

**Space, Time and Motion**  
**PHY 151/201**  
**Spring 2021**

What does it mean for an object to be in motion? More specifically, what is the cause of motion? How can it be quantified? Is it possible to think something is in motion when it is truly standing still? Is there a maximum speed that an object can move? In this course, we will engage in a careful study of dynamics—the science of the causes of motion and rest—paying particular attention to the ideas of space and time. We will focus on reading selections from Galileo's *Dialogues*, Pascal's *Physical Treatises*, Newton's *Principia* and Einstein's *Relativity*. Weekly laboratory sessions complement our classroom discussions.

**Course times and locations**

PHY 151: General Physics 1 (Algebra-based) will meet in Room F149 in the Fine Arts Building on Monday, Wednesday and Friday from 10:30 - 11:15 a.m. Zoom meeting ID: 996 9499 6731

PHY 201: Physics 1 (Calculus-based) will meet when and where PHY 151 meets; in addition, it will meet in Room S109 in Generac Hall on Thursday from 11:30 - 12:15 a.m. Zoom Meeting ID: 932 2143 4396

Laboratory sections will meet in Room S115 in Generac Hall on Tuesday and Thursday (Dr. Kuehn) and Wednesday and Friday (Dr. Davis) from 12:30-3:15.

**Required Text**

Kuehn, K. 2014. *A Student's Guide Through the Great Physics Texts: Volume 2: Space, Time and Motion*. Springer.

**Course instructors**

Kerry K. Kuehn, Ph.D.  
Professor, Dept. of Physics,  
Course website: [www.kerrykkuehn.com/PHY151/](http://www.kerrykkuehn.com/PHY151/)  
email: [kerry.kuehn@wlc.edu](mailto:kerry.kuehn@wlc.edu)

Office: Generac Hall Room S133  
Dr. Kuehn's Office Hours: MWF 12:45 - 2:15  
Personal Meeting ID: 414 443 8850  
Personal meeting URL: <https://zoom.us/my/kerry.kuehn>

**Grade components**

Homework assignments	10%	Laboratory presentation	10%	Final exam	30%
Laboratory exercises	20%	Weekly quizzes	30%		

**Grading scale**

A	100-93%	B	87-80%	C	74-67%	D	61-54%
AB	92-88%	BC	79-75%	CD	66-62%	F	53-0%

**What are we learning in this course?** This course will be divided into three units

*Unit 1: Galileo's Dialogues* (about 5 weeks). In this unit, we will read selections from Galileo's famous *Dialogues Concerning Two New Sciences*, in which he discusses the sciences of (1) the strength of materials, and (2) projectile motion. We will also have the opportunity to discuss ideas such as the law of the lever, scaling laws, pendulum motion, buoyancy, drag, sound, and even music theory.

*Unit 2: Pascal's Treatise on the Equilibrium of Fluids* (about 3 weeks). In this unit, we will take a closer look at buoyancy, hydrostatic pressure, Pascal's Principle, and Pascal's solution to paradoxes that arise in the study of fluids.

*Unit 3: Newton's Principia* (about 5 weeks). In this unit, we will take a careful look at the development of Newton's theory of Universal Gravitation. Topics include: inertia, momentum, force and acceleration, action-reaction pairs, collisions, centripetal force, conservation laws, and planetary motion.

*Unit 4: Einstein's Relativity* (about 2 weeks). In this final unit, we will explore Einstein's theory of space and time, focusing on the phenomena of time dilation, length contraction, and relativistic momentum and energy.

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**Course material** Each week on my personal website, [www.kerrykkuehn.com](http://www.kerrykkuehn.com), I will identify (i) which book chapter(s) you must read, (2) which youtube lectures you must watch, (3) which homework problems you must complete, (4) the week's lab exercise, and (5) any supplementary information that may be of interest.

**What will we do during our classroom time?** Wednesday and Fridays will be devoted primarily to discussion of the week's reading and lecture material. We will also spend considerable time working through the week's homework problems. This is designed, at least in part, to prepare you for our in-class quizzes every Monday (see below).

