Physics 504, Fall 2016

Advanced Mechanics

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Assignments and Links

Class times: Tu,Th 10:00-11:50 AM at KAP-138
Office hours: SSC-216B, Tu,Th 2:30 PM - 3:30 PM, or by appointment.

Website: http://physics.usc.edu/~bars/504/5042016

Pre-requisites:

Classical Mechanics at undergraduate level.

Books

— *Classical Mechanics*, third edition, Addison-Wesley, 2002,
Authors: H. Goldstein, C. Poole and J. Safko.

— *Classical Dynamics: a Contemporary Approach*, Cambridge University Press, 1998,
Authors: J.V. José and E.J. Saletan.

— *Mechanics*, 3rd edition, Course in Theoretical Physics, vol.I, Pergamon Press, 1988,
Authors: L.D. Landau and E.M. Lifshitz.

— Material from other sources will also be used, and provided in the form of class notes or internet links.

Grading

30% - In class participation is expected in the form of asking and answering questions and presenting assignments at the blackboard. The goal is to generate class discussions and greater interaction between students and teacher. The assignments will include reading material and homework problems. Students should expect to be called upon randomly to discuss the material. 30% of the grade will be assigned on the basis of in-class performance.

30% - Reading and homework problems will be assigned approximately once per week. Many sources with solutions to problems are available in the internet. Students can share ideas but are expected to write up their own work *clearly*. Copying solutions from each other, from the net or a solution manual will be considered plagiarism and will result in an automatic F grade for the course*. The assignments, which should be turned in by the Thursday of the following week, will be graded. The solutions will be posted at the course internet site.
*See: Academic Integrity Overview , Trojan Integrity Guide , Guide for Graduate Students

40%- Final exam, Thursday Dec.8, 11 AM – 2 PM, in class..

Course content:

This course will emphasize the Lagrangian and Hamiltonian formulations of classical mechanics based on the action principle. Various standard topics, such as canonical transformations, constrained system, small oscillations, Kepler problem, Hamilton-Jacobi theory, scattering theory and others will be covered. Some topics of current interest, such as some aspects of cosmology, global symmetry and gauge symmetry will also be discussed. The overall discussion will be developed at first in the context of non-relativistic dynamics and later will include examples in relativistic dynamics and continuous systems, including classical field theory. Throughout the discussion, examples will be provided as applications in various branches of classical and modern physics.

The material that will be covered is listed below in broad outline. The order of presentation does not correspond to the order of chapters in the recommended books, although a lot of the material and concepts are in some form in the book by Goldstein et.al.. Furthermore, some of the topics are not well covered in these books. For this reason, the relevant chapters in the books, and various additional sources, will be provided to the students as part of the reading assignments as the course develops.

- Elementary principles of mechanics.
- The action principle and the Lagrangian.
- The Hamiltonian approach and phase space.
- Canonical transformations.
- Oscillations.
- Central forces & Kepler problem.
- Global symmetries and conservation laws.
- Constraints.
- Gauge symmetries and constraints.
- Examples in non-relativistic and relativistic dynamics.
- Cosmology as an example of a constrained system in general relativity.
- Two-Time physics as an example.
- Hamilton-Jacobi theory.
- Action-angle variables and integrable systems.
- Perturbation theory.
- Scattering theory.
- Rigid bodies.
- Continuous systems, string theory and field theory.

Time will likely not permit to cover all the topics. In that case a selection will be made among the topics that are at the end of this list.

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Assignments and Links

Assignments:

Reading and problems:
Read the assigned material and solve the problems for the week. Turn in the solutions to the problems on the Thursday of the following week. Be prepared to present the solution of the problems on the blackboard and answer other relevant questions in class.

