Astrophysics

The Mid-term exam will be held on Wednesday, February 25, 2026, at 14.15-17.00 in M203

The exam will consist of a few questions from the list below plus two problems which will be similar to those solved at home or at class.
You can bring one A4 page with formulae (but with no text and explanations).
A calculator maybe needed for getting numerical results for the problems.

The answers to the questions should contain, e.g., the derivation of some formulae (if that is asked for) and/or a short physical description of what the formula and its different terms mean. There is no need to write a long essay on the topic of the question.

Questions

1. Derivation of the equation of hydrostatic equilibrium.
2. The dynamical, thermal and nuclear timescales (Estimation for the Sun).
3. Derivation of the virial theorem for a spherically symmetric star.
4. Lower limit on the stellar central pressure for density not increasing outwards.
5. Minimum mean stellar temperature. Corresponding values for the Sun.
6. Equation of energy production.
7. Convection. Derivation of Schwarzschild criterion for convective instability.
8. Derivation of the mean molecular weight. Mean molecular weight of ionized hydrogen, ionized helium, and ionized solar composition matter. Mean molecular weight per electron.
9. Estimations of the energy generation rate per unit mass for the Sun and main sequence stars.
10. Nuclear binding energy and its dependence on the masses of nucleus and nucleons. Binding energy per nucleon, its approximate dependence on the nucleon number. Efficiency of energy generation for fusion of H to He in terms of the rest mass.
11. Coulomb barrier. Temperature required for fusion of two protons if quantum effects are absent. Concept of quantum tunneling and Gamov peak.
12. pp-chain.
13. CNO-cycle.
14. He burning. Triple-α reaction.
15. Carbon, oxygen and silicon burning. Formation of the iron-group elements. s- and r-process.
16. Polytropic models of stars. Derivation of the Lane-Emden equation from the equations of hydrostatic equilibrium, mass conservation and the polytropic relation.

17. Lane-Emden equation and its solution for polytropic index n = 0.
18. Mass-Radius relationship for polytropic stars.
19. Eddington standard model.
20. Electron gas degeneracy (non-relativistic and relativistic). Chandrasekhar mass, physical reasons for the existence of the maximum stable mass.
21. The equations of stellar structure.
22. Basic physics of star formation. The Jeans instability, mass, density, length.
23. Protostars and pre-main-sequence stars.
24. The Hayashi track and the Henyey track.
25. Approximate evolutionary tracks of stars of various masses on H-R diagram. Main phases of evolution.
26. Main stages of evolution of solar-mass stars.
27. Approximate description of different evolutionary stages of massive stars and the timescales of nuclear burning.
28. Concept and derivation of Eddington luminosity. The existence of maximum stellar mass and its physical nature.