PHY 202 students, will also meet on Thursdays in order to work through additional problems that require more mathematical sophistication and that will prepare you for upper-level physics courses.

**Weekly quizzes** Every Monday, we will have a short (20 minute) quiz. Immediately afterwards, we will review the answers and score the quiz. The quizzes are designed to ensure that you are keeping up with the weekly course material.

**Weekly homework assignments** Every week, I will assign a few homework problems. These may be numerical, conceptual, or essay-style problems. You should complete the homework problems and upload your solution *via* MyWLC by noon on Saturday. I will simply check that you have uploaded a file to MyWLC, and assign a pass/fail grade. The homework problems are designed to encourage you to engage with the material and to prepare you for the weekly quizzes.

**Final exam** There will be one comprehensive final examination given during the finals week.

**Course objectives** There are a number of general objectives that I use to shape this course. I would like you to:

- understand nature—(specifically the sciences of statics and dynamics)
- improve reading comprehension and vocabulary—(through the reading and discussion of great texts)
- discern truth from error—(by analyzing and comparing the best ideas which have been written)
- articulate scientific ideas—(both verbally and in written form)
- solve problems—(conceptual, mathematical, experimental)
- provide a suitable foundation for advanced coursework in physics (talk to me about major or minor)

**Teaching philosophy** In this course, we will read and discuss some of the classic scientific texts dealing with space, time and motion. The scientific texts we will read are considered classics because they address timeless questions in a particularly honest and convincing manner. This does not mean that everything they say is true. In fact many classic scientific texts contradict one another. But it is by the careful analysis of the most reputable observations and opinions that one may begin to discern truth from error.

You will not understand everything you read; nobody does. The texts are challenging. Like great literature, these texts must be "grown into", so to speak. (Remember: nobody understands all of Shakespeare or all of the Bible the first time they read it, either!) So think of this course as a "first dip" into the deep end of the pool. These texts are classics because—like fine wine—both the beginner and the advanced scholar can profit by studying them.

Much of the time that we spend in the classroom will be devoted to discussion of the reading selections. As the discussion leader, I will typically ask questions regarding specific ideas which are found in the texts. For instance, I may ask, "What does the author mean by the term weight," or "Is it true that all matter has weight?" And if so, "How do you know?" The task will then be to try, as a group, to answer these questions.

It is critical that participants carefully read the assigned selections before engaging in classroom discussion. This will help participants to make relevant comments and to cite textual evidence to support or contradict assertions made during the course of the discussion. In this way, many assertions will be revealed as problematic, in which case they must then be refined or rejected altogether. This is precisely the method used by scientists themselves in order to discover and evaluate competing ideas or theories.

During our discussion, you may speak with complete freedom. There is only one rule: *any comment or question you make must be made publicly so that all others can hear and respond*. Most students are initially apprehensive about engaging in public discussion. This is natural. If you find yourself to be one of these it is important to realize that you do not need to make an elaborate point in order to engage in classroom discussion. Often, a short question can

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provide a simple avenue. For example, "I am unclear what the author means by the term *energy*. Can someone please clarify?" Write down questions like these in the margins while reading the text. Start like this. Pretty soon, you may find yourself joining gamely in classroom discussion.

**Laboratory exercises** Many reputable opinions regarding how nature works are wrong. In many cases, this is because these opinions do not conform to the way nature actually behaves. How can one determine how nature actually behaves? During our weekly laboratory session, we will carry out experimental investigations which attempt to reveal how nature works under controlled conditions. You will be provided with equipment and some general questions or suggestions related to the assigned reading for the week. It will be your responsibility to devise experimental techniques and procedures so as to clarify your understanding of nature.

**Laboratory equipment** You will be assigned a laboratory partner with whom you will carry out the various laboratory exercises. There are to be no more than two students in any laboratory group. Each group will be assigned a column of shelves containing a host of laboratory equipment. Your group is responsible for all of the equipment in this column. You may not use equipment from any other column of shelves. During the final laboratory session, the laboratory instructor will inspect your column of shelves and will assign a final laboratory grade based on the orderliness of your column.

