Syllabus
Classical Mechanics
(Physics 8210)
Fall Semester 2016

Instructor

Prof. Jens Oberheide, 102B Kinard Lab, Dept. of Physics and Astronomy, Clemson University, Tel. 864-656-5163, Email: joberhe@clemson.edu

Office Hours

MWF 1:30 – 2:30; Th 10:00 – 12:00; I have an open door policy: simply come on an as needed basis any time.

Prerequisite

Undergraduate Classical Mechanics (Physics 3210/3220 or similar).

Class Hours

MWF 11:15 – 12:05, 116 Kinard. If I am late for class and do not have a substitute, I do not expect students to wait more than 15 minutes.

There will be an additional recitation session per week, at a time to be determined. The recitation session is not graded. We will discuss and solve problems related to the week's material covered in the lectures. Attendance is not mandatory but strongly encouraged. Students are encouraged to request the discussion of specific problems they are interested in, given that the instructor is made aware of this request the business day before the recitation class.

Attendance Policy

Attendance is required for the first class. Thereafter, it is not required but is *strongly recommended*. It is the responsibility of the student to be aware of what is announced in class, including changes to homework assignments. Please also see the general statement on attendance in the Graduate Announcements.

Required Text

Classical Mechanics (Third Edition) by Goldstein, Poole & Safko; Addison-Wesley, ISBN 0-201-65702-3, 2002, 638 pages; List Price US$ 208.60; it is important that you have the 3rd edition. **The lecture will follow this book!**

Recommended Text

Classical Dynamics by Jose & Saletan; Cambridge University Press, ISBN 0-521-63636-1, 1998, 670 pages; List Price US$105.00. **An approach to Classical Mechanics that makes extensive use of geometric ideas. Quite interesting and particularly students with a theoretical physics orientation should read the book in parallel to the one by Goldstein, to get a broader perspective and for intellectual merit.**

Class Web Page

The course web site can be accessed via Blackboard. Course announcements, assignments, instructional material etc. can be found there.

Course Outline

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.

Course Objectives & Topics

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

Disclaimer: "Students may vary in their competency levels on these abilities. They can expect to acquire these abilities only if they honor all course policies, attend class regularly, complete all assigned work in good faith and on time, and meet all other course expectations of them as a student."

Homework

Written homework is very important to practice the theoretical concepts discussed in class. It will be assigned on a weekly basis. The lowest two written homework grades will be dropped at the end of the semester before the final course grade is calculated. Written homework is due on the date assigned. Late written homework will not be accepted without a very good excuse. Each student will also make an oral presentation of his/her written homework at least twice per semester in my office. The oral presentations count toward the final grade.

Student Lecture Notes

All students must provide typed lecture notes for assigned classes, approximately 3-4 times per semester. These 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. The instructor will then check –and grade– these notes and ask the student for revisions if needed. Revisions must be provided the following business day until 9 am. **The (revised) lecture notes will be provided to all students via blackboard, with the name of the student 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 blackboard. It is the student's responsibility to be aware of his/her 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.

Exams

There will be one mid-term and one final exam.

Course Grades and Weights

- 25% Written Homework
- 5% Oral Homework Presentation
- 10% Class Notes
- 25% Mid-term exam
- 35% Final exam

A: 85-100; B: 70-85; C: 55-70; F: <55 (no D grade)

Academic Integrity Policy

The graduate academic integrity policy, as stated in the Graduate School Policy Handbook, applies. In addition, students may discuss homework problems with other students, but only in general terms. **Copying homework solutions from the web is strictly forbidden!**

The official 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. In instances where academic standards may have been compromised, Clemson University has a responsibility to respond appropriately to charges of violations of academic integrity."

Disability Access Statement

It is university policy to provide, on a flexible and individualized basis, reasonable accommodations to students who have disabilities. Students with disabilities requesting accommodations should make an appointment with Disability Services (656-6848), to discuss specific needs within the first month of classes. Students should present a Faculty Accommodation Letter from Student Disability Services when they meet with instructors. Accommodations are not retroactive and new Faculty Accommodation Letters must be presented each semester.

Clemson University Title IX (Sexual Harassment) Statement

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 policy is located at http://www.clemson.edu/campus-life/campus-services/access/non-discrimination-policy.html. Jerry Knighton serves as Clemson's Title IX Coordinator and he may be reached at knightl@clemson.edu or 656-3181.