Appendix F

Course Descriptions

Seven new courses are required to implement the Space Physics program, and their course descriptions are contained in this appendix.

F.1 Course Description: Physics II Lab

Course No: PS2xx

Title: Physics II Lab (1 credit hour)

Catalog Description:
One three hour laboratory session per week with experiments chosen primarily from wave motion, transverse and longitudinal waves, superposition of waves, traveling waves and standing waves.

Corequisites: PS160 or PS208

Purpose: This lab will develop the students' understanding of wave motion, the principle means by which we make measurements (e.g., sight and sound). The student will measure the properties of transverse and longitudinal waves, including the superposition and propagation of waves.

Topic 1: **Free oscillations of simple systems:** Measure the frequency of simple harmonic systems and describe their equations of motion.

Topic 2: **Forced Oscillations:** Measure the resonance properties of oscillating systems.

Topic 3: **Traveling waves:** Study of the forced oscillations of an *open* system. Phase velocity and impedance.

Topic 4: **Standing waves:** Study of the forced oscillations of a *closed* system. Inertia and return force.

Topic 5: **Reflection:** Study of the superposition of standing and traveling waves. Derive reflection coefficients.

Topic 6: **Polarization:** Study of the polarization of electromagnetic waves. Relationship between partial polarization and coherence.

Topic 7: **Phase and group velocity:** Study the phase velocity of sound and group velocity of water waves.

Topic 8: **Interference and diffraction:** Measure the superposition of waves that have traveled different paths from the source to the detector. Physical meaning of coherence.

Topic 9: **Report writing:** written presentation of experiments, including error analysis.

Optional **Modulations, pulses, and wave packets:** Superposition involving different frequencies to form pulses and wave packets.

F.2 Course Description: Senior Physics Lab I

Course No: PS 4XX

Title: Senior Physics Lab I (3 credit hours)

Catalog Description:
Mirror optics, lens optics, emission and absorption line spectroscopy, diffraction grating spectroscopy.

Prerequisites: PS 305

Purpose: To familiarize the student with laboratory optics experiments. (Note: There will be several lab experiments for each topic).

Topic 1: **Plane Waves:** Refraction and reflection of plane waves.

Topic 2: **Mirrors:** Concave mirrors, convex mirrors, telescope design.

Topic 3: **Lenses:** Concave lenses, convex lenses, chromatic abberation, microscope design.

Topic 4: **Emission and Absorption line spectroscopy:** Hydrogen spectrum, Mercury spectrum, sodium spectrum, Zeeman effect.

Topic 5: **Diffraction gratings:** physical optics, Fresnel diffraction, Fraunhoffer diffraction, Youngs slits, circular apertures, spectrometer design.

Topic 6: **Lasers:** Coherence length, interferometers, polarization of light.

Topic 7: **Report Writing:** written presentation of experiments, including error analysis.

F.3 Course Description: Atomic/Nuclear Physics

Course No: PS4xx

Title: Atomic/Nuclear Physics (3 credit hours)

Catalog Description:
Multi-electron atoms, X-rays and gamma rays, radiative transitions in the atom and the nucleus. Basic properties of nuclei, systematics of nuclear stability, dynamics of nuclear reactions, nuclear models and nuclear forces. Introduction to particle physics and its applications to cosmic rays, stellar energy, and the formation of the elements.

Prerequisites: EP455

Purpose: This course is designed to give the student an understanding of atomic, nuclear, and particle interactions. The student will learn to calculate cross-sections and transition rates associated with atomic, nuclear, and particle interactions.

Topic 1: **Atomic Spectroscopy:** L·S and j-j coupling, energy-level diagrams for complex atoms, the Zeeman effect, excitation of atoms and the breadth of spectral lines.

Topic 2: **X-rays:** Production of X-rays, interaction of X-rays with matter, X-ray diffraction, refraction and reflection of X-rays.

Topic 3: **Basic properties of nuclei:** Angular momentum, magnetic moments, nuclear magnetic resonance, electric quadrapole moments, radioactivity, excited states of nuclei.

Topic 4: **Particle scattering:** Rutherford scattering, transformation from CM to laboratory coordinates, multiple coulomb scattering and energy loss by ionization, range, straggling, and general properties of particle scattering.

Topic 5: **Radioactivity:** the four radioactive series, age of minerals and of the earth, natural radionuclides, artificial radiactivity, alpha particle decay, beta-decay, neutrinos, theory of beta-decay and the study of the weak force.

Topic 6: **Nuclear Models:** the alpha-particle model, liquid-drop model, fission and fusion, the Fermi-gas model, the shell model.

Topic 7: **Nuclear forces:** two-nucleon system, scattering experiments, Fermi motion, and the study of the strong force.

Topic 8: **Introduction to elementary particles:** The Standard Model, the four fundamental forces in nature, the Dirac Theory of the electron.

Topic 9: **Modern Physics in Nature:** Cosmic rays, stellar energy, the formation of the elements.

F.4 Course Description: Astrophysics II

Course No: PS 4XX

Title: Astrophysics II (3 credit hours)

Catalog Description:
Radiative transfer in astrophysical environments; stellar atmospheres, stellar interiors, and gaseous nebulae. Emission and absorption processes. Interaction of radiation with matter.

Prerequisites: MA 345, PS 401.

Purpose: This course is designed to give the student a theoretical, computational and physical understanding of the various means by which radiation is transported within the cosmos.

