SFSU Physics 330: Analytic Mechanics I

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Lectures & Office Hours

Lectures: MWF 12:00-12:50, Online via Zoom
Office Hours: WF 13:00-14:30, Online via Zoom

Quick note on e-mail contact

So that I can identify and respond to e-mails from you expeditiously, please put [PHYS330] at the beginning of the subject line. I will respond to emails within 48 hours.

Course Website

`ilearn.sfsu.edu` – Please check frequently for new announcements, updates to the syllabus & schedule and links to additional learning resources.

Course Scope

Physics 330 is an intermediate course in "classical" Newtonian mechanics. In the first part of the course, we quickly review the fundamentals (kinematics, Newton's Laws of Motion, gravitation, oscillatory motion, work & energy, linear momentum, angular momentum & torque), but at a more mathematically sophisticated level, making full use of vector calculus, linear algebra, and ordinary differential equations. In the second part of the course, we cover new topics such as central-force motion, calculus of variations, Lagrangian dynamics, and Hamiltonian dynamics.

Course Content

Kinematics [1 week]: Derivatives of vectors applied to position, velocity and acceleration; general motion in 3D and the Frenet-Serret formulae; motion in polar, cylindrical & spherical coordinates.

Particle Dynamics [3 weeks]: Newton's Laws of Motion; gravitation; force problems with constraints; variable tension along ropes with mass; position-dependent forces in 1D; velocity-dependent drag forces; damped linear oscillations; forced oscillations and resonance; coupled oscillations.

Work & Energy [2 week]: Work-kinetic energy theorem; line integrals; Stokes's theorem and conservative forces; potential energy functions; potential energy of systems of particles, small oscillations around stable equilibria.

Linear & Angular Momentum [2 weeks]: Impulse-momentum theorem; conservation of momentum for systems of particles; momentum flow problems and the rocket equation; angular momentum of point particles and extended objects; inertia tensor; planar motion; rigid body motion; precession.

Calculus of Variations [1 week]: Derivation of Euler-Lagrange equations; application to minimization problems in physics.

Lagrangian Dynamics [3 weeks]: Generalized coordinates; virtual work & d'Alembert's Principle; Hamilton's Principle of Least Action and Lagrange's equations; application to problems with static and moving constraints; ignorable coordinates and conservation laws.

Central Forces [2 weeks]: Equations of motion; conservation of energy and angular momentum; exact solution to 2-body problem; Kepler's Laws; perturbations to circular orbits; changing orbits.

Hamiltonian Dynamics [1 week]: Application of Hamilton's equations; cyclic coordinates; Noether's theorem; Liouville's theorem.

Course Format & Teaching Methods

This is a lecture course. During class time, instructor will present theory and outline applications. Student questions are strongly encouraged throughout class time. Occasionally, students will work on in-class activities in groups.

Course Objectives

(1) To analyze real-world systems in mechanics, to make valid approximations and develop simplified models of such systems, and then to employ Newton's Laws of Motion, Lagrange's equations or Hamilton's equations to determine a system's temporal evolution.
(2) To understand and apply the fundamental conservation principles of classical physics (energy, linear momentum, angular momentum) and relate them to underlying symmetries of nature.
(3) To develop and apply mathematical tools (vector calculus, linear algebra, differential equations, calculus of variations, numerical/computational methods) to solve problems in classical mechanics.

