

PHY 401 CLASSICAL MECHANICS

Instructor: Dr. Romulo Ochoa
Science Complex - P132
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Office Hours: Tuesdays 1:30 p.m. – 3:00 p.m.
Wednesdays 1:30 p.m. -3:00 p.m.

Course Description

Newtonian mechanics is studied rigorously using advanced mathematical and numerical techniques. Topics treated include kinematics, dynamics, harmonic oscillations, central forces, many particle systems, rigid bodies, Lagrangians, and Hamiltonians. Scientific programming is used extensively in problem solving.

Course Materials

Text: S.T. Thornton and J.B. Marion, **Classical Dynamics of Particles and Systems**, 5th Edition, Thomson/Brooks Cole, 2004

Course Requirements

Class attendance, completion of homework associated with each chapter, a computer program, two tests, and a final exam.

Course Goals

1. To provide a foundation in classical mechanics necessary for further study in science, engineering, and technology.

Learning Objectives:

- 1.1. Develop an understanding of Newton's Laws.
 - 1.2. Students will be able to identify the forces acting on a system or object of interest and how they will influence the motion of the system.
 - 1.3. Students will be able to recognize and identify conserved quantities, such as linear momentum and energy, in physical events.
 - 1.4. Develop an understanding of Lagrangians and the scope of their applications.
 - 1.5. Students will be able to work with different coordinate systems and frames of reference.
2. Students will be able to solve differential equations relevant to physical problems.

Learning Objectives:

- 2.1. Students will set up and solve second order differential equations of a single variable.
- 2.2. Students will be able to use basic techniques from linear algebra, such as multiplying matrices and finding eigenvectors and eigenfunctions.
- 2.3. Students will learn to approximate functions using Taylor and Fourier series.

3. To contribute to the development of the student's thinking process through the understanding of the theory and application of this knowledge to the solution of practical problems.

Learning Objectives:

- 3.1. Identify the important variables in any given physical problem.
 - 3.2. Develop an appropriate strategy for solving physical problems using fundamental principles rather than secondary formulas.
 - 3.3. Successfully apply the appropriate mathematical methods to implement your solution.
 - 3.4. Evaluate your solutions to determine if they are physically reasonable.
 - 3.5. Develop spatial reasoning in three dimensions.
4. To engage in productive communication and collaboration with peers.

Learning Objectives:

- 4.1. Contribute productively to group discussions about physical phenomena and problems.
- 4.2. Clearly articulate their ideas about how the natural world behaves.
- 4.3. Use scientific reasoning and argumentation to defend their ideas against competing ideas.
- 4.4. Explain physical phenomena and mechanisms using both formal and informal language, as well as graphical, pictorial, mathematical, or other representations.

Course Outline

1. Newtonian Mechanics for a Single Particle (Ch. 2)
Newton's laws and inertial systems. Simple applications of Newton's laws, including constant applied forces, position-dependent forces, time-dependent forces and velocity-dependent forces, conservation theorems.
Homework 1, Part 1: Additional problems HW 1
Part 2: 2.3, 2.6, 2.7, 2.9, 2.12, 2.15, 2.23, 2.29, 2.39.
2. Oscillations (Ch. 3)
Linear restoring force: Harmonic motion. Damped harmonic and forced harmonic motion. Resonance. Introduction to chaotic motion.
Homework 2: 3.6, 3.10, 3.15, 3.20, 3.40, 3.44 and additional problems HW 2.
3. Lagrangian and Hamiltonian Mechanics (Ch. 6 and 7)
Euler equation and calculus of variations. Hamilton's variational principle. Generalized coordinates. Lagrange's equations of motion for conservative systems. Generalized momenta. Ignorable coordinates. Forces of constraint. Lagrange multipliers. Generalized forces. Hamilton's equations.
Homework 3: 7.3, 7.4, 7.5, 7.12, 7.14, 7.15, 7.17, 7.22, 7.24, 7.26, 7.28.
4. Mechanics of Rigid Bodies (Ch. 11)

Center of mass of a rigid body. Rotation about a fixed axis. Calculation of moment of inertia. Angular momentum. The physical pendulum. Laminar motion of a rigid body. Center of percussion. Eulerian angles.

