PHYS 304: Mechanics

Units: 4

Term—Day—Time:

- **Fall 2020**
- **Tuesdays and Thursdays from 8.00 am to 9.50 am**
- **Two 110 minutes classes per week, 13 weeks**

Location:

- **Online: https://usc.zoom.us/j/97702967446**

Instructor:

- **Dr. Marcin Abram**
- **e-mail: mjabram@usc.edu**

Teaching Assistant:

- **Chunyu Tan**
- **e-mail: chunyuta@usc.edu**

Students Hours (also known as Office Hours):

- **Two 60 minutes slots per week**
- **Tuesday 2-3 pm and Friday 10-11 am**
- **Online: https://usc.zoom.us/j/8934576028**
- **Everybody is welcome**
- **No appointment needed**

Course Description

Physics 304 is an intermediate-level course in classical mechanics, the study of the dynamics of macroscopic objects, which can range in size from a few microns to the scale of planets and stars. The USC prerequisites are Physics 151 or 161 and Math 245. We'll make heavy use of concepts from single-variable and multivariable calculus, as well as differential equations, right from the start. The goal is to build on ideas from introductory mechanics while developing a range of new math skills. The topics include free and driven oscillations, the calculus of variations, Lagrangian mechanics for free and constrained systems, Hamiltonian mechanics, rotational dynamics, general relativity and chaotic systems.

Learning Objectives

At the end of this course, you will be able to:

1. Describe (quantitatively and qualitatively) dynamics of macroscopic objects.
2. Describe physical systems using Lagrangian and Hamiltonian formulations of mechanics.
3. Apply single-variable and multivariable calculus to solve a range of classical physics problems, including free and driven oscillators, free and constrained systems of particles, systems in noninertial reference frames, etc.
4. Discuss modern advances in classical physics (e.g., nonlinear dynamical systems, chaos theory, etc.).

Prerequisite(s)

I have constructed the course with the understanding that you have completed (or you are familiar with the content of):

★ either PHYS 151 (Fundamentals of Physics I: Mechanics and Thermodynamics) or PHYS 161 (Advanced Principles of Physics I), and
★ MATH 245 (Mathematics of Physics and Engineering I).

Co-Requisite(s) or Concurrent Enrollment

None.

Recommended Preparation

To succeed with this class, review the information from:

★ Introduction to Physics (mostly the section devoted to mechanics; however, some basic information about electric and magnetic fields will be handy too).
★ Calculus (you should be able to solve single-variable and multivariable equations).
★ Mathematical Analysis (you should be able to solve simple integrals and linear differential equations).
★ Algebra (you should be fluent with complex numbers and matrix calculus).

Course Notes

This course will be comprised of:

- ★ lectures,
- ★ weekly quizzes (either qualitative questions or short, straightforward calculations),
- ★ weekly problem sets (mostly quantitative questions),
- ★ a student project (discussed below), and
- ★ a final exam.

The course will ordinarily be taken for a letter grade. Documents, including lecture notes, homework assignments, and additional readings, will be distributed online via the course Blackboard site.

Description and Assessment of Assignments

Weekly quizzes

Each Tuesday I will publish a short quiz (worth 5 points) on Blackboard. The questions will concern some basic ideas discussed in the class and/or the topics related to the recommended readings. There will be 12 quizzes in total. You will all have approximately 7 days to complete each quiz. As long as the quiz is open, you will be able to send multiple answers (the latest submitted answer will matter). The closing time for the quizzes is on Tuesdays at 8 am PT (Pacific Time). Specifically,

- ★ The *first* quiz closes on Tuesday, August 25, 2020 at 8 pm PT .
- ★ The *second* quiz closes on Tuesday, September 1, 2020 at 8 am PT.
- ★ ...
- ★ The *twelfth* quiz closes on Tuesday, November 10, 2020 at 8 am PT.

Weekly problem sets

Each Thursday I will publish a problem set. Typically, those questions will require you to write down solutions to various quantitative physical problems. Each problem set will be worth 10 points. There will be 12 problem sets in total. You will all have approximately 7 days to complete each problem set. The solutions should be sent in a pdf format (you can either write the solutions in LaTeX or you can write them by hand, scan the papers and create a pdf). The deadline for uploading the solutions is on Thursday at 8 am PT. Specifically,

- ★ The deadline for the *first* problem set is on Thursday, August 27, 2020 at 8 am PT
- ★ The deadline for the *second* problem set is on Thursday, September 3, 2020 at 8 am PT.
- ★ ...
- ★ The deadline for the *twelfth* problem set is on Thursday, November 12, 2020 at 8 am PT.

