

Study Guide for Test 3

I thought you might find this study guide helpful.

Equations:

You need to know the three equations:

$$d = \frac{3.26 \text{ ly}}{p} \qquad \frac{L}{L_{\odot}} = \left(\frac{T}{T_{\odot}} \right)^4 \left(\frac{R}{R_{\odot}} \right)^2 \qquad L = 4\pi d^2 B$$

The most important thing to know about the last equation is that you can always determine the brightness B , so if you can also get the distance or the luminosity, you can get the other one as well.

Nuclear Physics:

You are also supposed to know that the equation for the nuclear burning (fusion) of hydrogen is given by:



Remember that this process is like “burning” because it requires fuel and heat, but not oxygen. Also remember that neutrinos are fast little particles that can pass through almost anything.

Fusion is incredibly efficient; it makes lots of energy. This is because the nucleus is held together by the strong nuclear force, which is incredibly strong. This force affects protons and neutrons.

Spectra:

Remember that stellar spectra tell us a lot about a star, specifically, it tells us:

- (1) Temperature
- (2) Composition
- (3) Motion (Doppler shift)
- (4) Multiplicity (is it actually a double star?)
- (5) Orbit and masses (using Kepler’s laws and Doppler shift)

Almost all stars, including the Sun are made of (1) Hydrogen, (2) Helium, and (3) everything else, in that order.

Distance methods:

There were three methods discussed for measuring distances:

- Radar distancing Solar system only
- Parallax The nearest stars
- Spectroscopic parallax Most of our galaxy (main sequence stars only)

You should have some idea of how each of these methods work

The Sun

The Sun has several layers inside and outside. Working from the inside out, we have

- The Core – where nuclear fusion happens
- The Radiative Zone – the region outside the core where energy is transported by light
- The Convective Zone – the region higher up where gas circulation moves the heat
- The Photosphere – A thin region, this is the “surface” of the Sun that we see
- The Chromosphere – A cooler region that generates the dark lines in the spectrum
- The Corona – A superhot region surrounding the Sun – it is very thin
- The Solar Wind – Not really part of the Sun, this is gas leaving the Sun

Other features of the Sun:

- Granulation – little regions of circulation on the surface of the Sun
- Sunspots – dark spots on the surface of the Sun, caused by concentrated magnetic energy
- Flares, Prominences, etc. – A variety of features involving concentrated gasses above the surface of the Sun, caused by magnetic fields.
- Solar Cycle – An eleven year cycle caused by fluctuations in the Sun’s magnetic activity, it affects sunspots, flares, prominences, etc.

Temperature, Luminosity, and the Hertzsprung-Russell diagram

The temperature of a star can be determined from the peak of its spectrum, or its color. From hottest to coldest, the temperatures of a star are labeled by a letter called its *spectral type*, which are called O, B, A, F, G, K, M. These have subcategories 0-9, so G2 is hotter than G5 is hotter than K0.

The other parameter which describes a star is its luminosity L , which is how bright it actually is.

The Hertzsprung-Russell diagram is a graph showing the temperature and luminosity of a star, with hot stars on the left and cold on the right, and luminous stars at the top and dim ones at the bottom. We can use the H-R diagram to describe a whole group of stars (which would appear as a collection of dots), or to describe how a star is changing (as motion on the H-R diagram).

If you plot a group of stars on the H-R diagram, about 90 percent of the still-living stars, including the Sun, will be on the *Main Sequence*, which forms a diagonal band from the upper left to the lower right.

Stellar Evolution – General Comments

There are many steps in the evolution of stars. For the most part, all stars evolve pretty much the same way, except that heavy stars do everything faster. Also, for stars heavier than about 8 times then Sun's mass, there are some qualitative differences.

A *star* is something that generates heat by fusion. Anything lighter than about 0.08 times the Sun's mass never gets hot enough to burn by fusion. Anything heavier than about 150 times the Sun's mass burns so quickly it is nearly exploding, so it quickly gets lighter.