Topic 1: **Basic Definitions:** Specific intensity, flux, mean intensity, solid angle, energy density, Planck function, Boltzmann formula, Maxwell-Boltzmann distribution.

Topic 2: **Interaction of radiation with matter:** Einstein coefficients, statistical equilibrium, the two level atom, emission and absorption coefficients, free-free emission, radiative transfer equation.

Topic 3: **Stellar Atmospheres:** Gray atmosphere, Eddington approximate solution, emergent intensity, limb darkening, Saha equation.

Topic 4: **Realistic Stellar atmospheres:** Absorption coefficients for atomic hydrogen, bound - free absorption, free-free absorption, formation of absorption lines, equivalent widths, spectral line broadning.

Topic 5: **Gaseous nebulae:** HII regions, collisional excitation, collisional and radiative deexcitation, Stromgren sphere, emission line intensities, forbidden lines.

F.5 Course Description: Senior Physics Lab IIa

Course No: PS 4XX

Title: Senior Physics Lab IIa (3 credit hours)

Catalog Description:
Binary stars, spectroscopic binaries, proper motion, galaxy rotation curves, image processing.

Prerequisites: PS 4XX (Senior Physics Lab I)

Purpose: To familiarize the student with the various techniques that astronomers use to determine useful physical quantities from astronomical observations. (Note: There will be several lab experiments for each topic).

Topic 1: **Binary stars:** Calculating orbital elements for visual binaries.

Topic 2: **Spectroscopic binaries:** Calculating mass ratios for spectroscopic binaries.

Topic 3: **Proper Motion:** Calculating distances to nearby stars, asteroids and planets.

Topic 4: **Galaxy rotation curves:** Calculating the distribution of mass and the amount of dark matter in galaxies.

Topic 5: **Introduction to IRAF:** Basic image processing and image analysis.

Topic 6: **Report Writing:** written presentation of experiments, including error analysis.

F.6 Course Description: Particle Physics & Cosmology

Course No: PS4xx

Title: Particle Physics & Cosmology (3 credit hours)

Catalog Description:
Study of the evolution of the universe including large scale structure, Big-Bang cosmology, general relativity and the search for dark matter.

Prerequisites: MA441, PS4xx (Atomic/Nuclear Physics)

Purpose: This course is designed to give the student a working knowledge of the structure and evolution of the universe. The student will learn how nuclear and particle physics played a significant role in the dynamics of the early universe, and explore some of the current models.

Topic 1: **Large-scale structure of the universe:** homogeneity, high-redshift objects, pre-galactic history.

Topic 2: **The Standard Model:** the unified theory of elementary particles and forces.

Topic 3: **Big-Bang cosmology:** hot-big-bang hypothesis, evolution of big-bang including quantum gravity, inflation, baryosynthesis, nucleosynthesis, and matter dominating universe leading to star and galaxy formation. Microwave background.

Topic 4: **The cosmic asymmetry between matter and antimatter:** introduction to particle symmetries in Charge-conjugation/Parity violation.

Topic 5: **Some fundamental questions:** gravity, inflationary models, etc.

Topic 6: **Introduction to general relativity:** Equivalence principle, bending of light, gravitational shift of spectral lines, concept of curved space-time, the Schwarzschild metric.

Topic 7: **Experimental tests of Einstein's theory of gravitation:** Precession of the perihelion of mercury, deflection of light rays, radar echoes from planets.

Topic 8: **The search for dark matter:** physics of black holes, neutrinos, WIMPS and MACHOS. Galactic rotation rates.

Topic 9: **Cosmic Kinematics:** the Robertson-Walker metric, Hubble's law, Red shifts, angular size, apparent luminosity, and galaxy counts.

Topic 10: **Cosmic Dynamics:** Solution of Friedmann's equations, open vs. closed universe, and the cosmological constant.

F.7 Course Description: Senior Physics Lab IIb

Course No: PS4xx

Title: Senior Physics Lab IIb (3 credit hours)

Catalog Description:
Measurements of nuclear and particle systems using high-precision detectors and high-speed data acquisition.

Prerequisites: PS303, PS305, PS2xx (Physics III)

Purpose: This course is designed to enhance the students' laboratory skills for making high-precision measurements of nuclear and particle systems. The student will successfully complete 3 of the following labs with formal writeups. More labs may be added in the future.

Topic 1: **Measure the lifetime of a muon:** muons created from cosmic ray interactions in the earth's atmosphere are observed to decay into electrons in the laboratory. Students will measure the half-life of muons and learn about the weak interaction (one of the four forces of nature) responsible for radioactive decay.

Topic 2: **Nuclear magnetic resonance:** the properties of NMR will be studied, including the spin-flip of protons, spin-relaxation times, and NMR imaging.

Topic 3: **Measure ionizing cosmic rays:** measure the flux and angular dependence of cosmic rays (and their daughters) in the laboratory. Students will also learn the health risks associated with ionizing radiation.

Topic 4: **Rutherford scattering:** measure the angular distribution of charged particles scattered by the nucleus. Students will learn the concepts of double-differential cross sections used in nuclear/particle physics.

Topic 5: **Compton scattering:** measure the recoil electron energy due to Compton Scattering of X-rays on electrons. Students will learn the concepts used in X-ray telescopes.

Topic 6: **Trapping antimatter in a Penning trap:** confine and study the positrons (anti-electrons) emitted from a radioactive source. Students will learn how to confine and trap antimatter for several hours and days.

Topic 7: **Report Writing:** written presentation of experiments, including error analysis.