: Sections 1.2 – 1.7, linked to the "Useful Handouts" Module on the course Canvas site; you can skip the embedded physics examples for now. These sections cover important concepts, definitions, notation, and techniques that we will rely on for the rest of the quarter. Consider working through a few of the related end-of-chapter problems as well.
- Carefully read the two-page Vector Review linked to the "Useful Handouts" Canvas Module.

Note that textbooks often use boldface symbols to indicate vectors (e.g., **r, v, a**). When taking notes or writing solutions by hand (i.e., when boldface is not an option), be sure to *always* put an arrow above each symbol that represents a vector, or a "hat" (^) above each symbol that represents a unit vector (or "basis vector"). If any term in an equation is a vector quantity, then all terms in the equation must be vector quantities. Never write an equation that implies that you can add a vector quantity to a scalar quantity, or that you can set a vector equal to a scalar.

Prerequisites and corequisites:

Students must take the online Physics Placement Diagnostic described here before enrolling in PHYSICS 61. Also see the "Where do I start?" section of this webpage.

Because we want each student who enrolls in an introductory physics sequence to have a positive experience and to succeed, please ***consider carefully whether you satisfy important prerequisites for PHYSICS 61***.

- As listed in the Course Bulletin, the prerequisites are mastery of mechanics at the level of AP Physics C and AP Calculus BC or equivalent. *Please use the Physics Placement Diagnostic to guide you*. Do not ignore the advice! If you do, you might find that you are "in over your head" around the 3rd week of the quarter and will need to drop the class…
- Prior or concurrent enrollment in Math 51 or 61CM or 61DM is required.

Many students in PHYSICS 61 are considering majoring in Physics, Engineering Physics, Math, Computer Science, Electrical Engineering, or other quantitative majors; others are just interested in a mathematically rigorous treatment of physics.

If you are interested in physics but aren't yet ready for PHYSICS 61, don't worry – a not insignificant fraction of prospective Physics majors/minors and Engineering Physics majors (for which PHYSICS 61, 71, 81 are required) will begin with PHYSICS 41 and 43 and then take PHYSICS 61. Others are ready for PHYSICS 61 and then take PHYSICS 43 before completing PHYSICS 71 and 81. See these *six* different plans for the start of the Physics & Engineering Physics majors; each plan assumes a different starting point in math and/or in physics.

If you *are* ready to take PHYSICS 61 now, great! We are excited to be teaching this class and we're looking forward to a wonderful quarter together.

Communications:

- We will be using the Ed Discussion tool (linked in the left sidebar in Canvas) for class discussions of physics concepts, problems, course logistics, and more -- among students and with the teaching team. You can choose to make your communications anonymous to other students. We will open the forum during week 1.
- If you have an issue or question that is unique to your situation, then please send a message to phys61_teaching_team@lists.stanford.edu. But if your question might be of general interest, consider using Ed Discussion.

Lab Course:

The accompanying lab course (PHYSICS 61L) is an independent course, with separate enrollment, etc. If you have questions about the lab course, please contact the instructor, Julien Devin (jdevin@stanford.edu). The lab component is required for Physics majors/minors and Engineering Physics majors, it has pedagogical value for all students, and it builds community. We encourage you to enroll in the lab course regardless of your major.

Engaged learning in the classroom:

Each 80-minute class meeting on Monday, Wednesday and Friday will consist of mini-lectures (~5 to 15 minutes) interspersed with engaged learning – i.e., activities in which you will immediately build on or apply a new concept or reinforce formalism as it is introduced, to build physical reasoning in special relativity and mechanics. The active learning will be facilitated by members of the teaching team. You will be responsible for any material covered in class.

You should plan to ***attend every class*** (MWF) to take full advantage of the engaged learning materials. To encourage full participation throughout the quarter, 10% of the final grade is based on attendance in class. However, the more significant impact on your grade will likely be the deep understanding of the material and proficiency in applying the formalism that you will develop in class.

Do ***not*** plan to leave early for Thanksgiving week or arrive back late after Thanksgiving. Missing classes in the final weeks of the quarter will have a *particularly* negative impact on your learning in all your classes.

If you cannot attend a class due to an emergency, let the teaching team know in advance by sending an email to phys61_teaching_team@lists.stanford.edu.

