PERIMETER SCHOLARS INTERNATIONAL

Classical Physics

PSI 2022/2023

Instructor

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Teaching assistant

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How to get in touch with me: You can contact me by email, try coming to my office, or email to arrange a time to meet.

Land acknowledgement

Perimeter Institute acknowledges that it is situated on the traditional territory of the Anishinaabe, Haudenosaunee, and Neutral peoples.

Perimeter Institute is located on the Haldimand Tract. After the American Revolution, the tract was granted by the British to the Six Nations of the Grand River and the Mississaugas of the Credit First Nation as compensation for their role in the war and for the loss of their traditional lands in upstate New York. Of the 950,000 acres granted to the Haudenosaunee, less than 5 percent remains Six Nations land. Only 6,100 acres remain Mississaugas of the Credit land.

Course description

This is a theoretical physics course that aims to review the basics of theoretical mechanics, special relativity, and classical field theory, with the emphasis on geometrical notions and relativistic formalism, thus setting the stage for the forthcoming courses in Quantum Mechanics, and Quantum Field Theory in particular, as well as in General Relativity, String Theory, and Quantum Gravity. A rough plan of thecourse is the following:

1. The action principle & Lagrangian mechanics
2. Noether's first theorem
3. Hamiltonian mechanics
4. Poisson brackets, Canonical transformations
5. Hamiltonian flows and Symmetries in phase space
6. The Hamilton–Jacobi equation
7. Special relativity: kinematics
8. The Lorentz group and algebra
9. Relativistic notation
10. Relativistic mechanics
11. Electrodynamics and relativity
12. The Poisson–Laplace and wave equations, the Liénard-Wiechert potentials
13. Relativistic field theory
14. Stress energy tensor & angular momentum in electromagnetism

Course components

All lectures will be taught by Aldo. Tutorials will be held by Aldo with the help of Jackie, who will also correct your homework (under Aldo's supervision). Most tutorials will follow the standard problem-solving format, but with an emphasis on conceptual rather than computational matters.

Learning outcomes

By the end of this course students should be able to:

- translate between the Lagrangian and Hamiltonian formalisms of mechanics.
- provide a geometric account of time evolution and symmetry transformation in phase space by means of the Poisson brackets and their fundamental properties.
- explain the origin of the Hamilton-Jacobi equation and its relation to quantum mechanics.
- use Noether's first theorem in mechanics and field theory to derive conserved quantities (charges and currents) as well as the energy-momentum and angular-momentum tensors.
- compute dynamically relevant quantities using the relativistic notation, both in particle mechanics and field theory.
- derive the Lorentz-Fietzgerald length contraction and time dilation.
- use Green's theorem to solve the Poisson-Laplace and wave equations with the Green's function method, being able to choose the appropriate Green's function (propagator) for the application at hand.
- derive the Liénard-Wiechert potentials and explain their physical meaning.

Assessments

To complete the course, students will have to:

- Participate in the tutorials,
- *Timely* complete 3 homework assignments,
- Take the oral interview at the end of the course.

Note: Not only the interview, but also the in-class participation to the tutorials and the homework deadlines are strict requirements: if something comes up and you need a dispensation, you must contact Aldo as soon as possible.

Homework: homework deemed satisfactory will be handed back with comments. If the homework is deemed not satisfactory in certain respects, you will be provided feedback and asked to resubmit it by the following deadline. We will do our best to provide all feedback within a week of the submission deadline.

Interview format: at the beginning of your interview, you will be assigned one or two questions (depending on their format); you will then be given 20' on your own to prepare an answer to these questions, followed by a 30' interview where you will have 10-15' to present the answer you prepared followed by a series of follow-up questions. A complete list of the questions that you will be asked to prepare pre-interview is available in a separate document.

Homework submissions and deadlines

☞ Read this section carefully. The policy is new and former PSI students are probably not aware of its details. Feel free to contact me for any further clarification

You are expected to hand in your 3 homework assignments respectively by the following **deadlines**:

1. Monday September 18th
2. Monday September 25th
3. Monday October 2nd

This will be done via a **Dropbox submission link** provided on the Thinkific portal and on the homework question sheet. Email submissions are not accepted.

Note: the submission link will automatically close at 9PM of the submission date

Respecting these deadlines will allow you to optimally prepare for the interview and be done with the Classical Physics homework by the beginning of the following block.

However, we understand that this is a busy program and at times it will not be possible to respect these tight deadlines. For this reason, we have setup a late deadline system, to be used with moderation: for both your own and the TA's sake. The late deadline system works as follows:

If you are not finished with your homework by these dates, you are asked to submit what anyway what you have, specifying at the beginning of your copy that you need more time to complete the assignment. You can also specify whether you want or not feedback on what you have submitted until that point (this is useful if you feel "stuck", maybe not so much if you are just late).

Once you ask for an extension (with or without feedback), or if you are asked to resubmit, you will have 2 more weeks from the original deadline to resubmit your copy (**late deadlines**).

In the extreme circumstance that these 2 extra weeks have elapsed, and you are still not done with your homework, you will have to contact Dan or Angela with a formal request for extension. They will decide whether the conditions are met for this last extension, and in concert with Aldo will setup a final, **pass-or-fail deadline** (this will indicatively be 4 weeks past the original deadline). If a student does not complete the assignment by the pass/fail deadline (with any extensions) they will fail the course.

Further feedback

Aldo and Jackie will strive to give you regular feedback. Still, it could happen that you don't hear much from us: this is most likely because we think you are doing just fine. However, if you do have doubts or want to know more about how we think you are doing, do not hesitate to ask us!

Resources

The main reference for this course will be Aldo's lecture notes (please send him any typo you will find, and any kind of feedback/comment, e.g. about the lack of clarity of any given section). The lecture notes contain more details on the topic we will discuss than the live lectures could cover.

Roughly, each live lecture will attempt to cover one chapter of the lecture notes. You are invited to give a quick read to the relevant chapter before coming to the corresponding lecture.

For more see:

- Standard reference for virtually all the materials covered (albeit one that is a little dated, originally written in the 1950s): Landau & Lifshitz, Course of Theoretical Physics, vol 1 & 2, Pergamon Press (1975).
- The best book on electrodynamics ever written is (in my opinion) J.D. Jackson, Classical Electrodynamics, 3rd Edition, Wiley (1999). Its only issue is that it uses the "wrong" signature.

- Some material covered in this course is inspired by its treatment in S. Weinberg, The Quantum Theory of Fields, vol. 1, Cambridge (1995) -- I believe this will be your main reference for QFT 1.
- A fantastic, modern, reference on the mathematical aspects of Lagrangian, Hamiltonian, and Hamilton Jacobi mechanics is Marsden & Ratiu, Introduction to Mechanics and Symmetry, 2nd Edition, Springer (1999). The standard reference on this topic is however V.I. Arnold, Mathematical Methods of Classical Mechanics, 3rd Edition, Springer (1989) – a book originally written in the 1970s.
- I also enjoyed the historical account of Lanczos, The Variaitonal Principles of Mechanics, 4th Edition, Dover (1970).
- Beside these books, a couple of journal articles are quoted in the lecture notes.

Mental health resources

Information on mental health resources at Perimeter Institute can be found here.

Code of conduct

Students are expected to adhere to PI's code of conduct.

Accommodations

Accommodations for the various course components will be made according to PI's Accommodation Policy. Students can contact the instructor or People and Culture if accommodations are required.

Academic integrity

All students are expected to know, understand, and follow the academic integrity policies detailed on the University of Waterloo Academic Integrity website (https://uwaterloo.ca/academic-integrity/).