1. **Week of 08/22/2016. Elementary principles of mechanics**.
   - Read Chaps.1,2 in Goldstein
   - Solve problems in Goldstein ch.1, problems # 4, 9, 13, 14, 17, 22
   - Solutions. See also additional solved problems included in this file.
2. **Week of 08/29/2016. The action principle, the Lagrangian and Hamiltonian.**
   - Read Chaps 2,8.# in Goldstein
   - Solve problems in Goldstein ch.2, problems # 2, 12, 14, 18, 21, 23, 25
   - Solutions , see also these solved problems
3. **Week of 09/05/2016. Hamiltonian, Phase Space, Canonical transformations.**
   - Read Chaps.#8,9 in Goldstein
   - Solve problems in Goldstein ch.8, problems # 2, 14, 16, 19, 23, 26, 27
   - Solutions
4. **Week of 09/12/2016. Phase Space, Canonical transformations.**
   - Read Chap.#9 in Goldstein
   - Solve problems in Goldstein ch.9, problems # 1,4,5,6,8,21,23
   - Solutions
5. **Week of 09/19/2016. Poisson Brackets. Oscillations.**
   - Read Chaps.#9,6 in Goldstein
   - Solve problems assigned in class
   - Solutions , See also these solved problems on oscillations.
6. **Week of 09/26/2016. Oscillations.**
   - Read Chap.# 6 in Goldstein
   - ??problems??
   - Solutions , See also these solved problems on oscillations.
7. **Week of 10/03/2016. Oscillations.**
   - Read Chap.# 6 in Goldstein, and this file about the 3-body problem.
   - Solve problems in Goldstein ch.6, problems # 4,6,10,13,16
   - Solutions , See also these solved problems on oscillations.
8. **Week of 10/10/2016. Central forces & Kepler problem.**
   - Read Ch.#3 in Goldstein
   - Solve problems in Goldstein Ch.3, problems 11,13,14,18,19,21,27,31
   - Solutions , see also these solved problems on Central Forces.
9. **Week of 10/17/2016. Central forces & Kepler problem, solutions.**
   - Read Ch.#3 in Goldstein
   - Solve problems in Goldstein Ch.3, problems 11,13,14,18,19,21,27,31
   - Solutions, see also these solved problems on Central Forces.
10. **Week of 10/24/2016. Central forces & Kepler problem, scattering.**
    - Read Ch.#3 in Goldstein

- Solve problems in Goldstein Ch.3, problems 11,13,14,18,19,21,27,31
- Solutions, see also these solved problems on Central Forces.

11. Week of 10/31/2016. Global Symmetry, Noether's Theorem and Conservation Laws

- Read notes on symmetry
- Solve problems assigned in class
- Solutions

12. Week of 11/07/2016. Examples of Symmetry, Properties of Symmetry Generators

- Read notes on symmetry
- Solve problems assigned in class
- Solutions

13. Week of 11/14/2016. Hidden symmetries, H-atom, harmonic oscillator, Relativistic particle

- Read notes on symmetry and on relativistic particle
- Solve problems assigned in class
- Solutions

14. Week of 11/21/2016. Gauge symmetry in particle dynamics – general formulation

- Read notes on gauge symmetry in particle dynamics, and paper on cosmology
- Solve problems assigned in class
- Solutions

15. Week of 11/28/2016. Examples of gauge symmetries, 2T-physics, cosmology

- Read notes on 2T-physics (and paper) and some gauge choices that connect 2T to 1T-physics
- Solve problems assigned in class as follows:

- Based on the 2T-physics document, do the following 4 problems: #1 and #2 in section-2, #1 in section-5, and #1 in section-6.
- Solutions : For solutions see these papers. The gauge choices or setup in the papers are slightly different but the solutions are equivalent (in problems 1,2,3 two gauge choices are made rather than 3 gauge choices, in problem 4 the second order formalism is used rather than the first order formalism).
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FINAL: Thursday Dec.8, 11AM-2 PM, in class

Final problems and solutions

USEFUL LINKS AND NOTES

Physical Constants
LecturesOnSymmetries.pdf