Technology:

We want the engaged learning sessions to provide an environment for you to focus on just one thing – learning physics! – without distractions. Research has shown that we often *think* we are good at multiplexing, when in fact we are not... Therefore, we ask that you silence electronic devices, and **put away your phone and laptop for the entire class**. Research also shows that phones and open laptops negatively impact your learning *and* your neighbors' learning!

Before each class, we will provide learning materials as both electronic files in the relevant Lesson module in Canvas and as hardcopies. You can choose to work on either a hardcopy or on a PDF on your tablet (e.g., on an iPad with a stylus). However, **do not use your tablet for any purpose other than working on the lesson's materials**.

If you do not own a tablet and wish to use one, you can apply to check out an iPad plus stylus for the quarter (for free) through the Lathrop Learning Hub. The WebCheckout Patron Portal web interface is not very user friendly – but check on "New Reservation" and persevere!

Class environment:

Promoting questions - Our mission is to learn from each other. This happens through asking questions, active listening, and expressing ourselves in ways that promote understanding. Fear of asking questions can be a pernicious impediment to learning. In our engaged-learning classroom, valuable contributions to learning come from 'curiosity driven questions', but also from questions like "I don't understand why we can come to that conclusion... could we discuss it further?" or "How did that step work… could we go over it again?" or "I don't recall seeing that terminology/symbol/notation before… could we review the precise definition?" All these cases are bound to arise in PHYSICS 61 and we *welcome* these questions!

Within your engaged-learning groups, strong encouragement of questions benefits not only the person asking the question, but also the students who are responding. Our understanding of concepts can be quite muddled until we attempt to articulate them verbally or in writing. If you ask a question and receive a response from a classmate that doesn't bring full clarity, try responding with "Is this what you are saying?" and then describe *your* interpretation of the explanation in your own words. Everyone in your group can listen and provide feedback and input to bring further clarity. We also have a shared responsibility to promote equitable participation by ensuring that voices other than our own are heard.

A corollary is that the instructor gets to ask some basic questions too! For example, to determine the baseline knowledge from which students in the class are starting, or to ensure that a key point was understood, I may sometimes ask a seemingly “basic” question (for example, through an informal thumbs up/down poll). Please be responsive so that we get good feedback and can then efficiently move on. And, as we’ll see, sometimes “basic” questions reveal the most subtle concepts…

Two social rules - To facilitate the most effective and inclusive learning environment by promoting deliberate exploration of what we *don’t* know, we have a couple of “social rules”[2]:

1. Please resist acting surprised when people say they don't know something. Feigning surprise has no social or educational benefit.
2. Avoid subtle racism, sexism, homophobia, transphobia, and other kinds of bias. Subtle “-isms” are small things that make others feel uncomfortable. For example, saying “It's so easy, my grandmother could do it” is a subtle -ism.

If you find yourself breaking one of these rules, please apologize, use it as a learning experience, and then move on. If you see repeated feigned surprise, or hear a subtle-ism, you can point it out to the relevant person, either publicly or privately, or you can ask a member of the teaching team to intervene. After this, we ask that further discussion move off public channels. Please don't “pile on” to someone who made a mistake. The “subtle” in “subtle -isms” means that it may not be immediately obvious to everyone what was wrong with the comment. Please use it as a teachable moment, and then assume the message was received.

Keeping organized:

Because you will be receiving (or downloading) and annotating hardcopy (or electronic) versions of lecture notes and activities in each class meeting, we recommend that you think about how you will organize your annotated materials. (All materials will be available through the course Canvas site.)

Research has shown that writing key equations by hand, sketching diagrams or graphs, etc., is important for learning. Therefore, although a complete set of lectures and activities will be provided for each lesson, we recommend that you have a notebook or tablet for the class, where you can take notes *during* class, as well as between classes.

Course topics:

- Special relativity –
    - Einstein’s postulates, time dilation, length contraction.
    - Relativity of simultaneity; constructing and interpreting space time diagrams. Lorentz transformations.
    - Causality and the spacetime interval.
    - Invariance and four-vectors.
    - Mass, energy, and momentum for relativistic objects.
    - Collisions; relativistic dynamics.
- Dimensional analysis; vectors and scalars; unit vectors; cartesian and polar coordinates.

[2] Adapted from the social rules of The Recurse Center programming retreat center.

