PHYS 2443 Modern Physics - 4 credits

This is the third of a sequence of three Physics courses (Physics 3.3). The prerequisites for this course are Physics 1441-1442, or else Physics 1433-1434 with the permission of the departmental chair. Selected topics in modern physics include: Relativity, black holes, astrophysics and cosmology, quantum mechanics and its applications, nuclear physics and elementary particle physics. The laboratory component of the class includes experiments which led to the development of quantum mechanics, and also explores some of its applications.

Learning Outcomes

Upon successful completion of Modern Physics, students should be able to:

- Demonstrate an understanding of various optical phenomena such as interference, diffraction and polarization.
- Give examples of situations in which light as well as electrons behave like a wave and a particle.
- Demonstrate knowledge of the postulates of the special theory of relativity.
- Display an understanding of the various physical effects which occur for objects traveling close to the speed of light.
- Cite some of the historical experiments and observations that gave rise to early quantum theory.
- Show a comprehension of the basic features of the early models of the atom and the associated atomic spectra.
- Have an appreciation of various aspects of physics which are actively being explored today, such as condensed matter, elementary particle physics and astrophysics.
- Read a laboratory manual and follow the procedure
- Write a technical report of a given format
- Employ scientific reasoning and logical thinking
- Work with teams, including those of diverse composition
- Develop problem-solving strategy
- Analyze and model idealized physical processes
- Apply mathematical skills to physical systems
- Gather and interpret data and draw logical conclusions
- Communicate information about physical systems in a logical and clear manner

Assessment Tools

The modes of assessment support the learning outcomes:

- Two in-class examinations
- An in-class final examination
- Laboratory reports
- Laboratory oral presentation

The laboratory oral presentation is based on a research project topic that the instructor assigns to each student. The topics focus on specific experiments and predictions from quantum mechanics, Relativity and astrophysics.

Grading

The final grade is based on the following:

- Average of two 1 hour and 40 min. examinations = 40%
- Laboratory Grade = 25%
- Research project = 10%
- Final examination = 25%

Laboratory

This course is based on doing computer-based experiments in physics and traditional experiments. Although the experiments are done in-group, each student must write and type his own individual laboratory report. It consists of a title page, data sheet, computations, graphs, discussions and questions.

Textbooks

- **Physics for Scientists & Engineers with Modern Physics, Volume III** by Giancoli, 4th Edition. Pearson- Prentice Hall.
- Departmental handout materials
- Departmental handouts for Laboratory experiments

Topics

Week	Topic & Chapter	Chapter	Problems
1	**Special Theory of Relativity** a. Galilean – Newtonian Relativity & speed of light b. Postulates of the Special Theory of Relativity c. Time Dilation and Length Contraction	36	1, 2, 8
2	**Special Theory of Relativity** a. Lorentz Transformations b. Relativistic Momentum and Mass c. $E = mc^2$; Mass and Energy d. Doppler Shift for Light	36	13, 38, 41
3	**Astrophysics and Cosmology** a. Stars and Galaxies b. Stellar Evolution: Nucleosynthesis, and the Birth and Death of Stars c. Distance Measurements d. General Relativity: Gravity and the Curvature of Space	44	17, 18, 20
4	**Astrophysics and Cosmology** a. The Expanding Universe: Redshift and Hubble's Law b. The Big Bang and the Cosmic Microwave Background c. The Standard Cosmological Model: The Early Universe	44	36, 53, 54, 58
5	**Astrophysics and Cosmology**	44	

	a. Inflation b. Dark Matter and Dark Energy c. Large-Scale Structure of the Universe **Exam 1**		
6	**Early Quantum Theory and Model of the Atom** a. Electromagnetic waves b. Planck's Quantum Hypothesis c. Photon Theory; Photoelectric Effect d. Photon Energy, Mass and Momentum e. Wave – Particle Duality; the Principle of Complementarity f. Wave Nature of Matter g. Early Models of the Atom and the Bohr Model	37	10,17,41
7	**Quantum Mechanics** a. The Wave Function and the Heisenberg Uncertainty Principle b. The Schrödinger Equation and examples of its solution in one dimension c. Tunneling through a Barrier	38	5,18,24
8	**Quantum Mechanics** a. Hydrogen Atom: Schrödinger Equation and Wave Function b. Complex Atoms: the Exclusion Principle and Periodic Table of Elements	39	3,28,34
9	**Quantum Mechanics** a. X-Ray Spectra b. Lasers and Holography **Quantum Mechanics of Solids** a. Bonding in Molecules and Potential-Energy Diagrams for Molecules b. Molecular Spectra c. Bonding in Solids	39-40	39-41,40-1, 40-8
10	**Quantum Mechanics of Solids** d. Drude Free-Electron Theory of Metals; Fermi Energy e. Band Theory of Solids f. Semiconductors and Doping g. Applications: Semiconductor Diodes, Transistors and Chips (Integrated Circuits) **Exam 2**	40	26,31,43,54
11	**Nuclear Physics and Radioactivity** a. Structure and Properties of the Nucleus b. Binding Energy and Nuclear Forces c. Radioactivity: Alpha, Beta and Gamma Decays d. Conservation Laws in Nuclear Physics e. Detection and application of Radiation	41	25,27,39,41

12	**Nuclear Energy; Effects and Uses of Radiation** a. Nuclear Reactions and the Transmutation of Elements b. Nuclear Fission; Nuclear Reactors c. Nuclear Fusion d. Application of Nuclear Physics: Dosimetry, Radiation Therapy, Tracers in Research and Medicine, Imaging by Tomography: CAT Scans and Emission Tomography, Nuclear Magnetic Resonance (NMR), Magnetic Resonance Imaging (MRI)	42	5,7,23,37
13	**Elementary Particle Physics** a. High-Energy Particles and Accelerators b. Particles and Antiparticles c. Particle Interactions and Conservations Laws d. Neutrinos e. Particle Classification f. Particle Stability and Resonances	43	1,9,11
14	**Elementary Particle Physics** a. Strangeness? Charm? Towards a New Model b. Quarks c. The Standard Model: QCD and Electroweak Theory, Strings and supersymmetry	43-44	Ch.43 - 45,65
15	d. Grand Unified Theories e. Strings and supersymmetry **Final Exam**		

Laboratory Experiments.
1. Orientation and introduction to Excel
2. Property of electromagnetic waves: Interference, Polarization and Dispersion of light
3. Property of electromagnetic waves: Interference, Polarization and Dispersion of microwaves
4. Photons: Photoelectric Effect
5. Charge of electron
6. Measurements of e/m for Electron and mass of electron
7. Diffraction of electrons
8. Study of Spectral lines and Rydberg Constant
9. Measurements of e/m for Electron
10. An open cavity laser: He-Ne laser
11. Holography
12. a, b and g-Radiation: Radiation detection and absorption
13. Principles of acceleration of elentary particles: electron
14. Simulations of Dark Matter
15. Oral presentation of the Research project