Syllabus
Classical Mechanics
(Physics 8210)
Fall Semester 2021

Instructor Information:

Instructor:	Prof. Jens Oberheide http://globaldynamics.sites.clemson.edu/index.html
Office:	103 Kinard Lab
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Office Hours:	Wednesday 1:30 – 2:30 pm; I have an open door policy. Students are encouraged to come to my office on an as needed basis any time.
Class Hours:	MWF 11:15 – 12:05, Kinard 223; you may leave class if Prof. Oberheide has not arrived after 15 minutes
Recitation:	Attendance voluntary. About twice per month. Day and time will be announced in class.

Course Mode of Delivery

This is a traditional theoretical physics class. I will work out the physics on the board and will discuss its meaning with the class.

For each class, a notetaker will be assigned and the notes will be made available to the whole class through the Course Canvas site at https://clemson.instructure.com/courses/136238 ***You are still encouraged to take your own notes.***

Doing problems is critically important to understand the material. As such, ***weekly homework*** will be assigned. You will get feedback on your assignments and (most) solutions will be made available.

This is an in-person class and in-person attendance is expected for students without an online-only accommodation. The class will not be recorded, except if warranted by special circumstances.

There will be one midterm exam (tentatively on Oct 6) and one final exam (on Dec 7).

Course Information

Course Rationale: This course on analytical mechanics covers the Lagrangian and Hamiltonian approaches for single particles, many body systems, and rigid and continuous media. The classical mechanics of the special theory of relativity will also be discussed. Symplectic geometry for the mathematical formulation of the Hamiltonian theory will be introduced. The course will follow Goldstein.

Objectives:

1. Advance to a full understanding of Lagrangian mechanics, and Hamiltonian mechanics on phase space, including constraints.
2. A full understanding of small oscillations as an eigenvalue problem.
3. An theoretical understanding of the concept of canonical transformations and its applications.
4. An understanding of special relativistic generalizations of dynamics using spacetime geometry.
5. An introduction to concepts of classical field theory (optional).

Learning Outcomes:

1. Mastery of the Lagrangian theory
   a. Determine the nature of the constraints (holonomic or non-holonomic, time-dependent or static) and forces (conservative or non-conservative) for a given problem, and thereby identify the number of degrees of freedom and select appropriate generalized coordinates.
   b. Obtain the Lagrangian, the generalized forces and momenta for a given problem, and the appropriate equations of motion. Solve the equations for standard problems, including small oscillation approximations. Be able to apply the concept of Lagrange multipliers to obtain the forces of constraint for a given mechanical system.
   c. Be able to apply mechanical gauge transformations, and treat problems in which (i) generalized potentials appear (e.g., charged particles in electromagnetic fields, dissipate forces) and (ii) forces that do not have an associated potential or the existence of V(q) is ignored.
   d. Obtain conserved quantities from symmetry properties of the Lagrangian using the concept of cyclic coordinates and be able to interpret the physical significance of these quantities (e.g., linear & angular momentum, energy).

2. Application of the Lagrangian theory to central force problems
   a. Obtain the equation of motion in terms of an effective potential and solve if for standard central force problems, e.g., orbit equation, precession, etc.
   b. Be able to derive a scattering cross section for a given central force problem.

3. Application of the Langrangian theory to normal mode analysis
   a. Apply the Lagrangian theory to a system of coupled oscillators and write down the equations of motion.
   b. Apply the concept of normal mode theory to find the normal frequencies and normal modes of the system.
   c. Reconstruct the motion of the system from the normal modes.
4. Special relativity
   a. Apply Lorentz transformation to standard problems in special relativity.
   b. Be able to describe particle dynamics in terms of covariant tensor equations based on Minkowski geometry.
   c. Recognize the invariance of the scalar product and its consequences to an extent that allows the student to compute threshold energies in the center-of-momentum and laboratory systems for particle collision/production processes. Examples include Compton scattering and p+p processes.
5. Hamiltonian theory
   a. Recognize the concepts of Hamilton's principle and phase-space, be able to obtain the Hamiltonian for a problem with constraints, the resulting Hamilton's equations of motion and discuss conserved quantities from a cyclic coordinate perspective. Be able to recognize the resulting reduction of the dimensionality of the problem (number of degrees of freedom).
   b. Solve Hamilton's equations of motion for standard problems.
6. Canonical transformations
   a. Be able to find the canonical transformation for simple problems to make the problem easy to solve (cyclic coordinates).
   b. Be able to test for the canonical condition using generating functions, the symplectic condition, and Poisson brackets.
   c. Apply the Poisson bracket formalism to identify constants of motions. Be able to determine the time evolution of a generic dynamic variable of interest for a given Hamiltonian using Poisson bracket formalism.
   d. Recognize Liouville's theorem and be able to prove it from phase space considerations.
7. Further topics at the discretion of the instructor, e.g., an introduction to concepts of classical field theory

