PHYS 203: PHYSICS C: WAVES, OPTICS & MODERN PHYSICS

Citrus College Course Outline of Record

Heading	Value
Effective Term:	Fall 2023
Credits:	5
Total Contact Hours:	126
Lecture Hours :	72
Lab Hours:	54
Hours Arranged:	0
Outside of Class Hours:	144
Total Student Learning Hours:	270
Prerequisite:	PHYS 201 or PHYS 201H; MATH 191, which may be taken concurrently.
District General Education:	B2. Natural Sciences - Physical Sciences, B3. Natural Sciences - Laboratory
Transferable to CSU:	Yes
Transferable to UC:	Yes - Approved
Grading Method:	Standard Letter

Catalog Course Description

Core topics are waves, optics and modern physics. This course is intended for students majoring in physical sciences and engineering and is part of a three-semester course sequence. 72 lecture hours, 54 lab hours.

Course Objectives

- WAVES
- Understand the basic properties of waves such as wave speed, wavelength and frequency and in addition also understand phase, wave number and phase constant for sinusoidal waves.
- Draw and interpret history graphs and snapshot graphs for both transverse and longitudinal waves and understand how these graphs are related to the displacement function.
- Solve quantitative problems involving basic wave properties for waves on a string, sound waves and sinusoidal waves and interpret the results.
- Solve quantitative problems involving the Doppler effect and interpret the results.
- Understand and apply the principle of superposition graphically to any two waves.
- Understand that a standing wave is the result of the superposition of two traveling waves and describe the standing wave as displacement function that is the product of an oscillatory amplitude function and an oscillatory time function.
- Understand what is meant by a crest, trough, wave front, a node, an anti-node, a nodal line and anti-nodal line.
- Calculate the allowed wavelengths and frequencies of standing waves by applying boundary conditions.
- Solve quantitative problems involving standing waves and interpret the results.
- Understand how phase differences between waves (due to path length differences and/or inherent phase differences) cause constructive and destructive interference in 1, 2 and 3 dimensions.
- Understand the (phase difference) conditions for maximum constructive interference and perfectly destructive interference and apply them to solve quantitative problems.
- Understand beats as the superposition of two waves of unequal frequency and calculate the beat frequency between to nearly equal frequencies.
- WAVE OPTICS
- Understand how and why the interference of light occurs and how light diffracts through single slits and circular apertures.
- Understand the wave model and distinguish between the wave model and the particle model.
- Understand and calculate the interference patterns of double slits and diffraction gratings, including location of fringes, fringe spacing and diffraction grating slit spacing.
- Understand and calculate the diffraction patterns for diffraction through single slits and circular apertures including width of central maxima and location of dark fringes.
- Understand how interferometers make controlled use of the interference of light.
- RAY OPTICS
- Use the ray model of light to predict and/or explain the formation of images and to understand the limitations of optical systems.
- Use the law of reflection to calculate reflection angles.
- Solve quantitative problems involving refraction using Snell's law of refraction and, if applicable, dispersion curves.
- Understand and apply the condition for finding the critical angle of incidence.
- Understand objects as either reflectors, absorbers and/or sources of light and that filters only allow transmission of only a few chosen wavelengths.
- Draw ray diagrams for various optical components and use ray tracing to analyze lens and mirror systems.
- Distinguish between converging and diverging lenses; identify thin lenses by their shape (i.e., double-convex, meniscus, plano-convex, etc); distinguish between concave and convex mirrors
- Distinguish between real and virtual images; distinguish between real and virtual objects.
- Understand the basic properties of mirrors and lenses such as radius of curvature, index of refraction, near and far focal points and focal length.
- Use refraction theory to calculate the properties of lens systems and spherical mirrors using relationships such as the thin lens formula, the lens maker's formula, and the thin mirror equation; understand the sign conventions for refracting surfaces, thin lenses, and spherical mirrors used in these calculations.
- Distinguish between lateral magnification and angular magnification; calculate the magnification of various optical components and/or systems.
- Use ray tracing and the thin lens equation to understand and quantitatively analyze image formation in multi-lens systems, including telescopes, microscopes, cameras and the human eye.

