Objectives for Unit IV: Particle Physics and Cosmology

By the end of this unit, students should be able to:

4.0 Relate concepts related to particle physics and cosmology to real world situations and discuss various applications of the concepts to open problems in physics.

4.1 List the types of particles (bosons, fermions, hadrons, leptons, baryons, mesons, messengers) and their properties; classify given particles into these types, using data tables. Using data tables, classify and identify the properties of various fundamental particles.

4.2 Describe what happens if a particle combines with its anti-particle.

4.3 Name the six main conservation laws of particle physics and give the conditions under which they apply. Analyze given particle reactions or decays to test the main conservation laws, or to discover properties of a new unknown particle.

4.4 Describe briefly the patterns of particles grouped according to the Eightfold Way.

4.5 Build various hadrons with given properties from combinations of quarks, given quark tables.

4.6 State and rank the four "fundamental" interactions of nature and describe their properties, including what kind of particles they act on, their range, and their role in atomic, subatomic, and macroscopic processes.

4.7 Describe the role of virtual particles in particle interactions using a quantum field theory description. Use the Energy-Time uncertainty relation to connect the mass of a virtual messenger particle to the range of the corresponding force.

4.8 State and use the colorless rule for physically observable particles.

4.9 Describe the idea of camouflage. Explain in words and sketches how gluons can change quark color and how this leads to camouflage.

4.10 Distinguish between quarks and leptons, describe which interactions they feel, and list which properties (color, flavor, family membership) are affected by which interactions.

4.11 Draw and use Feynman interaction diagrams that include quark-gluon vertices, quark W-boson vertices, lepton-W boson vertices, or electron-photon vertices.

4.12 Construct Feynman interaction diagrams for given strong and weak interactions among particles, showing the underlying quark structure.

4.13 Given a particle's mass and quark constituents, list possible decay schemes and estimate decay times, using particle tables and the conservation laws. Also, describe in words and diagrams a possible proton decay scheme and explain why such an occurrence must be very rare.

4.14 Describe qualitatively the epochs of the Big Bang standard model of cosmology.

4.15 Calculate the energy, temperature, and time of critical events (symmetry breaking, particle decoupling, etc.), given particle data tables.

4.16 Describe three pieces of observational evidence that serve as tests of the Big Bang model and particle physics.