Physics 1: Space, Time and Motion
PHY 151/201
Wisconsin Lutheran College
Spring 2023

What does it mean for an object to be in motion? More specifically, what is the cause of motion? And how can it be quantified? Is it possible for something to appear to be in motion when it is really 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 will complement our classroom discussions.

Course times and locations PHY 151: General Physics 1 (Algebra-based) meets in S109 in Generac Hall on Monday, Wednesday and Friday. There are two sections: one from 8 am - 8:50 am, and one from 10:30 - 11:20 a.m.

PHY 201: Physics 1 (Calculus-based) also meets in S109 in Generac Hall on Thursday from 11:30 - 12:20.

Laboratory sections meet in Room S115 at the following times: Monday 7pm - 9:50 pm (Dr. Kuehn); Tuesday 12:30 - 3:20 pm (Dr. Brown), Wednesday 12:30 - 3:20 (Dr. Davis), Thursday 12:30 pm - 3:20 pm (Dr. Kuehn), and Friday 12:30 - 3:20 pm (Dr. Davis).

Course instructors
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Office Hours: tba

Grade components

Final exam	30%
Weekly quizzes	25%
Laboratory notebook	20%
Homework assignments	10%
Classroom discussion	10%
Laboratory oral presentation	5%

Grading scale

A	100%
AB	< 95%
B	< 89%
BC	< 83%
C	< 77%
CD	< 71%
D	< 65%
F	< 60%

What are we learning in this course? This course will be divided into four units (see approximate course calendar later in this syllabus.)

Unit 1: Galileo's Dialogues (about 6 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 topics such as the law of the lever, dimensional analysis and 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 at Pascal's solution to certain 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, Newton's laws, force and acceleration, action-reaction pairs, free body diagrams, 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.

Course material and delivery: Each week on my personal website, www.greatphysics.com/Volume2, I will identify (i) which book chapter you must read, (2) which video lectures you must watch, (3) which homework problems you must complete, (4) the week's laboratory 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 example problems and the week's homework exercises. This is designed, at least in part, to prepare you for our in-class quizzes every Monday (see below).

PHY 201 students, will also meet on Thursdays in order to work through additional problems that require more mathematical sophistication and that will prepare them for upper-level physics courses.

Weekly quizzes Just about every Monday, we will have a short (about 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 space, time and motion)
- 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)

Reading classic scientific texts In this course, we will be reading and discussing 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 both the beginner and the advanced scholar can profit by studying them.

Classroom discussion 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 "mass," or "do all objects have mass" 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 speaking up in class. 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 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 cary 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.
- 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 presentations 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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Approximate Syllabus

Wk.	Topics	Text
1	Dimensional analysis, units, scaling, early modern views of the nature of matter	Galileo's *Dialogues Concerning Two New Sciences*
2	Archimedes' principle, the effect of buoyancy and drag on bodies falling in fluids, pendular and periodic motion	
3	sound waves, vibrations, frequency & pitch, consonance & dissonance, torque, equilibrium, law of the lever	
4	strength of materials, beam breaking, uniform acceleration	
5	position, velocity and acceleration, mean speed theorem, early modern views on force and acceleration	
6	two-dimensional kinematics, projectile motion	
7	deductive and inductive reasoning, causality, final cause, hydrostatic paradox, pascal's principle, pressure	Pascal's *Treatise on the Equilibrium of Fluids*
8	Spring break (no classes)	
9	hydrostatic pressure, barometers, siphons	
10	Mass, momentum, inertia, force, centripetal force, absolute and relative motion	Newton's *Mathematical Principles of Natural Philosophy*
11	newton's laws of motion, force addition, action-reaction pairs, free body diagrams	
12	conservation of momentum, center of mass position and velocity, elastic and inelastic collisions	
13	rotational motion, centripetal force and acceleration, principle of parsimony, principle of induction, philosophy of nature	
14	Kepler's laws of motion, Newton's universal law of gravitation, natural theology and Newton's argument from design	
15	principle of relativity, speed of light postulate, relativistic time dilation and length contraction	Einstein's *Relativity*
16	Relativistic energy and momentum	
17	Final exams	