Outline and synopsis of 210PHY412 module
Part II – Stellar structure and evolution (Dr. S. Smartt)

Lecture 1: The observed properties of stars
1. Introduction and learning outcomes for the module.
2. The observable properties of stars
3. Recap of previous concepts – basic stellar parameters, the HR diagram, colour magnitude diagrams, absolute magnitudes
4. Observed mass-luminosity relations
5. Star clusters – open clusters and globulars

Lecture 2: The equations of stellar structure I
1. Introduction to the equations describing stellar structure, basic assumptions
2. The equation of hydrostatic support
3. The equation of mass conservation
4. Accuracy of the hydrostatic assumption
5. Accuracy of the spherical symmetry assumption
6. The dynamical timescale

Lecture 3: The equations of stellar structure II
1. The minimum value for central pressure of a star
2. The Virial Theorem
3. Minimum mean temperature for a star and the Sun
4. The physical state of stellar material
5. Radiation and gas pressure

Lecture 4: The equations of stellar structure III
1. Energy generation in stars
2. Source of energy generation
3. Equation of energy production
4. Method of energy transport
5. Convection and conditions for convection
Lecture 5: The equations of stellar structure IV
1. The equation of radiation transport
2. Summary of the four equations of stellar structure
3. Solving these equations: boundary conditions, and use of mass as an independent variable
4. Temporal evolution of the models
5. Influence of convection

Lecture 6: Nuclear reactions in stellar interiors
1. Binding energy of atomic nuclei
2. Occurrence of fusion reactions: quantum tunnelling and the Gamow Peak
3. Hydrogen burning – PP chain
4. Energy production and neutrino emission
5. The CNO Cycle
6. He burning – the triple-α reaction
7. Later stages of nuclear burning and statistical equilibrium – carbon, oxygen, silicon burning
8. The s-process and r-process

Lecture 7: The structure of main-sequence stars – homologous stellar models
1. Equation of state of an ideal gas
2. Mean molecular weight
3. Opacity and approximate form for opacity
4. Homologous stellar models
5. Comparing the homologous series with observed parameters: mass-luminosity and luminosity-temperature relations

Lecture 8: Polytropes and simple models
1. What is a simple stellar model
2. Polytropic models
3. Derivation of the Lane-Emden equation
4. Analytical and computational solutions of the Lane-Emden equation
5. Comparison with real models
6. How does a polytropic model of the Sun compare with the detailed Standard Solar model?

Lecture 9: General stellar evolution
1. Computation of realistic stellar models
2. Examples of results from stellar evolution calculations
3. Discussions of the differences between low, intermediate and high mass stars
4. Comparisons of the stellar codes with observations: binary masses and observational HR diagrams of stellar clusters
5. Influence of input physics – convection and stellar mass-loss
Lecture 10: Evolution of solar-type stars
1. The main-sequence lifetime
2. End of H-burning, ascent of the red giant branch, the Hayashi tracks and forbidden zone
3. Tip of the red giant branch and the He flash
4. He-burning on the AGB
5. Pulsations and formation of Planetary nebulae

Assignment Class I
Discussion of the essays on the solar neutrino problem

Lecture 11: Evolution of high mass stars
1. The IMF – massive stars are rare
2. Typical evolution of 10, 25 and 100 solar mass stars
3. H-burning and main-sequence lifetimes
4. Post main-sequence evolution
5. Structure of massive stars before collapse
6. The influence of mass-loss: formation of Wolf-Rayet stars
7. Stellar rotation and its influence on evolution

Lecture 12: End states of stars: white dwarfs, neutron stars and black holes
1. White dwarfs – the final state of intermediate mass stars
2. Electron degeneracy pressure
3. Chandrasekhar limit
4. Neutron stars and pulsars
5. Very massive stars and black holes
6. Observed masses for neutron stars and black holes

Lecture 13: Supernovae I
1. What is a supernova – historical note
2. The different types of supernovae observed
3. Typical lightcurves and spectra of supernovae
4. Massive stars and core-collapse supernovae
5. Stellar evolution and progenitor stars

Lecture 14: Supernovae II
1. Type Ia supernovae - thermonuclear explosions
2. Progenitor models for type Ia SNe
3. Supernova surveys and the accelerating Universe
4. Detection of dark energy with Type Ia SNe
Assignment Class II
Sample exam questions and various mathematical problems to aid understanding and learning.