Stellar Evolution – Outline

The steps are shown at the right. Two of these stages (shaded yellow) are not really stages of the star (Molecular cloud is the mommy to many stars, and Planetary nebula is the gas that is ejected late in a low-mass star's life). Four stages (shaded blue) are stages where the star is not undergoing nuclear fusion, because either the star isn't "born" yet, or it is already dead.

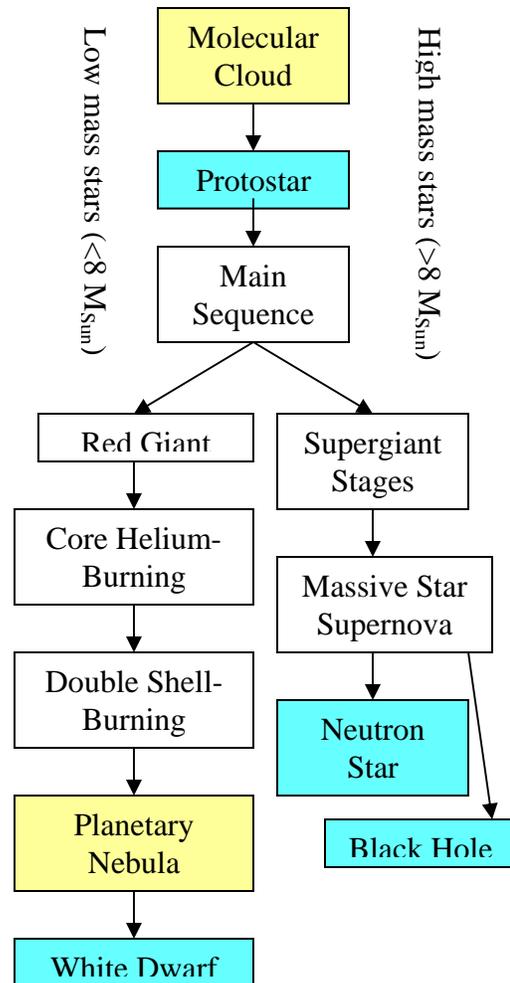
For each of the stages, you should have a pretty good idea of how large the star is (compared to the other stages), and what is going on at the center. The three final stages are called "compact objects" because they are so small (White dwarf: size of Earth; Neutron Star: Size of large city; Black Hole: size of small city)

Double Star Evolution

When two stars are born together, they can affect each other's evolution, but only if they are relatively near each other (a tight binary). Even then, the influence is minimal except when one star or the other star is in its giant stages

When the first star becomes a giant, it may transfer mass to the other star. This can make the stars move together, move apart, or change the lighter star into the heavier star. It's complicated. Eventually the first star dies and becomes a compact object (white dwarf, neutron star, or black hole).

When the second star becomes a giant star, it can transfer its mass to the first star. Because the first star has enormous gravity, the infalling gas can have interesting effects.



These effects depend on which type of compact object you have:

White dwarf: Nova or White Dwarf Supernova

Black Hole: X-Ray binary

Neutron Star: X-Ray binary, X-Ray pulsar, X-Ray burster

In each case, you should have some idea of how they work and why it can produce such spectacular results.

Miscellaneous Facts

Black holes have so much gravity that nothing, not even light, can escape. Probably the most common way to make a black hole is from a massive star supernova from an especially heavy star (30 solar masses or more). These events are probably responsible for gamma ray bursters; spectacularly bright stellar explosions whose details are still unclear. They can also be formed when two neutron stars in a binary system merge.

Giant stars experiencing mass loss (red giant stage and double shell burning stage) are probably the main source of carbon, nitrogen, and oxygen which make up, for example, much of the planets. Heavier elements probably come mostly from supernova explosions (both types).

Degeneracy pressure is a quantum mechanics effect that says that two particles of certain types don't like to be at the same place at the same time. White dwarfs are prevented from collapsing to a point by electron degeneracy pressure. Neutron stars, which contain only neutrons, are held up by neutron degeneracy pressure. Black holes aren't held up by anything – gravity crushes them to a point (we think).