Senior Physics Lecture Module:  
High-Energy Physics (Normal and Advanced)

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, 2009. A week-by-week timetable can be found at the Senior Physics website. The lectures will mostly be held in Lecture Theatre 2 and will be common to advanced and normal students. The class will be split for 4 of the lectures, with the advanced lectures remaining in Lecture Theatre 2 and the normal lectures being given in Lecture Theatre 5.

Assessment

There will be 2 assignments for this module contributing 25% to the total assessment. Note that some questions in the assignment will be common to both the normal and advanced streams. Assignments should be completed individually and handed in to the Student Support Office by the due date. Late assignments will receive a penalty. 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 of advanced stream. The final exam constitutes 75% of the total assessment for this unit. The learning outcomes for this module provide a guideline for examinable material.

High Energy Physics – 19 Lectures

Lecturers:

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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.
- **Conservation Laws & Symmetry** – Charge, baryon number, lepton number, quark numbers, strong isospin and isospin families, addition of isospin and Clebsch-Gordan coefficients, charge conjugation, parity and time operations, symmetry, the fall of parity, CP conservation, K mesons and CP violations, CPT conservation.
- **Relativistic Mechanics** – Relativistic mechanics and interactions, stationary targets and colliding beams
- **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.
- **Quark Model & QCD** – Multiplets, quantum chromodynamics, gluons, evidence for colour, asymptotic freedom, quark/gluon jets.
• Studying Particles – Production and detection of different types of particles, modern instruments and devices, reconstructing particle decays, future detectors.
• HEP & The Early Universe – Relationship of HEP and cosmology, the expanding universe, back to the beginning and the hot Big Bang, matter-antimatter asymmetry.

Learning outcomes & Specific Objectives:
By the end of this module, you should be able to meet the objectives listed below. Understanding a topic implies that you should be able to perform simple calculations relevant to that topic.

• The Particle Zoo & Fundamental Forces
  – understand similarities and differences between the fundamental particles and interactions
  – describe potential quark configurations to give baryons & mesons
  – understand the concept of spin and properties of excited quark states
  – describe what we mean by particle interaction and decay
  – use Feynman diagrams to construct particle interactions
  – calculate the relative probabilities of interactions based upon coupling constants
  – 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 do calculations involving the Cabibbo mixing angle

• Conservation Laws & Symmetry
  – understand the concept and implication of symmetry in physics
  – use conservation laws to determine which interactions are possible
  – understand that only some conservation laws are universal
  – understand the physical basis of C, P & T transformations
  – understand the concept of strong isospin and isospin families
  – understand vectorial conservation of strong isospin
  – use Clebsch-Gordan coefficients to compare strong interaction rates
  – describe the Wu experiment and its implications for parity conservation
  – understand CP symmetry and describe how this is broken in weak interactions

• Relativistic Mechanics
  – calculate the properties of interactions using relativistic mechanics
  – understand the concept of a virtual particle
  – understand the difference between fixed target and colliding beam experiments

• Neutrinos
  – describe why β-decay requires the existence of neutrinos,
  – understand helicity and its implication for Wu’s experiment
  – demonstrate that neutrino interaction rates are tiny
  – understand what is meant by neutrino mixing
  – calculate neutrino mixing probabilities
• **Quark Model & QCD**
  - describe the use of strong isospin and hypercharge to explain multiplet structure
  - explain why colour was introduced to explain quark properties
  - 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

• **The Standard Model & Beyond**
  - understand what the standard model encompasses
  - understand the limitations of the standard model and the unification of forces
  - describe some of the proposals for extending the standard model

• **Studying Particles**
  - describe how particles are generated
  - describe how particles interact and how they are detected
  - interpret and analyze specific examples of particle events

• **HEP & The Early Universe**
  - understand the relationship between particle physics and cosmology
  - describe the observational evidence for a hot big bang universe
  - calculate the redshift of an object
  - understand the scale factor and its relation to observational quantities
  - understand how the observed matter-antimatter asymmetry in the Universe today may have arisen

**Text and Reference Books**

There is no set text book for this unit. Copies of lecture slides will be available via WebCT. The following reference books may also be useful.

- Kenyon, I. R., 1987, *Elementary Particle Physics*

**Additional Resources**

Students are advised to familiarize themselves with the particle physics and cosmological concepts presented in *University Physics* (11th or 12th Edition).

There are a number of websites that discuss aspects of particle physics. These include:

- [http://hyperphysics.phy-astr.gsu.edu/hbase/particles/parcon.html](http://hyperphysics.phy-astr.gsu.edu/hbase/particles/parcon.html)

Popular articles on particle physics include:

C. Quigg, *The Coming Revolutions in Particle Physics*, Scientific American (February 2008)