PHYS 2303: Mechanics II (winter)

Calendar description: This course is a continuation of PHYS 2302, where students continue to develop their problem-solving skills with increasingly sophisticated topics in Classical Mechanics. These topics include central forces (celestial mechanics), many-body and rigid-body dynamics, conservation of momentum and angular momentum, coupled oscillators, and waves.

Note: Credit cannot be given to students who already have a credit for PHYS 2301.1(.2), Analytical Mechanics.

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Overview

This course is the second of three in the mechanics stream in which everything is still discussed in terms of Newton's laws of motion rather than the Euler-Lagrange formalism reserved for PHYS 3300, Classical Mechanics. Some of the ideas such as Kepler's Laws, collisions, torques and angular momentum, will have been seen by students in PHYS 1210 and PHYS 1211, but at a much less sophisticated level. Ideas completely new to students will be central forces, variable mass problems, treating angular momentum as a vector, and, most profoundly, coupled oscillators and the wave equation.

There is no lab portion to this course.

Prerequisites

MATH 2301 Linear Algebra
MATH 2311 Intermediate Calculus II

> Students entering PHYS 2303 are expected to have mastered vector algebra including the dot and cross products, and to have had a good introduction to the algebra of series, Taylor and binomial expansions, partial derivatives, line, surface, and volume integrals, the

theorems of Gauss, Green, and Stokes, vector spaces, matrices, determinants, and eigenvalues/eigenvectors. Concurrent to this course, students should be enrolled in MATH 2303 (Differential equations). Early in the semester, the instructor can rely on the very simple ODEs considered in PHYS 2302. Later in the term when the wave equation is derived, instructors can rely on the added sophistication gained by students having taken most of MATH 2303.

PHYS 2302 Mechanics I

This course gives a thorough overview of Newtonian Mechanics of one particle, simple, damped, and driven harmonic oscillations, and motion of a single particle in 3-D. Accelerating frames if reference are also covered, but this topic is not necessarily prerequisite to anything discussed in this course.

Dependent courses

PHYS 3200 Mathematical Methods in Physics I

PHYS 3200 will draw on examples from classical physics, such as those discussed in PHYS 2303. Further, the mathematical maturity and physical intuition gained from this course will be essential.

PHYS 3300 Classical Mechanics

PHYS 3300 begins with the calculus of variations, derives the Euler-Lagrange equations, and then launches into the Lagrangian and Hamiltonian formulations of mechanics. Thus, many of the same ideas and problems taught in PHYS 2302 and 2303 are revisited in PHYS 3300. Therefore, the instructor of PHYS 3300 relies much more heavily on the enhanced problem-solving skills of a student completing PHYS 2303 than any concepts in physics covered, such as the conservation of energy, momentum, and Newton's laws which were essentially covered in PHYS 1200 (University Physics I) anyway.

PHYS 3500 Quantum Mechanics I

PHYS 3500 will assume incoming students will be very familiar with the wave equation, both mathematically and how it is frequently used to model various phenomena in classical physics.

PHYS 3600 Experimental Physics I

PHYS 3600 depends, in part, upon the physics maturity gained by students in the second-year mechanics stream, but not directly on any specific lecture material (other than, perhaps, oscillations and waves).

Student Outcomes

The overall aim of the Classical Mechanics stream (300) is to develop the student into a solver of dynamic problems, and to build the student's physical intuition into a reliable tool that can be applied to any physical problem.

Students completing PHYS 2303 should have developed the following skills:

1. understand what constitutes a "well-posed" problem;
2. break up a well-posed problem into its mathematical components;
3. understand what constitutes a "system", and how to define it;
4. apply and be aware of simplifications;
5. how and where to apply specific math skills;
6. be able to exploit the symmetry of a problem

Typical problems students completing PHYS 2303 should be able to solve:

1. Determine the orbit of a comet given observations of its speed, distance from the earth, and the angle between its velocity and displacement from the sun.
2. What is the speed of a rocket launched horizontally after its fuel runs out?
3. If you kick a metre stick resting on the floor at one end, what is its angular speed immediately after impact?
4. A billiard ball is struck by a horizontal cue with "top English" (half way between its top and centre). What is its final speed in terms of the initial speed immediately after impact?
5. What are the natural frequencies of vibration of three masses coupled together by two springs confined to move in one dimension?
6. If a rigid beam is struck by a hammer, how quickly does the wave propagate down the beam?
7. What will appear on a distance screen when light passes through a diffraction grating?

Curriculum

1. central forces
    - Newton's law of gravity
    - Kepler's laws, celestial mechanics
    - stability of orbits, apsidal motion
    - Rutherford scattering
2. multi-particle and extended systems
    - centre of mass
    - linear momentum and collisions
    - variable mass problems: the rocket equation
    - kinetic energy, laminar motion
    - moment of inertia, angular momentum, torques
    - impulse, collisions with rigid bodies
3. coupled oscillators and waves
    - potential energy and stability
    - coupled oscillators
    - the wave equation
    - travelling waves
    - wave superposition, beating, dispersion
    - two- and N-slit interference

Suggested texts

Analytical Mechanics (7th ed.) by Fowles and Cassiday (ISBN 0-534-49492-7)

- a classic for this subject at this level, used at SMU for decades though may be going out of print
- no vector calculus required

First half of *Classical Dynamics* by Thornton and Marion (ISBN 0 5344 0896 6)

- 4.5/5 stars (63 reviews) on amazon.ca as of 8/20
- second half *may* serve for PHYS 3300
- suitable level for second year, but may be a little too light for third year

Notes to the instructor

1. Students will have a background in matrix algebra including eigenvalues and eigenvectors (MATH 2301/2320) necessary for the coupled oscillator unit. Differential equations will come from the curriculum on very simple ODEs from PHYS 2302, and more importantly from MATH 2303 taught concurrently to this course. The added sophistication of solving ODEs gained in MATH 2303 won't be needed until the last unit on waves.

2. The most important outcomes of this course are problem-solving skills and the clever use of symmetry and mathematics to solve problems of classical dynamics. This will be tested most rigorously by problems in the rigid body unit outlined in the curriculum section.

3. While there is no associated lab portion for this course, a discussion with the instructor of PHYS 3600 (Experimental Physics I) to determine what if any labs in classical dynamics will be performed by students next year would allow you to foreshadow these in your lectures, and perhaps use components of these labs as demonstrations.