Note, that in those written assignments, the completeness and the clarity of your solution (your calculations or derivations) will matter as much as the final correct answer. Sending just a single final value (even if correct) is not enough. See the table below:

Grade Component	Below expectations (below 4 points)	Meets expectations (4-8 points)	Exceed expectations (9-10 points)
Completeness (50%)	Few questions are answered. Only some cases are considered (for example positive forces were examined, but the student considered neither negative forces nor the special case when F=0).	Most questions are answered. The most obvious cases are considered (for example non-zero forces are examined, but the student didn't consider a special case when F=0).	All questions are answered. All cases are considered.
Clarity (25%)	It is hard to follow the solutions. The solution has some major shortcuts and hidden assumptions. Steps of the calculations are not explained. In general, the author requires the reader to be *very* familiar with the content of PHYS 304 in order to understand the answer.	The teacher (or other professional physicists) can understand the solution but a non-expert might have some troubles to do so. The solution has some minor shortcuts or some non-explained assumptions. Not every step of calculations are explained, but it is still possible to follow the author's logic.	A non-expert (e.g., a fellow student) could understand the solutions. All concepts and used techniques are defined and explained. Whenever it is applicable, the solution is accompanied by illustrative plots that are explained and interpreted.
Validity (25%)	Major mistake in the calculations. The final value is incorrect.	Small mistake in the calculations (e.g., a wrong sign, a missing constant). The final answer is close to the correct value (e.g., by a small factor; twice too large or twice too small).	All calculations are correct. The final answer (value) is correct.

A Student Project

Your task is to:

- ★ prepare an article (limit of 10 pages) on one of the topics below.
- ★ Peer-review two articles prepared by your colleagues.
- ★ Address the comments that you received from your peers.
- ★ Record a short summary (2-3 minutes) of your work (either as a video-presentation or a narrated slideshow).

The objective of this assignment is to a) explore literature regarding modern topics in the field of classical mechanics, b) synthesize the acquired knowledge in the form of an article, c) write peer-review comments, d) respond to peer-review comments, e) summarize the main points in a form of a short presentation.

Projects Propositions (choose one):

- ❏ *(For those who like Physics)* Compare three formulations of classical mechanics: 1) Newtonian, 2) Lagrangian, and 3) Hamiltonian formulation. Discuss the context in which each formulation is the most likely to be used. Present examples of problems solved in each formalism. Discuss applications of each formalizm in other branches of physics (for example Hamiltonian formalism is really popular in Theoretical Quantum Physics).
- ❏ *(For those who like programming)* Describe solutions of classical nonlinear mechanical systems (a good starting point could be a driven damped pendulum; however, you are also encouraged to look at other systems). Using the programming language of your choice, visualize different solutions for the chosen system. Find the range of parameters that lead to stable and chaotic solutions. Characterize (and visualize) the chaotic solutions. Describe the role of the non-linearity for the existence of chaotic behavior.
- ❏ *(For those who like math)* Explore solutions to logistic equations. Plot the sequence of points generated by logistic equations for a range of parameters. For some values of the parameters, the solutions lead to chaotic behavior. Characterize the chaotic solutions and experimentally find (some) bifurcation points. Contrast your findings with the literature.
- ❏ *(For those who like astronomy)* Discuss the problem of three (or more) moving bodies in a vacuum. The bodies have a non-zero mass and interact with each other via the gravitational force. Discuss the possibility of making long-term predictions regarding the position of those bodies. Characterize if the orbits of those objects can be stable. Describe the chaotic behavior of the system. Contrast your findings with the precision to which we are able to predict the position of planets in our Solar System. Is our Solar System chaotic? With more than three bodies (for example with 5) even more interesting solutions are possible. As one possible direction (I don't want to limit you, only give some possible starting points) you might examine the "space invaders" concept (particles appearing from spatial infinity) illustrated for example in X. Xia, *The Existence of Noncollision Singularities in the N-Body Problem*, Annals of Mathematics **135**, 411-468 (1992).
- ❏ *(For those who like reading)* Compare different takes on the question if a Newtonian system is deterministic. Describe the "space invaders" concept and the "Norton's Dome" construction. Confront those examples with the statement that made Mark Wilson in *"Determinism and the Mystery of the Missing Physics"*, The British Journal for the Philosophy of Science **60**, 173–193 (2009). Express your own opinion. Are Newtonian systems deterministic or not?
- ❏ *(For those who don't like the above projects)* Modify the above propositions or propose your own project. Discuss your choice with the teacher.

