12998-352(8) Atomic- and Nuclear Physics (1½ ℓ, 1½ p)

2015

Course summary:

Magnetic dipole moments, spin-orbit coupling, radiation transition rates, Zeeman effect, Helium atom. Nuclear structure and properties, radioactive decay, the nuclear force, introduction to nuclear models, apparatus of nuclear physics, elementary particles.

Continuous assessment
P Physics 254, 334

Outcomes of course:

I. **Atomics Physics**
Students are skilled on an introductory level in the theoretical modelling of atomic structure and its correspondence with experimental observation. It also serves as a unified application of quantum mechanical techniques, classical electromagnetism and mechanics as well as optics in order to describe the internal structure of atoms.

II. **Nuclear Physics**
Students are equipped with a basic knowledge of nuclear physics.

Lecturers:

Dr. PH Neethling (Atomic Physics)
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Dr. JA Stander (Nuclear Physics)
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Course content:

I. Atomic Physics - 9 (50minute) Lectures
This is an introductory course in Atomic Physics. The quantum mechanical description of one electron atoms leads to the set of allowed radial eigenfunctions and the spherical harmonics with associated eigenvalues and the gross structure in the hydrogenic energy level scheme. Probability densities, quantised orbital angular momentum and associated magnetic dipole moments are discussed. The Stern-Gerlach experiment and introduction of electron spin is covered. Spin-orbital interaction leading to the lifting of the ell-degeneracy and the fine structure in the spectrum is discussed. Radiational transitions are covered in an extremely rudimentary fashion. The Zeeman effect is discussed. This is followed by treating the two-electron atom and the case of identical half-integer spin particles and the Pauli exclusion principle.

II. Nuclear Physics - 9 (50 minute) Lectures
Nuclear structure and properties, nuclear stability, partial decay constants, radioactive series, multipole radiation, nuclear reaction mechanisms, magnetic moment, electrical quadrupole moment, introduction to nuclear models, nuclear energy.

Detailed Contents of Atomic Physics

a. One Electron Atoms

i. Introduction
ii. Development of the Schrödinger equation
iii. Separation of the time-independent equation in its spatial components iv.Solutions of the separate differential equations
iv. Eigenvalues, associated quantum numbers and degeneracy
v. Eigenfunctions
vi. Spatial probability distribution
vii. Orbital angular momentum and its quantization
viii. Eigenvalue equations

b. Magnetic dipole moment, electron spin and radiational transition probabilities

i. Introduction
ii. Magnetic dipole moment associated with orbital movement
iii. The Stern-Gerlach experiment and electron spin
iv. Spin-orbital interaction
v. Quantization of the total angular momentum
vi. Spin-orbit interaction energy and the fine structure in the hydrogenic energy eigenvalues
vii. Isotope and Lamb shift
viii. Radiational transitions and selection rules
ix. A comparison of the older and modern quantum theories

c. **The Zeeman Effect**

i. Spatial quantization of the total angular momentum in a weak external magnetic field
ii. Die Landé g-factor
iii. Lifting of the j-degeneracy in a weak magnetic field
iv. Die normal en anomalous Zeeman effect
v. The polarization of the Zeeman components

d. Multi-Electron Atoms

i. Introduction
ii. Identical particles
iii. The Pauli exclusion principle

Detailed Contents of Nuclear Physics

1. **Introduction:**
   Historical review; Objectives of the study of nuclei; Terminology; Occurrence of nuclei; Sizes of nuclei; Atomic masses; Binding energy; Angular momentum and parity; Excited states of nuclei.

2. **Radioactivity and disintegration:**
   Introductory terminology; Radioactive decay; Occurrence of radioactivity; Conservation laws for radioactive decay; Properties of neutrinos; Gamma decay and internal conversion; The Mossbauer effect.

3. **Nuclear reactions:**
   Cross sections in nuclear reactions; Reaction mechanisms

4. **Other nuclear properties:**
   Magnetic dipole moment; Electric quadrupole moment; Isospin.

5. **Nuclear models:**
   The strong interaction between nucleons; Liquid drop model; Fermi gas model; Shell model; Collective model.

Practical (Tutorials):

Tutorial sessions are used for assistance in problem solving in this course.

Study material:

Class notes supplied by department.

Learning opportunities:

Lectures as per time table

Assessment:

Methods of Assessments
Continuous assessment

Venue and time of assessment opportunities
Assessments are conducted during contact sessions. Also see timetable.

Calculation of final mark for the module:
4 or more assessments counting a maximum 25% each.

Admission to examination:
Not applicable.