Course Outline: The book from Goldstein includes 13 chapters and it is impossible to cover all of them in one semester. The course will thus focus on chapters 1-3, 6-9, 13, to meet the objectives and learning outcomes. Some elements of chapters 4 & 5 (rigid bodies) will also be covered but rather short as this material is commonly covered in undergraduate mechanics and/or can easily be studied on your own.

- ***Class:*** In each lesson, you will learn the key topics from the course material in the book by Goldstein. You are expected to read the relevant text ***before each class***.

- ***Lecture notes:*** As the **assigned notetaker** (about twice per semester), you will learn to professionally summarize the relevant material of the lecture such that a student who could not attend the class will be able to understand what was being taught. This is also an important training in scientific writing.

  Notes are due (per email in pdf format) the day of the next class until 9 am: on Wednesday at 9 am for a Monday class, on Friday at 9 am for a Wednesday class and on Monday at 9 am for a Friday class. I will then check –and grade– these notes and ask the assigned notetaker for revisions, if needed. Revisions must be provided the following business day until 9 am. **The (revised) lecture notes will be provided to <u>all</u> students via Canvas, with the name of the assigned notetaker printed on top of the notes.** The lecture notes will count toward the final grade. General instructions re the structure and expectations for the lecture notes will be posted on Canvas. It is your responsibility to be aware of your assignment to take notes for a particular class. Failure to submit notes and/or revisions on time will result in an 0% grade for the assignment in question.

- ***Homework:*** These assignments will give you the chance to apply what you have learned and to demonstrate development of your skills related to the course content. You will turn in handwritten solution during class. Typed homework solutions are a waste of time and will not be accepted. Each assignment will include questions related to the textbook material. These assignments will be your homework grade and will be done ***once a week.*** To truly learn physics, you need to do many more problems – there's no substitute for that. You are thus encouraged to attack problems in Goldstein not given as a homework – and I will be happy to help you if you are stuck.

- ***Recitation:*** Depending on where we are in the course, we will do additional recitation sessions about twice per month, at a time to be determined, most likely in the evening to avoid collision with TA assignments. The recitation session is not graded. We will discuss and solve problems related to the material covered in the lectures. Attendance is not mandatory but strongly encouraged. You are encouraged to request the discussion of specific problems you are interested in, given that I'm made aware of this request the business day before the recitation class.

- ***Canvas:*** We are not going to use Canvas a lot but I will post homework solutions and other docs (like the syllabus) there.

Method of Teaching: This is a lecture course based upon the seminal textbook from Goldstein. You should prepare by reading the chapters and try to solve as many problems as possible. Exams will be administered in class.

Grading: Assignments in this course are divided into these general categories, which carry the following weight in your final grade calculations:

Category	Weight
Written Homework	30%
Class Notes	10%
Midterm exam	25%
Final exam	35%

There will be ***one midterm exam*** (tentative date: Wed, Oct 6 during class) and one ***final exam*** (Tue. Dec 7, 8 – 10:30). The two lowest homework scores will be dropped for the final grade calculation.

Late homework won't be accepted if you do not give me a very good reason.

You will be allowed to prepare your own equation sheet (1 page, front and back, handwritten) for the exams.

You are treated as a professional in the course. Accordingly, the grading is strict, but fair. Reading the directions and grading criteria provided for each assignment is the key to understanding how you will be graded.

