PHYS 2300: Vibrations, Waves and Optics (fall)

Calendar description: This course focuses on the production, propagation and manipulation of waves including light. Topics include geometric optics, forced damped oscillators, elasticity and distortion, the wave equation, wave speed and propagation, polarisation, wave packets, interference and diffraction, 3-D waves, plane and circular waves, and physical optics.

Classes 3 hrs. and lab 3 hrs. per week; 1 semester.

Contents

Overview

This course is essentially a follow-on from the waves and oscillations unit done in PHYS 1101, where approximately three weeks were spent on the subject. About half of this course should be spent on formal wave theory, with the remaining half divided between oscillations and optics. Former versions of this course concentrated primarily on optics; this strategy is no longer being adopted.

The lab portion of this course is described separately at PHYS 2300L. The instructors of the lab portion enjoy some autonomy in how the lab is conducted, but it is the instructor of the lecture portion of the course, hereafter the "lecturer", who is responsible for the overall course, assigns final grades to the students, and is judged by student evaluations. Therefore, the lab instructor needs to consult with the lecturer in how the lab is conducted, and where there is disagreement the view of the lecturer shall prevail.

Prerequisites

PHYS 1101 University Physics II

PHYS 2300 builds primarily on the unit on waves and oscillations which opens PHYS 1101. Some ideas of dynamics and the problem solving skills learned in PHYS 1100 (University Physics I) will also be needed.

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 in MATH 2311 [e.g., simple differential equations, partial derivatives, and the *nabla* operator (∇)].

Dependent courses

PHYS 2301 Analytical Mechanics

As part of its curriculum, PHYS 2301 discusses coupled oscillators, 3-D oscillators, and vibrating beams, all of which will depend heavily on the topics of oscillations and waves taught in this course.

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 material in the lab portion of this course (PHYS 2300L), but not directly on the lecture portion (PHYS 2300).

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 2300 should begin to develop the following skills:

1. how to set up a problem and present its solution;
2. understand what constitutes a "system", and how to define it;
3. how and where to apply specific math skills;

4. break up a complex problem into simpler pieces.

Typical problems students completing PHYS 2300 should be able to solve:

1. How should a telescope/microscope be designed to maximise field of view? depth of view? magnification power? light collecting power?
2. How do resistance and an externally applied force affect the motion of a simple harmonic oscillator?
3. Write down the equation of motion of a lateral perturbation on a wire under tension; of a pressure perturbation in the air; of a depression on the surface of a lake.
4. What will appear on a distance screen when light passes through a diffraction grating?

Curriculum

1. geometric optics
    - ray diagrams and lens laws
    - Rayleigh criterion
    - application to telescopes
2. forced damped oscillators (math available from MATH 2311 by mid-September?)
    - spring and LRC circuits
    - resonance
    - graphical representation
3. elasticity and distortion
    - stress and strain
    - torsion bar, and the wave equation (partial derivatives available from MATH 2311 by beginning of October?)
4. waves in 1-D
    - longitudinal (wave equation for sound waves)
    - transverse (wave equation for waves along a taut wire)
    - transverse waves in the vacuum (electro-magnetic waves)
    - standing waves, normal modes
    - Doppler shifting
    - propagation of waves through different media (Bragg's Law)

   - polarisation

5. interference and diffraction
   - Huygens/Fresnel principle
   - Frauenhofer diffraction (2-slit, n-slit, diffraction grating)
   - thin films
   - beating
   - Fourier analysis (Fourier series and transforms taught in PHYS 3300)

6. waves in 3-D
   - 3-D wave equation
   - plane and circular waves

Suggested texts

Physics of Vibrations and Waves by Pain (ISBN 0 471 99408)

- the math is at the right level as it assumes no partial derivatives, no vector calculus, and no eigenalgebra
- covers all the topics in oscillations and waves
- has some coverage of geometric optics, though a supplement for optics is still necessary.

Vibration and Waves by French (ISBN 0 393 09936)

- somewhat more sophisticated mathematically than Pain (*e.g.*, uses eigenalgebra approach to coupled oscillators, though this is a topic for the follow-on course PHYS 2301)
- no optics, geometric or otherwise.

Optics by Hecht (ISBN)

- was the text used in this course before the curriculum revision of 2007, and when this course emphasised optics over waves and oscillations.
- sacrifices too much on the physics of waves and oscillations
- implies an ordering of the material very different from that suggested in the curriculum section
- thorough coverage of optics.

None of these texts is ideal. We seek suggestions for a better balanced text on oscillations, waves, and optics, or else an inexpensive and appropriate optics supplement to Pain, which could be a "course pack".

Notes to the instructor

1. As taught previously to 2007, the main shortcoming of this course was its use of the wave equation only as it applies to light, and little if any discussion on oscillations. It depended on knowledge of Maxwell's equations, and did not exploit all the other examples of waves in nature (along a wire, sound, on the surface of water, etc.)

   As revised, this course still includes optics, but the ubiquity of the wave equation is now the main topic without the need of vector calculus (although partial derivatives are fair game) or Maxwell's equations which are not fully introduced until the end of Electricity and Magnetism (PHYS 2400) taught in the semester following this course.

2. 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.

3. It is strongly recommended that the instructors of the lecture and lab (PHYS 2300L) portions of this course communicate regularly, particularly at the beginning of term. For example, the unit on geometric optics must lead the course so that the first labs make sense. In general, well-coordinated lectures and labs will maximise the student's experience in this course.

4. Portion of course grade assigned to the lab portion should be between 20% and 30%.

5. It has been departmental policy that students repeating this course may be be exempt from repeating the lab portion *if*:

   - the grade attained in the lab portion in the previous attempt of the course was a C− or better;
   - the grade attained in the lab from the previous attempt of the course is used as the lab grade for the current attempt.