- Mechanics (covered at a deeper level than typically seen in high school, with an emphasis on full vector formalism, first-principles understanding, and development of physical reasoning) –
  - Kinematics in three dimensions.
  - Applying Newton's Laws, central and contact forces, linear restoring forces and harmonic motion. Static and dynamic equilibrium.
  - Momentum of particles and *systems*. When is momentum conserved? Center-of-mass frame.
  - Kinetic energy. Work. Work-energy theorem. Conservative forces and conservation of energy. Effective potentials. Elastic and inelastic collisions.
  - Angular momentum and torque (as vectors), moment of inertia, translation plus rotation, theory and applications of precession and gyroscopic motion.
- Along the way, techniques for solving differential equations that frequently appear in physics.
- The equivalence principle and Einstein's "happiest thought".

Also see the separate set of detailed *learning goals* for the course (available separately on the course Canvas site).

More on problem sets:

Problem sets will be a very important part of your learning experience. We will facilitate opportunities for you to work with and learn from each other as you work on your problem sets, with guidance from the teaching team. New problem sets will be posted online each Tuesday or Wednesday and will generally be due by 9pm the following Tuesday, with a number of exceptions. The due date for each problem set will appear at the top of the problem set.

See the separate instructions in the Problem Set module (available after the first class) on how you will upload your problem set solutions electronically using the Gradescope application and how you will have the opportunity to recover up to half of any deducted points on problems you seriously attempted on the first round, by identifying and discussing the misconceptions or mistakes through "*Reflections & Revisions*".

We have chosen Tuesday at 9pm as the usual problem set due date/time with the expectation that you will have seriously tackled every problem and written up most of your solutions by Monday morning – the day before the problem set is due. You can then take advantage of TA-staffed Group Study Hours (and informal study groups) on Monday and Tuesday to clarify any issues you had and put the finishing touches on your solutions.

Late problem sets will generally not be accepted. We expect you to attempt every problem and write up what you can before each problem set is due at 9pm. We will strive to post solutions shortly after 9pm and provide quick turn-around on grading so that you derive the full benefit of problem sets through a timely *Reflection & Revision* process, which we will describe in more detail after the quarter starts. Your Reflections & Revisions are due on Wednesday at 9pm, eight days after your problem set solutions were originally due.

Feel free to use Wolfram Alpha, Mathematica, Desmos, or other computational tools to check or plot results. However, you are expected to be able to solve all problems *without* these tools and demonstrate this ability in your problem set solutions, unless explicitly specified otherwise.

Additional textbooks at a similar level, for reference:

If you would like to see different perspectives on any of the topics we will cover, you may want to look at one of these textbooks, all of which are available through the Stanford Library Course Reserves, in either an electronic or hardcopy version:

1. *Spacetime Physics*, by Edwin Taylor and John Wheeler. A "classic" special relativity text. Free electronic version available here on author's website.
2. *Six Ideas that Shaped Physics: Unit R – The Laws of Physics are Frame-Independent*, by Thomas Moore. Very pedagogical (but somewhat wordy) introduction to special relativity. Unfortunately sets "c=1", so dimensional consistency is less apparent.
3. *An Introduction to Classical Mechanics*, by David Morin. (Available online here through Stanford Libraries.)
4. *Problems and Solutions in Introductory Mechanics*, by David Morin. Good for practice problems. Electronic version is quite inexpensive (e.g., $5.95 on Kindle).
5. *Classical Mechanics*, by John Taylor.

More about Group Study Hours:

What is the purpose of the *weekly Group Study Hours*?

The Group Study Hours offer an opportunity for you to work together with your classmates on establishing a deeper understanding of concepts we have covered in class and applying them to the problems on your weekly problem sets, with a member of the teaching team (a Teaching Assistant or the instructor) available to coach you and address subtle issues that come up.

Weekly Group Study Hours are also an opportunity to discuss how the concepts you are learning apply to broader fields of physics, to discuss discoveries in physics you have heard about in the news, or to raise any questions of interest to you and other students in the class – e.g., courses you might want to take in the future, career opportunities in physics, etc.

What are the benefits of *Group Study Hours*?

For you:

- The weekly Group Study Hours offer an opportunity for collaborative learning, for developing your problem-solving techniques, and for establishing a deeper understanding of concepts by articulating your questions and brainstorming solutions.
- You will learn from questions posed by other students -- especially when *you* try to address them!
- The weekly Group Study Hours are a great opportunity to build community and find a "study group" that suits your learning style. You can then set up informal study times to get together.