Homework 4:

5. Noninertial Reference Systems (Ch. 10)

Accelerated coordinate systems and inertial forces. Rotating coordinate systems. Dynamics of a particle in a rotating coordinate system. Effects of Earth's rotation. The Foucault pendulum. Homework 6: 10.3, 10.6, 10.9, 10.18, 10.20, and 10.22.

6. Gravitation and Central Forces (Ch. 5 and 8)

Gravitational force between a uniform sphere and a particle. Potential energy in a gravitational field. Kepler's laws of planetary motion. Energy equation of an orbit in a central field. Orbital energies in an inverse-square field. Effective potential. Orbital transfers: gravitational boost and braking.

Homework 4: 5.4, 5.7, 5.15, 8.5, 8.10, 8.14, 8.25, 8.28 and additional problems HW 4

IV. Assessment of Student Performance

1. Tests (35 points)

2. Final exam (32 points)

3. Homework problems (20 points)

Late homework will not be accepted. Homework should be handed in an ordered and neat presentation; points will be deducted for lack of these.

4. Computer programs (10 points)

5. FCI, Clicker, and class participation (3 points)

| Grading Scale | |
|---------------|--------------|
| Final Score | Letter Grade |
| 92.5 – 100 | A |
| 89.5 – 92.4 | A- |
| 86.5 – 89.4 | B+ |
| 82.5 – 86.4 | B |
| 79.5 – 82.4 | B- |
| 76.5 – 79.4 | C+ |
| 72.5 – 76.4 | C |
| 69.5 – 72.4 | C- |
| 66.5 – 69.4 | D+ |
| 59.5 – 66.4 | D |
| 0 – 59.4 | F |

Exam or Test Absences Policy

I. Final Exam: The final exam schedule is known well in advance. Serious personal illness and death in immediate family will be the only acceptable excuses. All students must follow the general guidelines stated below. All excused students must take their make-up final exam

before 2:00 PM on the last day of the final exams, or they will receive an incomplete (I) or an F. It is the student's responsibility to request the make-up and provide a timely and acceptable proof.

II. Tests: You should make every effort to take the test at its scheduled date. If you cannot: You must **inform** the instructor about the nature of your absence before the missed test (for non-emergency absences) or within 24 hours after the missed test (for emergency absences); By the following class period you must show the instructor (or arrange to be shown) a **proof** that the absence is excusable; it is the student's responsibility to contact the instructor in a timely manner and provide an acceptable excuse.

III. Excuses:

Non-acceptable: Travel plans, weddings, lack of preparation, busy schedules; too many other obligations, assignments, or tests; job interviews, doctor's appointments or any other engagements or appointments that can be scheduled at different times, and alike, **will not be accepted** and the student will receive zero points for the test - **no exceptions**. The test dates are known ahead of time, so please plan accordingly.

Acceptable: Personal illness, death in one's family, and alike.

IV. Taking the Make-Up:

A student will be allowed to take a make-up only for an excused absence;

Unless otherwise stated in writing by her/his physician, s/he must take the make-up **within seven days** of the missed examination.

If the student fails to inform the instructor, does not provide an acceptable proof, or does not take the make-up in a timely manner, s/he will be given zero.

The make-ups will be **different** from regular examination, so **timely notification** of the instructor is essential.

Fourth Hour:

In this class, the deep learning outcomes associated with TCNJ's 4th hour are accomplished by a series of rigorous educational assignments that extend beyond the typical scheduled class time. These include activities such as out-of-class problem sets, and out-of-class online learning activities such as video lectures and reading assignments.

