PHYS 2302: Mechanics I (fall)

Calendar description: This course is designed to give the student a firm introduction to Newton's Laws of motion, to develop the student's ability to set up and solve problems in physics, and apply mathematical skills acquired in this course and other courses. Topics include a review of vectors and coordinate systems, rectilinear motion, simple damped and driven harmonic motion, projectile motion, conservation of energy, and accelerating frames of reference.

Note: Credit cannot be given to students who already have a credit for PHYS 2300.1(.2), Vibrations and Waves.

Contents

Overview

This course repeats some of the topics in mechanics covered in PHYS 1210 and PHYS 1211 but at a more sophisticated level, and introduces further ideas in mechanics that many students will not have seen before, such as driven oscillation and accelerating frames of reference. This is the first of three university-level courses in mechanics offered to majors and honours students by the department which terminates with PHYS 3300, Classical Mechanics.

There is no lab portion to this course.

Prerequisites

MATH 1211 Introductory Calculus II

Students will be expected to have mastered differentiation and 1-D integration covered in the first year calculus courses. In addition, some of the intermediate level mathematics taught in MATH 2311 (Intermediate Calculus II) in the same semester will be used after they are introduced there [e.g., line integrals, partial derivatives, the *nabla* operator

(∇)]. While students are not expected to have had any training in differential equations, some self-contained lessons in solving the simplest ODEs is necessarily part of the PHYS 2302 curriculum because the oscillations unit depends upon it and the mathematics department does not offer its course in differential equations (MATH 2303) until the winter semester.

PHYS 1211 University Physics II

Students will be expected to have a good understanding of many ideas in mechanics introduced in the two first-year PHYS courses, including PHYS 1211 and its predecessor, PHYS 1210. Of particular importance are Newton's Laws of motion, conservation of momentum and energy, kinematics and projectile motion, and Hooke's law (simple harmonic motion).

Dependent courses

PHYS 2303 Mechanics II

PHYS 2303 begins essentially where PHYS 2302 leaves off, and skills acquired in the latter will be taken for granted by the instructor in the former. This includes problem solving skills, a heightened mathematical ability including solving simple ODEs, using Newton's laws of motion mathematically, knowing how and when to apply conservation laws, a firm grasp of motion of a single particle in 3-D, and how damped and driven oscillators differ from simple harmonic oscillators.

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 2302 should have developed the following skills:

1. how to set up a problem and present its solution;
2. break up a complex problem into simpler pieces.
3. apply and be aware of simplifications;
4. how and where to apply specific math skills;
5. be able to exploit the symmetry of a problem

Typical problems students completing PHYS 2301 should be able to solve:

1. A man in a "Bosun's chair" pulls himself up at constant speed. What force must he apply to the rope?

2. A mass slides down an incline with friction and then reaches the horizontal at the bottom. How far will it slide before stopping?

3. How do damping and an externally applied force affect the motion of a simple harmonic oscillator?

4. What is the maximum range of a cannon ball fired from the ground to a target up on a hill?

5. A bead slides freely along a rod. If you fling the beed off the rod, what is its speed as it leaves the rod?

Curriculum

1. Newtonian mechanics in 1-D
   - vectors and coordinates
   - free body diagrams
   - separable first order ODEs
   - position- and velocity-dependent forces

2. oscillators
   - second order ODEs, inhomogeneous ODEs
   - simple harmonic motion
   - damped harmonic motion
   - driven, damped harmonic motion, resonance

3. Newtonian mechanics in 3-D
   - elements of vector calculus
   - work-kinetic theorem, conservation of mechanical energy
   - constrained motion
   - projectiles with and without air resistance
   - multi-dimensional oscillators, electromagnetic foeces

4. non-inertial reference frames
   - translational and rotational acceleration
   - dynamics in an accelerating reference frame; Coriolis theorem
   - effects of earth's rotation; projectiles and Foucault pendulum

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 should be taking MATH 2311 (Intermediate Calculus) and MATH 2301/2320 (Linear Algebra) in the same semester as this course. The instructor is advised to communicate with these math instructors to determine if the math skills needed have already been taught, or will soon be taught to minimise duplication of math instruction.
2. The most important outcome of this course is general problem-solving skills, including the use of very simple ODEs in solving problems involving Newton's 2^{nd} law, a prime example being oscillators. Indeed, this is the most difficult part of the course, as most students will not have seen Newton's laws as anything but $F = ma$. To treat this now as a second order ODE—even very simple ones—is a challenge for most.
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.