Intermediate Classical Mechanics

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Course Syllabus

1 Course Description

This course is designed for the enthusiastic high school students who wish to explore exciting topics in classical mechanics beyond conventional high school topics. We will start by reviewing the very basic ideas of kinematics and dynamics such as Newton's laws of motion, momentum, and energy. We will conclude with the advanced theoretical topics of Hamiltonian and Lagrangian dynamics. In between, we will study examples from central forces, non-inertial reference frames, gyroscopic motion, and fluid dynamics. Along the way, we will emphasize both theory and applications so that students can appreciate the intricate relationship between the two prominent directions of current cutting-edge physics research.

Prerequisites: We will use basic one-variable calculus extensively in this course. Thus, it is expected that students taking this class know differentiation and integration of both algebraic functions (e.g. $f(x) = x^2 + x$) and transcendental functions (e.g. $f(x) = \cos x$.). As this course is dedicated to the study of some advanced topics in classical mechanics, it is helpful for students to have seen basic Newtonian mechanics before this class.

2 Course Instructor

Christian I. Cardozo-Aviles (`cica@mit.edu`) – I am a second-year electrical engineering and computer science and physics student at MIT. My primary areas of interest in physics are electricity and magnetism, which weave themselves into my studies in electrical engineering, and cosmology, on which I produced "Cosmology for the Science Enthusiast," a ten minute video introduction to the universe that went on to be well-received by members of the MIT community at a campus-wide screening (the video is available at `https://www.youtube.com/watch?v=eaLWEjp8uaE`). Having taught for past MIT ESP programs, I can undoubtedly say I am very excited to working with you all this spring, enlightening you about classical mechanics and its fundamentality to the things around us.

Phong T. Vo (`vophong@mit.edu`) – I am a third-year undergraduate Physics major at MIT. My current research interest is in experimental and theoretical condensed matter physics, and theoretical particle physics. In addition to my research and schoolwork, I also dedicate much of time sharing what I know with others through teaching. As such, I look forward to discovering classical mechanics with you over the next two months.

3 Textbook References

1. *An Introduction to Mechanics* by Daniel Kleppner and Robert J. Kolenkow
2. *Mechanics* by Lev Landau and Evgeny Lifshitz

4 Course Schedule

We expect to cover the following topics in the following order. However, as the course progresses, we are happy to adjust the schedule to accommodate student interests and needs.

1. February 21st – **Preliminary Concepts**
   (a) Review of basic calculus
   (b) Introductory vector analysis
   (c) Introductory vector calculus
   (d) Basic kinematics in different coordinate systems
2. February 25th – **Dynamics**
   (a) Newton's Laws of Motion
   (b) Gravitational forces
   (c) Tension
   (d) Friction
   (e) Normal force
   (f) Spring force
3. March 7th – **Momentum and Energy**
   (a) Conservation of momentum
   (b) Many-body dynamics
   (c) Impulse
   (d) Work-energy theorem
   (e) Potential energy and conservative forces
4. March 21st – **Fixed-Axis Rotation and Rigid-Body Motion**
   (a) Angular momentum
   (b) Torque
   (c) Fixed-axis rotation
   (d) Chasles' Theorem
   (e) The gyroscope
5. March 28th – **Central Forces and Fluid Dynamics**
   (a) The two-body problem
   (b) Energy diagrams
   (c) Planetary motion

(d) Kepler's Laws
(e) Density and pressure
(f) Pascal's Principle and Archimedes' Principle
(g) The continuity equation
(h) Bernoulli's Equation

6. APRIL 4TH – **Non-Inertial Reference Frames**
   (a) Reference frames
   (b) Galilean invariance
   (c) Fictitious forces
   (d) Uniformly accelerating frames
   (e) Rotating frames

7. APRIL 11TH – **Theoretical Mechanics**
   (a) Generalized coordinates
   (b) Hamilton's Principle
   (c) Euler-Lagrange Equations
   (d) Noether's Theorem
   (e) The Hamiltonian
   (f) Hamilton's Equations