Additional Resources

Arya, A. P., "Introduction to Classical Mechanics," 2nd Ed., Prentice Hall, 1998.

Fowles, G. R. and Cassiday, G. L., Analytical Mechanics, 7th Ed., Thomson Brooks/Cole, 2005.

Serway, R. A., "Physics for Scientists and Engineers," 9th Ed., Thomson-Brooks/Cole, 2016.

Spiegel, M. R., "Theoretical Mechanics," Schaum's Outline Series, McGraw Hill, 1992.

Taylor, J. R., "Classical Mechanics," University Science Books, 2005.

Walker, J. "Halliday and Resnick Fundamentals of Physics," 10th Ed., J. Wiley & Sons, 2013. Young,

H. D. and Freedman, "University Physics," 15th Ed., Pearson/Addison-Wesley, 2020.

SELECTED TCNJ POLICIES

Final Examinations

The final exam is not scheduled until the middle of the semester. Therefore, do not plan on any travel until after the last day of the exam period. TCNJ's final examination policy is available on the web:

<http://policies.tcnj.edu/policies/digest.php?docId=9396>

Attendance

Every student is expected to participate in each of his/her courses through regular attendance at all class sessions. It is further expected that every student will be present, on time, and prepared to participate when scheduled class sessions begin. While attendance itself is not used as a criterion for academic evaluations, grading in this course is based on participation in quizzes to be given at the beginning of several classes. No make-ups or extensions will be given unless a student has a genuine emergency. If a student misses an exam or assignment deadline, they must contact the instructor within 36 hours to explain the situation; otherwise the student will earn a zero for that exam or assignment.

Students who must miss classes due to participation in a field trip, athletic event, or other official college function or for a religious holiday should arrange with their instructors for such class absences well in advance. In every instance, however, the student has the responsibility to initiate arrangements for makeup work.

TCNJ's full attendance policy is available at: <http://policies.tcnj.edu/policies/digest.php?docId=9134>

Academic Integrity Policy

Academic dishonesty is any attempt by the student to gain academic advantage through dishonest means, to submit, as his or her own, work which has not been done by him/her or to give improper aid to another student in the completion of an assignment. Such dishonesty would include, but is not limited to: submitting as his/her own a project, paper, problem set, report, test, or speech copied from, partially copied, or paraphrased from the work of another (whether the source is printed, under copyright, or in manuscript form). Credit must be given for words quoted or paraphrased. The rules apply to any academic dishonesty, whether the work is graded or ungraded, group or individual, written or oral.

TCNJ's academic integrity policy is available at:

<http://policies.tcnj.edu/policies/digest.php?docId=9394>

COMMITMENT TO DIVERSITY, EQUITY, INCLUSION, ACCESS AND BELONGING “The TCNJ community is composed of people with diverse backgrounds, perspectives, and experiences, and the college is committed to diversity, equity, inclusion, access and belonging. The college's Campus Diversity Statement can be viewed here: <https://diversity.tcnj.edu/campus-diversity-statement/>.”

CLASSROOM ENVIRONMENT AND COMMITMENT TO STUDENT SUCCESS, SAFETY AND WELL-BEING “The TCNJ community is dedicated to the success, safety and well-being of each student. TCNJ strictly follows key policies that govern all TCNJ community members rights and responsibilities in and out of the classroom. In addition, TCNJ has established several student support offices that can provide the support and resources to help students achieve their personal and professional goals and to promote health and well-being. You can find more information about these policies and resources at the “TCNJ Student Support Resources and Classroom Policies” webpage here:

<https://academicaffairs.tcnj.edu/tcnj-syllabus-resources/>.

Students who anticipate and/or experience barriers in this course are encouraged to contact the instructor as early in the semester as possible. The Accessibility Resource Center (ARC) is available to facilitate the removal of barriers and to ensure reasonable accommodations. For more information about ARC, please visit: <https://arc.tenj.edu/>.”