For the teaching team:

- We get to know you better!
- We enjoy the opportunity to share our enthusiasm for physics with you, the students.
- Your questions help us understand challenges with the course material and how to teach the material more effectively.

How do I use *Group Study Hours*?

- Just come to one or more of the weekly Group Study Hours that suit your schedule. It's fine to arrive at any point during the designated time.
- Join a group of students who are working on problems you would also like to tackle.
- If you did not fully understand a concept during class, raise it with the other students and/or a member of the teaching team. We will work through the concepts together!

Guidelines for using generative AI tools in PHYSICS 61:

You are welcome to use generative AI tools (such as ChatGPT or Bard) to explore concepts relevant to this course – much as you would use Wikipedia, or Google or other search engines. However, there are **important differences**. Whereas you are generally able to check the source of information in Wikipedia or a Google search, that ability is lost in generative AI. Therefore, you should **check the accuracy of responses** to questions posed to a generative AI tool – particularly in physics and mathematics! In other words, use them as a starting point for further exploration – not the final word.

On the other hand, **using generative AI tools to substantially complete a question on a problem set or learning assessment** (e.g., by entering the question and essentially copying the answer) is **equivalent to having another person write your solution, which is not permitted under the Stanford Honor Code**.

For more context, see this Office of Community Standards page on Generative AI Policy Guidance.

Honor Code:

It is expected that you and I will follow Stanford's Honor Code in all matters relating to this course. You are responsible for understanding the University's Honor Code policy; see this website for details. If you have any questions regarding this policy, please contact me.

The best way to learn the material in this class and to prepare for the Learning Assessments is to first work through the problems on your own and/or with your classmates, *without* consulting solutions that someone else has written up or generated. In this course, we *encourage* students to discuss physics issues and problem-solving strategies related to assigned problems. ***However, the solutions to problems must be written up independently.***

Unpermitted collaboration and plagiarism includes copying solutions from solution manuals – hardcopy or online – and representing it as one's own work. You are also not permitted to use sites[3] such as Stack Overflow, Quora, Chegg, online tutors, social media, Q&A forums, or generative AI tools for the purpose of completing Learning Assessments or problem sets. This is akin to consulting another person, and is prohibited *unless expressly permitted by the teaching staff.* Compromising your academic integrity may lead to serious consequences, including (but not limited to) failure in the assignment, failure in the course, disciplinary probation, suspension from the university, or dismissal from the university.

Access and accommodations:

Stanford is committed to providing equal educational opportunities for students with disabilities. Students with disabilities are a valued and essential part of the Stanford

[3] By extension, do not share PHYSICS 61 materials with these sites!

community. Our goal is to provide an equitable and inclusive learning environment for all students.
If you experience disability, please register with the Office of Accessible Education (OAE). Professional staff will evaluate your needs, support appropriate and reasonable accommodations, and prepare an Academic Accommodation Letter for faculty. To get started, or to re-initiate services, please visit oae.stanford.edu. If you already have an Academic Accommodation Letter, we invite you to share your letter with us (burchat@stanford.edu). Academic Accommodation Letters should be shared at the earliest possible opportunity so we may partner with you and OAE to identify any barriers to access and inclusion that might be encountered in your experience of this course.

Course continuity:

Stanford as an institution is committed to the highest quality education, and as your teaching team, our first priority is to uphold your educational experience. To that end we are committed to following the syllabus as written here, including through short or long-term disruptions, such as public health emergencies, natural disasters, or protests and demonstrations. However, there may be extenuating circumstances that necessitate some changes. Should adjustments be necessary we will communicate clearly and promptly to ensure you understand the expectations and are positioned for successful learning.

COVID protection:

While face masks are not currently required in classrooms, Stanford strongly recommends masking in crowded settings and when ill with respiratory symptoms. Individual instructors have the option of requiring masks in classes; in such cases, students will be informed in advance on Canvas and by email. You can find the most current policies on campus masking requirements on the COVID-19 Health Alerts site.

Backup plans:

- In the event that the instructor must quarantine and/or is ill, students will continue to meet in their regular classroom and the instructor will join by Zoom and/or another member of the teaching staff will teach the class.
- In the event of circumstances that prohibit in-person instruction (e.g., related to COVID or air quality), we will immediately switch to remote learning over Zoom. Zoom numbers for classes, Group Study Hours, etc., will be posted on the course Canvas site. Sign into Stanford Zoom (https://stanford.zoom.us) with your SUNet ID.