Theoretical Astrophysics I: Physics of Sun and Stars
Lecture 13: Quiz!!!

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What are we doing today?

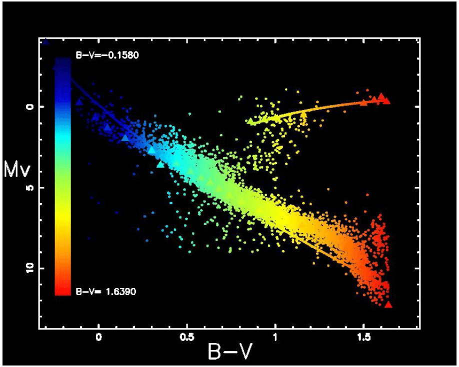
- This will be a set of short questions, numerical problems, theoretical / conceptual questions to test what you remembered and help you prepare for the exam.
- You can expect that the problems at the exam will be somewhat more specific.

Question 1:

If a star is in hydrostatic equilibrium, what two forces are in balance? Derive the appropriate expression.

Question 2:

On the given HR diagram, mark the stars that belong to the main sequence, red giants and white dwarves.



Question 3:

If a blue giant and a red giant star have the same absolute brigthness, and blue giant has effective temperature of 20 000 K, while the red giant has effective temperature of 3 000 K - how do their radii relate?

Question 4:

Write down the equation of state (relationship between pressure, density and temperature) for a gas that only consists of Hydrogen and Helium and is: a) completely ionized; b) completely neutral

Question 5:

Recall the homology relationship between the mass and luminosity of the main sequence stars. What can it tell us about the dependence of the star lifetime on its mass? Which stars live longer, stars of high mass or low mass?

Question 6:

Explain briefly why the red giant phase lasts much shorter than the main sequence phase.

Question 7:

Related to the previous question - how come that we see so many giants then?

Question 8:

Explain the conceptual difference between convective and radiative energy transport.

Question 9:

Starting from the radiative transfer equation:

$$\cos\theta \frac{dI_\nu}{\rho dz} = -\kappa_\nu I_\nu + j_\nu. \tag{1}$$

show that flux density (energy per unit surface per unit time) is proportional to the gradient of temperature and inversely proportional to the mean opacity $\overline{\kappa}$.

Question 9 - Answer:

$$\cos\theta \frac{dI_\nu}{\rho dz} = -\kappa_\nu I_\nu + j_\nu. \tag{2}$$

Dividing the whole equation by κ_ν, multiplying by $\cos\theta$ and integrating over all angles will yield:

$$\frac{4\pi dK_\nu}{\rho\kappa_\nu dz} = -H_\nu. \tag{3}$$

Integrate over frequencies and divide by c to get the gradient of the radiation pressure on the l.h.s. This will necessitate introduction of a mean opacity.

$$\frac{1}{\rho\overline{\kappa}}\frac{dp}{dz} = -\frac{H}{c}. \tag{4}$$

As $p = \frac{1}{3}aT^4$, we can easily see that $H \propto \frac{1}{\overline{\kappa}}T^3\frac{dT}{dz}$.

Question 10:

Name the three most important nuclear reactions / chains of nuclear reactions occurring in main sequence stars. In what kinds of stars do they occur?

Question 11:

Describe shortly what are the end states of stars with 0.3, 1 and 20 solar masses? Explain why.

Question 12:

Stellar structure models are one dimensional and consider all quantities to depend on radius only. Why is this a good approximation for most stars? When is one-dimensionality no longer a good approximation?

Question 13:

There are three evolutionay timescales that arise from the equations of stellar structure. What are they and what do they describe? Describe an evolutionary stage where a star evolves in each one the timescales.

Question 14:

Why does convection (heat transport by fluid motions) occur? Name two physical situations where convection ensues and describe in which kind of stars such situations occur.

Question 15:

Explain what the Chandrasekhar mass is and what happens if it is exceeded.

Question 16:

What are Cepheids and why are they important for astrophysics?

Question 16a:

What are Supernovae Type 1a and why are they important for astrophysics?

Question 16a - answer

Supernovae 1a are an example of the so called "cataclysmically variable" stars. They exhibit a rapid, enormous change in brightness, due to the sudden onset of TN reactions through the accretion of material onto the white dwarf in a binary star system. Due to this specific formation mechanism (the explosion happens as soon as a critical mass is reached), they have very well defined absolute brightness, which makes them a standard candle - similar to Cepheids.

Question 17:

Name two methods how can you estimate the masses of stars from observations.

Question 18:

What is a black body and why you can approximate stars to be black bodies?

Question 18 - Answer

A black body is a theoretical concept of the body that is in thermal equilibrium - it has constant temperature, and all the absorbed energy is emitted back into the space according to Planck's law, that stems from the equlibrium distribution of photons.
For the majority of their volume, stars are so dense, that the photon mean free path is very short, so that the star locally behaves as a black body. Still, due to a temperature gradient, photons are leaking outward. At the surface, stars depart from black bodies, witnessed by the spectral lines and discontinuities in their spectra, but the general shape of the spectra and differences between the spectral classes can still be understood by an approximation of black body radiation.

Question 19:

Name the equations of state that can be used describe the gas in stellar interiors and give examples of star / evolutionary phases where each one is dominant.

Question 20:

How can you determine the ages of stars?