Structure and Formatting:

The article should be submitted in PDF format (single-space text, standard margins and font size). If any numerical methods were used to visualize or to calculate some solutions, a link to a GitHub repository with relevant code, scripts, or notebooks (in case of Mathematica or Jupyter/Python) should be provided. If you are using numerical methods, you are free to use any language of your choice - as long as the code is clear and well commented (to give me a chance to understand what

you did). For those who decided to use numerical methods, the length of the paper can be shorter than the 10 pages (to make sure that the work load is balanced between different projects; after all, writing programs and debugging them takes time).

Steps:

1. Choose your topic.
2. Find relevant literature. Read about your topic.
3. Make a plan for your article. Decide which aspects you are going to describe and which leave out. After all, you have limited space (only up to 10 pages including figures and bibliography).
4. Complete the necessary calculations (depending on your topic, there will be some numerical or analytical calculations). Prepare plots and figures.
5. Write your article.
6. Proofread your article. Make sure that all key terms are defined. Make sure that the article has the right structure (introduction, the main content, summary, bibliography).
7. Prepare a pdf of your article. Make sure that the number of pages is below or equal to 10 pages. Make sure that your name and the title are visible on the first page.
8. Submit the pdf using a Blackboard **by Friday, October 9, not later than 1.00 pm**.
9. Choose two articles prepared by your peers. Read those articles. Using the Blackboard forum, give each author two suggestions that they can use to improve their papers. To make sure that each person will receive an equal number of comments, only the first two comments under each project will count for credit (though you are still welcome to give more than two comments if you wish, they will just not count as extra credit). You should complete this action **by Friday, October 23, not later than 1.00 pm**.
10. Read the suggestions you received from your peers. Address them (either incorporate the suggested changes or challenge them, describing why you think those changes would not improve the quality of your article).
11. Record a short summary of your work (2-3 minutes) of your work (either as a video-presentation or a narrated slideshow).
12. Submit both your video and the improved version of your article **by Friday, November 6 at 1.00 pm**.

Additional Notes:

You are free to use any sources. Just remember to cite the books or articles you used. If you decided to use quotes, remember to cite them correctly. Plagiarism is a major violation of the university academic integrity standards and will be reported to the responsible authorities at USC.

When you write your article, think about your audience. Your main audience is not the teacher, but rather your peers. Write in a way that your peers can understand the concepts that you describe. You can assume certain fluency in using mathematical language in your readers, but do not assume that the people necessarily have any prior familiarity with the topic of your paper.

Final Exam

You will be asked to solve similar problems as those that are included in the weekly problem sets. The official date for our exam is Tuesday, November 17 at 8-10 a.m., see https://classes.usc.edu/term-20203/finals/.

Many of you might be in different timezones. In order to accommodate depending on demand, I may decide at a later date to change the exam from a synchronous (2 hour) exam to an asynchronous "take-home" and "open-book" exam, where you have either 24 or 48 hours to solve a few open-ended questions.

Technological Proficiency and Hardware/Software Required

None required.

Note, that some students' projects might require a basic knowledge of a programming language (it could be one of many: R, Python, Julia, Java or C++) or basic proficiency in mathematical software (e.g., Mathematica, MATLAB). However, this is optional. There are other projects that require no programming skills whatsoever (where all solutions can be solved analytically or using standard approximation techniques). So if you do not like programming, you have options to avoid tasks that require numerical calculations.

Required Readings and Supplementary Materials

We will mainly follow John R. Taylor, *Classical Mechanics* (2005) and (partially) L. D. Landau and E. M. Lifshitz, *Mechanics* (1976).