- Understand and calculate properties of optical systems such as f-number, numerical aperture, power of a lens, angular resolution or spatial resolution.
- Understand that chromatic and spherical aberrations and diffraction limit the resolution of optical systems.
- MODERN PHYSICS
- Understand the experimental evidence for the wave nature of matter and for de Broglie wavelength; understand the relationship between linear momentum and the de Broglie wavelength.
- Understand how a mechanical wave travels through a medium and how the wave speed is related to the properties of the medium.
- Understand the experimental evidence for the particle nature of light; understand the photon model of light and how the frequency of a photon is related to its energy.
- Understand experimental evidence about the structure of atoms and their properties including experiments such as JJ Thomson's cross-filed experiment, Millikan's oil drop experiment and Rutherford's alpha particle on gold foil experiment.
- Distinguish between continuous emission, discrete emission and discrete absorption spectra and spectral curves.
- Understand Wien's law for blackbody radiation and apply it to solve related quantitative problems.
- Apply the Balmer formula to calculate the wavelengths of the hydrogen emission spectrum.
- Recognize that some phenomena (such as discrete emission spectra and the photoelectric effect) cannot be explained by classical physics.
- Understand the photoelectric effect experiment and its implications for photon-matter interactions; understand the various parameters of the experiment (work function of a metal, threshold frequency, stopping potential, electron energy) and how they are related to each other; understand Einstein's postulates about photons and their interaction with matter and how they explain the photoelectric effect.
- Understand the Bohr model and use it to explain discrete spectra and its implications for the quantization of speed, energy, radii, and angular momentum.
- Calculate energies and wavelengths for hydrogen and hydrogen-like ions.
- Draw and/or interpret energy-level diagrams of the stationary-state energies.
- Describe a traveling wave as a function of two variables that describes the displacement of the medium in terms of the position in the medium, time, and wave parameters (wave number, frequency, and phase constant).
- Distinguish between binding energy, ionization energy and the ionization limit.
- Understand wave functions as descriptors of particles in quantum mechanics, including pictorially and graphically.
- Apply the basic ideas of probability to wave functions and use the wave function to calculate the probabilities of detecting particles.
- Recognize the limitations on knowledge imposed by the Heisenberg uncertainty principle and use it to calculate uncertainties in position or momentum.
- Normalize and interpret a wave function.
- Draw wave functions with appropriate shapes for a given potential energy well.
- Use potential energy functions and boundary conditions to make quantum mechanical models (i.e., to find the appropriate wave function and determine allowed energy levels) and to calculate specific quantities such as probabilities, wavelengths, etc.
- Understand quantum phenomena such as bonding and tunneling and their applications in modern technology (such as diodes, quantum-well lasers, scanning tunneling microscopes, and capacitors in semiconductor devices).
- Understand, interpret and apply the quantum mechanical solution of the hydrogen atom.
- Apply Schrodinger's quantum theory to multi-electron atoms and obtain a qualitative understanding of the energy-level structure of multi-electron atoms and the periodic table of the elements.
- Distinguish between the principal quantum number, the orbital quantum number, the magnetic quantum number and the spin quantum number.
- Understand the quantum mechanical basis for the shell model of the atom.
- Understand the emission and absorption of light as allowed transitions satisfying one or more selection rules, interpret spectra, and solve related quantitative problems.
- Understand the lifetimes of excited states and their exponential decay and solve related quantitative problems.
- Qualitatively understand stimulated emission and lasers.
- NUCLEAR PHYSICS
- Understand the basic structure of the nucleus; distinguish between isotopes and isobars; describe a nucleus in terms of its nucleons.
- Calculate the binding energy of a nucleus.
- Understand how the strong force holds the nucleus together.
- Apply and interpret a simple shell model of the nucleus.
- Distinguish between the concepts of power and intensity; understand the decibel scale for sound intensity.
- Understand why some nuclei are unstable and undergo nuclear decay.
- Calculate half-lives of radioactive decay
- Distinguish between the three types of radioactive decay (alpha decay, beta decay and gamma decay) and solve related quantitative problems.
- Understand the biological applications of nuclear physics including radiation dose and magnetic resonance imaging.
- RELATIVITY
- Understand and reason with the concepts of event and reference frame.
- Use the Galilean transformations of position and velocity to calculate position and speeds in different reference frames.
- Understand how the principle of relativity leads to the relativity of simultaneity and length and thus to time dilation and length contraction.
- Use the Lorentz transformations of position and velocity to calculate position and speeds in different reference frames.
- Calculate relativistic momentum and energy.
- Understand mass-energy equivalence as described in E=mc^2
- LABORATORY
- Design and implement laboratory investigations to analyze phenomena appropriate to the course.
- Develop expertise in clear, cogent reporting of experimental design, observations, analysis, and conclusions in a variety of formats

ranging from informal discussion, poster and oral presentations to formal laboratory papers.