Student Learning Outcomes

(1) Describe motion with position, velocity and acceleration vectors in rectilinear, cylindrical polar, and spherical coordinate systems.
(2) Show that the acceleration vector can be represented with two components: a component tangent to the trajectory that is associated with a change of speed, and a component perpendicular to the tangent, pointing toward the center of curvature, that is associated with a change of direction of motion.
(3) Apply Newton's Laws of Motion to compute motion of particles or systems of particles subject to the following forces: normal force, tension, friction, gravity, pressure, drag force, spring force.
(4) Apply the principle of conservation of linear momentum to compute motion for systems of particles in which both mass and momentum change or flow (e.g. the rocket equation, growing raindrop).
(5) Apply the principle of conservation of energy to compute motion of particles or systems of particles subject to only conservative forces. (e.g. motion of rocket in non-uniform gravitational field).
(6) Construct and interpret potential energy vs. position graphs and describe corresponding motions.
(7) State the mathematical properties for conservative forces and describe how they are related to each other: (i) work done around closed loops is zero for conservative forces; (ii) conservative forces are curl-free; (iii) work done by conservative forces is path independent; (iv) conservative forces can be expressed as a gradient of a potential energy function; (v) mechanical energy of a system is conserved if all particles are subject to only conservative forces.
(8) Write an integral-type functional for various physical quantities (e.g. arc length of a curve on a surface, light travel time in a refractive medium, action of a dynamical system) and then employ the calculus of variations to determine functions that make the functional stationary.
(9) Calculate the temporal evolution of a system of particles using Lagrange's equations.
(10) Calculate the temporal evolution of a system of particles using Hamilton's equations.
(11) Employ a perturbation analysis to find frequencies of small oscillations around stable equilibria.
(12) Relate conservation principles with underlying symmetries: (i) conservation of linear momentum is associated with translational invariance; (ii) conservation of angular momentum is associated with rotational invariance; (iii) and conservation of energy is associated with time invariance.
(13) Compute the orbit of a mass subject to a central force. Describe how conserved quantities (energy and angular momentum) are related to the shape of orbits.
(14) Compute the precession rate of a spinning top and its analogues by equating the rate of change of rotating angular momentum and torque.

Required Learning Materials

Recommended texts for reference include "Classical Mechanics" by John E. Taylor or "Classical Mechanics" by R. Douglas Gregory. An excellent, free, online book for reference is "Newtonian Dynamics" by Prof. Richard Fitzpatrick (U. Texas, Austin): `http://farside.ph.utexas.edu/teaching/336k/Newton/index.html`

Prerequisites & Corequisites

(1) Math 228 (Calculus III), Math 245 (Elementary Differential Equations & Linear Algebra), or for a more rigorous treatment, both Math 325 (Linear Algebra) & Math 376 (O.D.E.s).
(2) Physics 220 & 230 (Introductory mechanics and introductory electromagnetism).

Assignment of Grades

Grades will be determined according to the following rubric:

Weekly Homework:	50%
Best 8 of 10 Written Quizzes:	40%
Best 2 of 3 Oral Quizzes:	10%

Letter grades will assigned according to the following scheme:

	A: 90.0% – 100.0%	A-: 85.0% – 89.9%	
B+: 80.0% – 84.9%	B: 75.0% – 79.9%	B-: 70.0% – 74.9%	
C+: 65.0% – 69.9%	C: 60.0% – 64.9%	C-: 55.0% – 59.9%	
D+: 50.0% – 54.9%	D: 45.0% – 49.9%	D-: 40.0% – 44.9%	F: 00.0% – 39.9%

I may, at my discretion, curve upwards if I feel my exams were too difficult and/or the class performed above my expectations despite actual course scores. I will never curve downwards.

Homework

You cannot learn physics solely from lectures. You must work through many problems, seeing how the theoretical concepts discussed in lecture apply in various contexts. Homework is an integral part of the learning process; how serious you take the homework will ultimately determine how much you will understand physics and how well you will do in the course overall. There will be approximately one homework assignment per week. Most problems will require analytic solutions, however there will usually be one problem per assignment that will involve graphing and numerical solution with computer software such as MATLAB, Mathematica, or Python.

You can turn in one assignment up to one week late for any or no reason, with no penalty. After that, unexcused late homework assignments will be penalized 25% per week (including Thanksgiving week). All requests for excused lateness will require external documentation.

Policy on Collaboration & Academic Integrity

You are strongly encouraged to discuss course material with your fellow classmates. When working on homework, first try to solve the problems on your own. Struggle. Struggle some more. If you get stuck, feel free to discuss overall methods and approaches with your classmates, but not the details! Your written solutions should be solely your own, and should be written-up in isolation from your fellow classmates. Copying is strictly prohibited. Using the internet to download solutions manuals is also considered cheating. Cheating via any method on exams will result in a grade of zero on that exam and being reported to the department chair and/or college dean for possible discipline. Please see the official plagiarism and academic ethics policies for the Department of Physics & Astronomy at: `http://www.physics.sfsu.edu/Academics/Policies.html`

Add, Drop, Withdrawal & Repeat Policy

The add/drop deadline is Monday, September 14. You can drop yourself from the class online without any penalty and without any record, for any reason. After September 14, students must petition for an official withdrawal. **The withdrawal deadline is Monday, November 16.** Documents must be provided to support the petition to withdraw. If the petition is approved, the designation "W" will appear on the transcript. Students are only allowed to repeat a class once at SFSU. Note that designations of W, WU, NC count toward this limit.