Note, that the digital version of L. D. Landau and E. M. Lifshitz, *Mechanics* (1976) is available for *free* via the USC library (go to https://libraries.usc.edu/, search for *Landau Mechanics*, enter the Elsevier ScienceDirect Books Complete and download chapters of the book).

Grading Breakdown

Course Element	Points
Weekly Quizzes(12)	60 (=12x5)
Weekly Problem Sets (12)	120 (=12x10)
A Student Project	100
Final Exam	100
TOTAL	**380**

Grading Scale

Course final grades will be determined using the following scale.

Final Grade	% of Total Points	Number of Total Points (rounded down)
A	[90% - 100%]	342-380
A-	[85% - 90%)	323-341
B+	[82% - 85%)	311-322
B	[78% - 82%)	296-310
B-	[75% - 78%)	285-295
C+	[72% - 75%)	273-284
C	[68% - 72%)	258-272
C-	[65% - 68%)	247-257
D+	[62% - 65%)	235-246
D	[58% - 62%)	220-234
D-	[55% - 58%)	209-219
F	[0% - 55%)	0-208

Assignment Submission Policy

Late solutions to quizzes or problem set solutions will not be accepted. Note, that the grading brackets in the table above are lower than in other courses. It means that you can be late (or omit) two weekly quizzes (2x5 points) and two problems sets (2x10 points) and still be able to collect up to 350 points and receive A.

Grading Timeline

I will make every effort to grade and return homework within one week after it is received. Homework solutions will be either described during the lectures or posted on Blackboard.

Additional Policies

Names, Gender:
If you have a name and/or pronouns that differ from those in your official USC records, please let me know.

If I am mispronouncing your name, please correct me. I am highly empathetic on this point because my given name (Marcin) and is pronounced [ˈmartʂin] using the International Phonetic Alphabet and often mispronounced.

Mental Health:
If you feel that experiences outside of class are impacting your course performance, please come and talk to me. If you would rather consult someone outside the classroom, USC Counseling and Mental Health (https://studenthealth.usc.edu/counseling/) and Academic Counseling (https://undergrad.usc.edu/services/counseling/) are great resources.

Equity and Diversity and Title IX:
The Office of Equity and Diversity (OED) and the USC Title IX Office works with faculty, staff, visitors, applicants, and students around issues of protected class: https://eeotix.usc.edu/. Incidents of bias, hate crimes and microaggressions can be confidentially reported to: https://studentaffairs.usc.edu/bias-assessment-response-support/.

Accomodations:
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me as early in the semester as possible. If you have registered accommodations with the Disability Services and Programs Office (https://dsp.usc.edu/), please communicate those to me at your earliest convenience so we can discuss your needs in this course. For those on or near campus, DSP is located in STU 301 and is open 8:30 a.m.5:00 p.m, Monday through Friday. They can be contacted online or by phone at (213) 740-0776 (Phone), (213) 740-6948 (TDD only), or via email, ability@usc.edu.

Statement for observance of religious holidays
USC's policy grants students excused absences from class to observe religious holidays: http://orl.usc.edu/life/calendar/absences/. In this case, please contact your instructor in advance to agree on alternative course requirements.

Zoom Classroom Policies
The pandemic has upended our collective and individual lives. Logistically speaking, we are spread across multiple time zones, and I can only expect attendance for students for whom our course time falls within reasonable learning hours in their time zone, i.e., between 7:00 AM and 10:00 PM, see https://www.provost.usc.edu/policy-and-guidelines-for-asynchronous-learning/ (the section about the Class Participation and Attendance in Synchronous Sessions). If you are in a timezone, that prevents you from attending the classes (or if you have other situations like family responsibilities, e.g. taking care of children or dependents, that prevent you from attending the synchronous sessions), please let me know as soon as possible.

Camera Policy
The official Camera Policy can be found at https://www.provost.usc.edu/policy-and-guidelines-for-asynchronous-learning/.

Seeing your faces can help me to gauge if the tempo of the lectures is adequate. Therefore, it would be a great help if you keep your cameras turned on. However, I acknowledge that there might be many reasons why you might wish to keep privacy. You might also face bandwidth limitations that prevent you from using the camera. I encourage the use of virtual backgrounds and earphones/headsets whenever it is possible to mitigate privacy concerns.