Letter grade: A: 85-100%; B: 70-85%; C: 55-70%; F:<55%; no D grade and no +- grades.

Required Textbook:

- *Classical Mechanics* (Third Edition) by Goldstein, Poole & Safko; Addison-Wesley, ISBN 0-201-65702-3, 2002, 638 pages; List Price ~US$ 220; it is important that you have the 3rd edition. **The lecture will follow this book!**
- *Classical Dynamics* by Jose & Saletan; Cambridge University Press, ISBN 0-521-63636-1, 1998, 670 pages; List Price US$83.98. **An approach to Classical Mechanics that makes extensive use of geometric ideas. Quite interesting and particularly students with a theoretical physics orientation (or those who plan to use general relativity in their research) should read the book in parallel to the one by Goldstein, to get a broader perspective and for intellectual merit.**

Web Sites: The course web site is on Canvas, accessible at https://clemson.instructure.com/courses/136238 It will be used to post homework solutions and some needed material such as the syllabus – so, essentially a file repository.

Course Policies

The following policies are the standard syllabus material with COVID-19 specific provisions in red. Please read completely.

Prerequisites: Undergraduate classical mechanics (Physics 3210/3220 or similar).

Attendance Policy: This course is designed for active in-person learning and engagement. Attendance and active participation in this course will provide the most benefit for learning. Since you are treated as professionals in the course, ***attendance is not required but highly recommended. I reserve the right to drop any student from the course who stops attending/participating for extended periods of time.*** See also the specific COVID-19 information below.

Any exam that was scheduled at the time of a class cancellation due to inclement weather will be given at the next class meeting unless contacted by the instructor. Any assignments due at the time of a class cancellation due to inclement weather will be due at the next class meeting unless contacted by the instructor. Any extension or postponement of assignments or exams must be granted by the instructor via email or other means of communication within 24 hours of the weather-related cancellation.

Specific COVID-19 related attendance information: If you are sick or if you have been tested positive: **do not come to class until you have been cleared again.** Let me know as soon as possible (email of Canvas notification of absence) and we will work out how to proceed. You won't be penalized for that, and we will develop a continued plan of study to succeed in the course.

University Policies

Academic Integrity: The Clemson University statement on academic integrity reads: "As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating or stealing in any form."

Student Accessibility Statement: Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to a class should let the professor know, and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848 or by emailing studentaccess@lists.clemson.edu. Students who receive Academic Access Letters are strongly encouraged to request, obtain and present these to their professors as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester. You can access further information here: http://www.clemson.edu/campus-life/campus-services/sds/.

Clemson University Title IX Statement: Title IX Policy: Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity (e.g., opposition to prohibited discrimination or participation in any complaint process, etc.) in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. The University is committed to combatting sexual harassment and sexual violence. As a result, you should know that University faculty and staff members who work directly with students are required to report any instances of sexual harassment and sexual violence, to the University's Title IX Coordinator. What this means is that as your professor, I am required to report any incidents of sexual harassment, sexual violence or misconduct, stalking, domestic and/or relationship violence that are directly reported to me, or of which I am somehow made aware.

This policy is located at http://www.clemson.edu/campus-life/campus-services/access/title-ix/ . Ms. Alesia Smith is the Executive Director for Equity Compliance and the Title IX Coordinator. Her office is located at 223 Holtzendorff Hall, phone number is 864.656.3181, and email address is alesias@clemson.edu.

COVID-19 Related Expectations for Face Coverings: Per current Clemson University policy. I kindly ask all students to consider wearing a mask during class and office hours.

Clemson University is committed to providing a safe campus environment for students, faculty, staff, and visitors. As members of the community, we encourage you to take the following actions to be better prepared in case of an emergency: (a) Ensure you are signed up for emergency alerts (https://www.getrave.com/login/clemson), (b) Download the Rave Guardian app to your phone (https://www.clemson.edu/cusafety/cupd/rave-guardian/), (c) Learn what you can do to prepare yourself in the event of an active threat (http://www.clemson.edu/cusafety/EmergencyManagement/)