**Laboratory notebook** You must keep a record of your work during the laboratory sessions. To this end, you will need to purchase a lab notebook which must be brought to lab on your first laboratory session. Your lab notebook must be sturdy, must be at least 8.5 x 11 inches and must be quad-ruled (graph paper). You must allow the first few pages in your lab book to serve as a table of contents. The purpose of the lab book is to serve as a single source which contains all of the information relevant to your experiments. In particular, during each laboratory session, you should record the following information in your laboratory notebook:

- Your name and your laboratory partner's name, the date and a title for the experiment.
- A neat sketch of any experimental apparatus you use, along with labels (make and model).
- A clear description of your experimental procedure(s), including difficulties which you experienced in carrying out your experiments.
- Tables containing any data which you collect. You must never write data anywhere else: not on scrap paper, not on the back of your hand, nowhere. Also, you must write down an estimated uncertainty in any measurement which you perform. For instance, if you use a stop watch to time a falling ball, you should estimate the precision with which you were able to record the time. This is always slightly larger than the resolution of the device being used.

Your lab report must be written in blue or black ink. It must be written in chronological order. That is, you might first describe some of your procedure, then record some data, then describe some more of your procedure, then some more data, and finally do some analysis. The important thing is that you write clearly and that you spread out your writing so that the reader of your notebook can easily ascertain what you did, and reproduce it if necessary. If it contains computer printouts of data tables or plots, these must be trimmed to fit neatly on a page and secured with tape. Do not fold or stack your plots. All plots must occupy at least half of a laboratory book page (*i.e.* don't make tiny plots).

Before leaving the lab, your instructor will assign you a grade based on the neatness, clarity and completeness of your laboratory notebook.

**Laboratory grading** Laboratory notebook pages must be scanned and uploaded using the course management software by the date assigned by your laboratory instructor. Each student will receive a weekly laboratory grade which will range from 0% to 100%, based on their laboratory notebook. What follows are a few example students and the grade each received for one particular week.

- The 100% student conceived of an appropriate experimental program and has systematically executed it. When he or she ran into difficulties, he was able to arrive at a reasonable solution or work-around. His data is of good quality, and his analysis involves a reasonable assessment of sources of systematic error.
- The 80% student conceived of an appropriate experimental program and has systematically executed it. Although he or she was able to complete his experiments, either his data was inconclusive, or his analysis involved a significant systematic error which for which he was unable to account.

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- The 60% student conceived of an appropriate experimental program, but was unable to complete significant portions of the laboratory assignment.
- The 0% student completed little or none of the laboratory assignment.

**Laboratory discussion sections** After collecting your data and performing some preliminary analysis, you will be prepared to share your experiments and your results with your classmates. Therefore, each week at the beginning of the lab section we will spend 15 minutes discussing the previous week's laboratory experiment. Each individual will be assigned a week during the semester on which to do a formal presentation. The formal presentations must include:

- acknowledgement of the collaborators on your experiment
- description of the problem you were trying to solve, and how this relates to the week's lecture,
- a description of how you attempted to solve the problem, including a detailed description of your experimental apparatus and procedure,
- plots or tables of your data, along with a description of how you analyzed your data, and
- a summary of the significance of your laboratory work. It is not good enough to simply state your results without any analysis of their meaning. If your results are different than you had expected, then you must address this issue directly. This should include an analysis of any systematic errors. Be sure to distinguish between systematic and random errors.

The presentation should last no more than ten minutes, and will be followed by a short question and answer session. Be sure to bring visual aides that will allow others to get a clear look at you experimental setup and any data or plots you have prepared. The grade you receive will depend upon both the quality of your data and the extent to which you address the points mentioned in the previous section.

The laboratory discussion time will be aimed at understanding the meaning and significance of the experiments performed during lab sessions, and at discussing ways in which the experiments might have been performed so as to achieve the most meaningful results.

**Final thoughts** I want to encourage you to come to me with any concerns you may have during the course of the semester, whether they be physics questions or difficulties with reading or discussion. This course is designed to stretch your mind, but not to "break" you. Reading the classics in any field is challenging, but very rewarding. I would very much like to help you succeed and to enjoy this class! My contact information is listed at the beginning of this syllabus, so please feel free to contact me!