Course Schedule: A Weekly Breakdown

	Topics	Readings	Deliverables
Week 1 August 18 August 20	Introduction, Newton's Law of Motion, Projectiles, Air Resistance, Motion in Uniform Magnetic and Electric Field.	Taylor Chapters 1 and 2.	
Week 2 August 25 August 27	Momentum, Angular Momentum, Energy, Conservation Laws.	Taylor Chapters 3 and 4.	Quiz 1 (Aug 25) Problem Set 1 (Aug 27)
Week 3 September 1 September 3	Oscillations, Driven and Damped Oscillators, Resonance, Fourier Series.	Taylor Chapter 5.	Quiz 2 (Sep 1) Problem Set 2 (Sep 3)
Week 4 September 8 September 10	Calculus of Variation, the Euler-Lagrange Equations, Lagrange's Equations with Constraints.	Taylor Chapters 6 and 7. Landau Chapters 1, 2 and 3.	Quiz 3 (Sep 8) Problem Set 3 (Sep 10)
Week 5 September 15 September 17	Two-Body Central-Force Problem, Reduced Mass, Equation of the Orbit, Mechanics in Noninertial Frames, Coriolis Force.	Taylor Chapters 8 and 9.	Quiz 4 (Sep 15) Problem Set 4 (Sep 17)
Week 6 September 22 September 24	Collision Theory, Scattering.	Taylor Chapter 14. Landau Chapter 4.	Quiz 5 (Sep 22) Problem Set 5 (Sep 24)
Week 7 September 29 October 1	Coupled Oscillators and Normal Modes. Small oscillations.	Taylor Chapter 11. Landau Chapter 5.	Quiz 6 (Sep 29) Problem Set 6 (Oct 1)
Week 8 October 6 October 8	Nonlinear Systems and Chaos Theory. Bifurcation Diagram. The Logistic Map. *(Midterm Grading Period begins)*	Taylor Chapter 12.	Quiz 7 (Oct 6) Problem Set 7 (Oct 8) Student Project (Oct 9)
Week 9 October 13 October 15	Motion of a Rigid Body, Principal Axes of Inertia, Euler's Equations and Euler Angles.	Taylor Chapter 10. Landau Chapter 6.	Quiz 8 (Oct 13) Problem Set 8 (Oct 15)
Week 10 October 20 October 22	Hamiltonian Mechanics. Applications of Lagrange's Equations and Hamiltonian's equations.	Taylor Chapter 13. Landau Chapter 7.	Quiz 9 (Oct 20) Problem Set 9 (Oct 22) Peer Reviews (Oct 23)
Week 11 October 27 October 29	Special Relativity.	Taylor Chapter 15.	Quiz 10 (Oct 27) Problem Set 10 (Oct 29)
Week 12 November 3 November 5	Continuum Mechanics, the wave equation, stress tensor, Hooke's Law. *(Midterm Grading Period ends)*	Taylor Chapter 16.	Quiz 11 (Nov 3) Problem Set 11 (Nov 5) Final Paper (Nov 6) Final Presentation (Nov 6)
Week 13 November 10 November 12	A buffer week (in a case we had a delay). Revisions.		Quiz 12 (Nov 10) Problem Set 12 (Nov 12)
FINAL November 17	Official Examination Day is Tuesday, November 17 at 8-10 a.m. *(Final Grading Period begins)*		

Note, that the Midterm Grading Period is 10/5 - 11/6 and the Final Grading Period is 11/17 - 12/10.

Student Hours (also known as Office Hours)

I will host two 60 minutes meetings per week, on Tuesday at 2-3 pm and on Friday at 10-11 am. You can access them via Zoom: https://usc.zoom.us/j/8934576028. Those Student Hours (also known as Office Hours) are a dedicated time, when you can come to ask questions and resolve confusion about course material, as well as to discuss career and educational goals as they relate to this course.

No appointment needed, however if you sent me an email a day earlier, announcing a type question you have, I might be able to prepare a better answer for you in advance.

If you have any sensitive questions, you can also contact me via mail, mjabram@usc.edu and we can schedule an 1-on-1 appointment via Zoom outside the student hours period.

Contact for Support Systems

Support Systems

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
uscsa.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.