Expected Code of Conduct

Classroom discussion and participation are strongly encouraged. However, please refrain from unrelated chatter. Also, please remember to place cell phones and other electronic communication devices on silent or vibration mode so as not to distract your fellow classmates. If you must arrive late or leave early, please sit toward the back of the room near the doors so as to minimize disruption.

Disability Access

Students with disabilities who need reasonable accommodations are encouraged to contact me early in the semester. The Disability Programs and Resource Center is available to facilitate the reasonable accommodations process. The DPRC, located in Student Services Building 110, can be reached by phone at 415-338-2472 (voice/TTY) or by e-mail at `dprc@sfsu.edu`.

Religious Holidays

The faculty of SFSU shall accommodate students wishing to observe religious holidays when such observances require students to be absent from class activities. It is the responsibility of the student to inform the instructor, in writing, about such holidays during the first two weeks of the class each semester. It is the responsibility of the instructor to make every reasonable effort to honor the student request without penalty, and of the student to make up the work missed.

Student Disclosures of Sexual Violence

SF State fosters a campus free of sexual violence including sexual harassment, domestic violence, dating violence, stalking, and/or any form of sex or gender discrimination. If you disclose a personal experience as an SF State student, the course instructor is required to notify the Dean of Students. To disclose any such violence confidentially, contact:

The SAFE Place - (415) 338-2208; `http://www.sfsu.edu/~safe_plc/`
Counseling and Psychological Services Center - (415) 338-2208; `http://psyservs.sfsu.edu/`
For more information on your rights and available resources - `http://titleix.sfsu.edu`

Recording of Lectures & Privacy

As the instructor of this course, I will be using Zoom to record our class sessions/lectures for the sole purpose of supporting student learning. To maintain privacy, I will post links to the recordings in our campus's learning management system iLearn to limit access to the members of this course only. It is expected that students also refrain from sharing these recordings outside the context of this course. Students who have privacy concerns may turn off their video and/or change their user name for the duration of the session.

At the beginning of each recorded Zoom session, you will be prompted to acknowledge that the session is being recorded and that you would like to continue in the session. These recordings will be retained for one semester beyond the end of this course, to support students who may have received an incomplete grade, and will then be deleted. As always, any student who has concerns about these recordings may speak with me at any time during the semester to discuss your concerns.

COVID-19 and Our Campus

Your health and safety are our paramount concerns at SF State. During the COVD-19 pandemic, every member of our Gator community is expected to do their part in keeping fellow students, faculty, and staff safe and well. Feeling well and safe will support you in focusing on your academic success. For the limited number of classes meeting face-to-face, in-person class attendance is an option, but not a requirement. Students will be allowed to take such classes virtually or be provided with other remote options for course completion. Please consult the campus plan website (`https://news.sfsu.edu/campus-plan`) for up-to-date information. For all students attending in-person, the following are required:

- Wear a face covering when around other people outside of those in your household.
- Stay at least 6 feet physically distant from people outside the members of your household.
- Stay home if you have one or more symptoms of COVID-19 (Please check in with the SF DPH website for the most up-to-date symptoms & testing: `https://www.sfcdcp.org/wp-content/uploads/2020/04/GetTestedSF-Eng-052920.pdf`).
- If you would like to discuss reasonable accommodations based on disability related to COVID-19, please contact the Disability Programs & Resource Center: `dprc@sfsu.edu`.

Information is changing rapidly, as our health professionals, scholars, and researchers are learning more about COVID-19, and as such, we encourage you to frequently check your San Francisco State University email account and `https://news.sfsu.edu/campus-plan/students-families` for the most current information.

- You are encouraged to keep your emergency information updated on Campus Solutions in order to receive campus emergency alerts: `https://upd.sfsu.edu/ENSFAQ`.
- You are also encouraged to provide your contact information to receive city of SF emergency alerts, including COVID-19 updates and instructions for public safety: `https://sfdem.org/get-city-alerts`.
- If you have any questions regarding COVID-19 or your own health during this time, please reach out to Student Health Services: `https://health.sfsu.edu`.
- If you are feeling overwhelmed, you are encouraged to connect with our on-campus health professionals in Counseling & Psychological Services: `https://caps.sfsu.edu`.
- If you are looking for education on how to keep yourself and your loved ones healthy, then reach out to our Health Promotion & Wellness Team: `https://wellness.sfsu.edu`.