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<b>Unit 1: Galileo's Dialogues Concerning Two New Sciences</b>		
<b>Week 1 (Feb 1-5)</b>		
Topic	<i>ASG Ch 1 &amp; 2. Introduction to dimensional analysis and scaling.</i>	
Lab	<i>Water coherence (Ex.2.4)</i>	
<b>Week 2 (Feb. 8-12)</b>		
Topic	<i>ASG Ch 3 &amp; 4. Atomism, Archimedes' principle, buoyancy, drag</i>	
Lab	<i>Archimedes' Principle (Ex. 3.4) and Falling Bodies (Ex. 3.5)</i>	
<b>Week 3 (Feb. 15-19)</b>		
Topic	<i>ASG Ch 5 &amp; 6. Pendular motion, tension, resonance, law of the lever</i>	
Lab:	<i>Harmony (Ex. 5.6)</i>	
<b>Week 4 (Feb. 22-26)</b>		
Topic	<i>ASG Ch 7 &amp; 8. Torque, static equilibrium, uniformly accelerated motion.</i>	
Lab	<i>Beam Breaking (Ex. 6.8)</i>	
<b>Week 5 (Mar. 1-5) No class Tuesday</b>		
Topic	<i>ASG Ch 9 &amp; 10. Mean speed theorem, force and acceleration,</i>	
Lab	<i>Ramp lab (Ex. 10.2) Tuesday lab section do lab on Week 9</i>	
<b>Week 6 (Mar. 8-12)</b>		
Topic	<i>ASG Ch 11 &amp; 12. Projectile motion.</i>	
Lab	<i>Artillery (Ex. 11.4)</i>	
<b>Unit 2: Pascal's Treatise on the Equilibrium of Fluids</b>		
<b>Week 7 (Mar. 15-19)</b>		
Topic	<i>ASG Ch 13,14 &amp; 15 fluid equilibrium, hydrostatic pressure, Pascal's principle</i>	
Lab	<i>U-tube (Ex. 14.4), Torricelli's law (Ex. 14.5)</i>	
<b>Week 8 (Mar. 22-26)</b>		
Topic	<i>ASG Ch 16,17 &amp; 18. Siphons, atmospheric pressure and the weight of air.</i>	
Lab	<i>Bell jar (Ex. 16.6) and Canoe conundrum (Ex. 15.3)</i>	
<b>Unit 3: Newtons Mathematical Principles of Natural Philosophy</b>		
<b>Week 9 (Mar. 29 - Apr. 2) No class Thursday or Friday</b>		
Topic	<i>ASG Ch 19 &amp; 20. Mass, momentum, force, absolute and relative motion.</i>	
Lab	<i>None</i>	
<b>Week 10 (Apr. 5-9) No class Monday</b>		

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Topics	<i>ASG Ch 21 &amp; 22. Newton's laws, conservation of momentum.</i>
Lab	Force and Rotation (Ex. 20.3)
<b>Week 11 (Apr. 12-16)</b>	
Topics	<i>Ch 23 &amp; 24. Collisions. Centripetal force and acceleration.</i>
Lab	Collisions (Ex. 22.7)
<b>Week 12 (Apr. 19-23)</b>	
Topic	<i>Ch 25 &amp; 26. Induction, deduction, rules of reasoning, planetary motion,</i>
Lab	Centripetal force (Ex. 24.4)
<b>Week 13 (Apr. 26-30) No class Wed.</b>	
Topic	<i>Ch 27 &amp; 28. Universal gravitation, hypotheses and natural theology.</i>
Lab:	None
<b>Unit 4: Einstein's Relativity</b>	
<b>Week 14 (May 3-7)</b>	
Topic	<i>The principle of relativity, relativistic time dilation and length contraction.</i>
Lab:	Relativity (Ex. 29.2)
<b>Week 15 (May 10-14)</b>	
Topic	<i>Relativistic momentum and energy.</i>
Lab:	Speed of Light (Ex. 31.7)
<b>Week 16 (May 17-21): Final exams</b>	