Major Course Content

1. Waves
   a. Traveling Waves
      i. The Wave Model
      ii. 1D, 2D and 3D Waves
      iii. Power & Intensity
      iv. The Doppler Effect
   b. Superposition of Waves
      i. Standing Waves
      ii. Standing Sound Waves & Musical Acoustics
      iii. Interference in One, Two & Three Dimensions
      iv. Beats
2. Wave Optics
   a. Interference of Light
      i. Interferometers
   b. Diffraction
      i. Huygen's Principle
      ii. Single & Multiple Slit Diffraction
      iii. Circular Aperture Diffraction
      iv. Diffraction Gratings
3. Ray Optics
   a. Light Sources
   b. The Ray Model; Principal Rays & Ray Diagrams
   c. Law of Reflection; Specular vs Diffuse Reflection
   d. Refraction
      i. Law of Refraction
      ii. Total Internal Reflection
   e. Image formation: Mirrors & Lenses
      i. Real vs Virtual Images
      ii. Plane Mirrors
      iii. Spherical Mirrors
      iv. Diverging vs Converging Lenses
      v. Thin Lenses
      vi. Thin Lens Equation & the Thin Mirror Equation
      vii. Lens Maker's formula
      viii. Lateral Magnification
   f. Color & Dispersion
      i. Colored Filters vs Colored Objects
      ii. Dispersion
      iii. Rayleigh Scattering
   g. Optical Instruments
      i. Multi-lens Systems
      ii. Angular Magnification
      iii. Resolution/Resolving Power
      iv. Chromatic and Spherical Aberrations
      v. The Camera
      vi. The Microscope
      vii. The Telescope
      viii. The Human Eye
4. Modern Physics
   a. Experimental Foundation of Modern Physics
   b. Structure of Matter
      i. X-ray Diffraction
   c. Matter Waves & Energy Quantization
   d. The Bohr Model
   e. Wave Functions
   f. Heisenberg Uncertainty Principle
   g. Quantum Mechanics
      i. Probability and Wave Functions
      ii. Schrodinger's Equation
      iii. Quantum Mechanical Models
      iv. Quantum Mechanical Tunneling
   h. Atomic Physics
      i. The Hydrogen Atom
      ii. Electron Spin
      iii. Multi-electron Atoms & the Periodic Table of Elements
      iv. Spectroscopy
         1. Photons & Energy Quantization
      v. Stimulated Emission
5. Nuclear Physics
   a. Nuclear Structure
   b. The Strong Force
   c. The Shell Model
   d. Radiation & Radioactivity
      i. Nuclear Decay Mechanisms
   e. Applications of Nuclear Physics
6. Relativity
   a. Galilean Relativity
   b. Einstein's Principle of Relativity
   c. Simultaneity, Time Dilation & Length Contraction
   d. The Lorentz Transformations
   e. Relativistic Momentum & Energy

Lab Content

1. Experimental Design
2. Traveling Waves
3. Interference I: Standing Waves on a String
4. Interference II: Acoustic Standing Waves
5. Interference III: Interferometers
6. Ray Optics I: Image Formation
7. Ray Optics II: Human Eye
8. Ray Optics III: Optical Instruments
9. Microwave Diffraction
10. Spectroscopy

Suggested Reading Other Than Required Textbook

Journal Articles related to course material.

Examples of Required Writing Assignments

J.J. Thomson studied the ionization of atoms in collisions with electrons. He accelerated electrons through a potential difference, shot them into a gas of atoms, then used a mass spectrometer to detect any ions produced in the collisions. By using different gases, he found that he could produce singly ionized atoms of all the elements that he tried. When he used higher accelerating voltages, he was able to produce doubly ionized atoms of all elements except hydrogen. (a) Why did Thomson have to use higher accelerating voltages to detect doubly ionized atoms than those used to detect singly ionized atoms? (B) What conclusion(s) about hydrogen atoms can you draw from these observations?

Examples of Outside Assignments

(a) Use ray tracing to find the location and orientation of the image formed by the lens system shown in the figure. (b) Calculate the image position and height and compare to your answers in part a.
What is the probability that an electron will tunnel through a 0.50nm air gap from a metal to a STM probe if the work function is 4.0eV?

Instruction Type(s)

Lab, Lecture, Online Education Lab, Online Education Lecture

IGETC Area 5: Physical and Biological Sciences

5A. Physical Science, 5C. Science Laboratory