The University of Sydney

Senior Physics Lecture Module:
High-Energy Physics

MODULE OUTLINE

This lecture module covers the basic constituents of matter, such as quarks and leptons, examining their fundamental properties and interactions, and their origin at the creation of the universe.

Lectures

This module consists of 19 lectures in Semester 2, 2006. A week-by-week timetable can be found at the Senior Physics website. Most lectures will be held in Lecture Rm 5. A few lectures will be split, with the Advanced stream remaining in Lecture Rm 5 while the Normal stream will move to either Lecture Rm 4 or Rm 414. The dates for the split lectures will be announced during the first lecture.

Assessment

There will be 2 assignments for this module contributing 25% to the total assessment. Assignments should be completed individually and handed in to the Student Support Office. You may discuss the questions with your peers and the course lecturers. Ensure that your script is marked with your name and SID, and indicate whether you are taking the Normal or Advanced stream. The final exam constitutes 75% of the total assessment for this module. The learning outcomes for each part of this module provide a guideline for examinable material.

High Energy Physics – 19 Lectures

Lecturer:

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Course Content:

- The Particle Zoo & Fundamental Forces – The discovery of particle physics, properties of quarks and leptons, families of quarks and leptons, fundamental interactions, force charge & force mediators, Feynman diagrams, quark mixing and the Cabibbo angle.
- Studying Particles – Historical; Cloud and bubble chambers, Modern; accelerators, relativistic mechanics and interactions, stationary targets and colliding beams
- Conservation Laws – Charge, baryon number, lepton number, quark numbers, strong isospin and isospin families, addition of isospin and Clesch-Gordan coefficients.
- Violations of Conservation Laws – Charge conjugation, parity and time operations, symmetry, the fall of parity, CP conservation, K mesons and CP violations, CPT conservation.
- Neutrinos – Radioactive decay and the need for neutrinos, helicity and left-handed neutrinos, neutrinos and parity violation, neutrino interactions and the solar neutrino problem, neutrino mixing.
- Unification – Quantum electrodynamics, quantum chromodynamics, gluons, evidence for colour, asymptotic freedom, quark/gluon jets, unification.

- Cosmology & the Early Universe – The need for high energy physics, the expanding universe, back to the beginning and the hot Big Bang, matter-antimatter asymmetry, the early history of the universe and phase transitions, nucleosynthesis and the cosmic microwave background.

Learning outcomes:

- The Particle Zoo & Fundamental Forces – Understand the existance and difference between the fundamental particles; quarks, leptons & bosons. describe potential quark configurations to give baryons & mesons, understand the existence of excited quark states and their physical implications, understand the spin orientation on the physical properties of particles, describe what we mean by particle interaction and decay, use the fundamental vertex of a Feynman diagram to construct particle interactions, calculate the relative probabilties of interactions based upon their coupling constants (g^2), understand the similarities and differences between the fundamental interactions, describe the Yukawa hypothesis of the strong interaction, understand the implication of the massive W/Z bosons in the weak force, understand quark-lepton symmetry and calculate the mixing angle within the Cabibbo hypothesis.
- Studying Particles – Describe how particles are generated, how they interact and how they are detected, use relativistic mechanics to calculate the energy of interaction in the case of a beam onto a stationary target and also in the case of two interacting beams.
- Conservation Laws & Symmetry – Understand the concept and implication of symmetry in physics, use the fundamental conservation laws to determine which interactions are possible and which are forbidden, understand that some conservation laws are universal whereas others can be violated by particular forces, understand what C, P & T transformations are and what you would physically expect under such transformations, understand the concept of isospin and how different particle can be members of the same isospin family, understand what it means for isospin to be conserved in a vectorial sense, and use Clebsch-Gordan coefficients in strong interactions, describe the 1957 experiement of Wu and its implications for parity conservation, understand CP symmetry and describe how this is broken in K meson interactions
- Neutrinos – Describe why β-decay requires the existance of neutrinos, understand what is meant by helicity and how this can explain the results of Wu's experiment, calculate how little neutrinos interact, understand what is meant by neutrino mixing and calaculate the change in neutrino flavour in particular circumstances.
- QCD, the Standard Model & Unification – Understand what the standard model encompasses, describe the nature of hypercharge and its use in describing the octet and decuplet groups of particles, explain why colour was introduced to explain quasars, calculate the effect of colour on interactions involving quarks, understand asymptotic freedom and its implications for quarks, describe what is meant by sea-quarks and their physical implications, understand where the physical model breaks down and what is meant by the unification of forces, describe the Georgi-Glashow model for unification and its physical implications.
- Cosmology & the Expanding Universe – Calculate the redshift of an object, describe the observational evidence for an expanding Universe and understand what this implies, understand the meaning of scale factor and its relation to observational quantities and use it in calculations of the physical evolution of the Universe, understand what is meant by dark energy and describe its influence on cosmic evolution, describe significant events in the early epoch of the Universe.

Text and Reference Books

There is no set text book for this module. Lecture notes will be available via WebCT. The following reference books may also be useful.

- Martin, B. R. & Shaw, G., 1997, *Particle Physics*
- Kenyon, I. R., 1987, *Elementary Particle Physics*
- Feynman, R. et al, 1970, *The Feynman Lectures in Physics*

Additional Resources

Students are advised to familiarize themselves with the particle physics and cosmological concepts presented in **University Physics (**11^{th} **Edition)**.

There are a number of websites that discuss aspects of particle physics. These include:
`http://particleadventure.org/`
`http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html`
`http://scienceworld.wolfram.com/physics`

Popular articles on particle physics include:
G. J. Feldman & J. Steinberger, **The Number of Families of Matter**, Scientific American, (February 1991)
H. Georgi, **A Unified Theory of Elementary Particles and Forces**, Scientific American (April 1981)
H. Harari, **The Structure of Quarks and Leptons**, Scientific American (April 1983)
C. Quigg, **Elementary Particles and Forces**, Scientific American (April 1985)
C. Sutton, **Subatomic Forces**, New Scientist (February 1989)