Quiz rules:
  1. You may use one "cheat sheet", **handwritten**, not photocopied or computer-generated, front and back OK. Attach a copy when you turn in (or fax in) your quiz. No other books, notes, etc. (NOT EVEN THIS SHEET!)
  2. You can use a scientific calculator (logs and antilogs (10 to the x); sines and cosines, square roots). No constants or formulas in the memory!
  3. Sign the pledge – no cooperative work, telephone calls, text messages during the quiz, etc.

Constants you should memorize:
    Speed of light (3 E5 km/s);   1 AU = 1.5 E8 km ;   1.6 km = 1 mile;   1 radian ≅ 57.3 deg

Constants you should have on your cheat sheet:
    Gravitational constant G = 6.6 E-11 ;   Mass of Sun = 2 E30 kg; Luminosity of Sun = 4 E26W
    Energy in 1 kg of mass = m c*c = 9 * E16 J! (1 J = 1 Nt-m = 1 kg-m-m/s-s)

You should know:
1. That **nuclear fusion** is the energy source for stars in the largest fraction of their lifetime. The core of a star is in **hydrostatic equilibrium** (i.e. balances **gravity** pushing in and **pressure** pushing out. The pressure comes from the energy given off by the fusion.)
2. What the **Hertzsprung-Russell diagram** is (luminosity vertical versus color, horizontal). Stars that are Hydrogen-burning are on the "**main sequence**" (upper left to lower right).
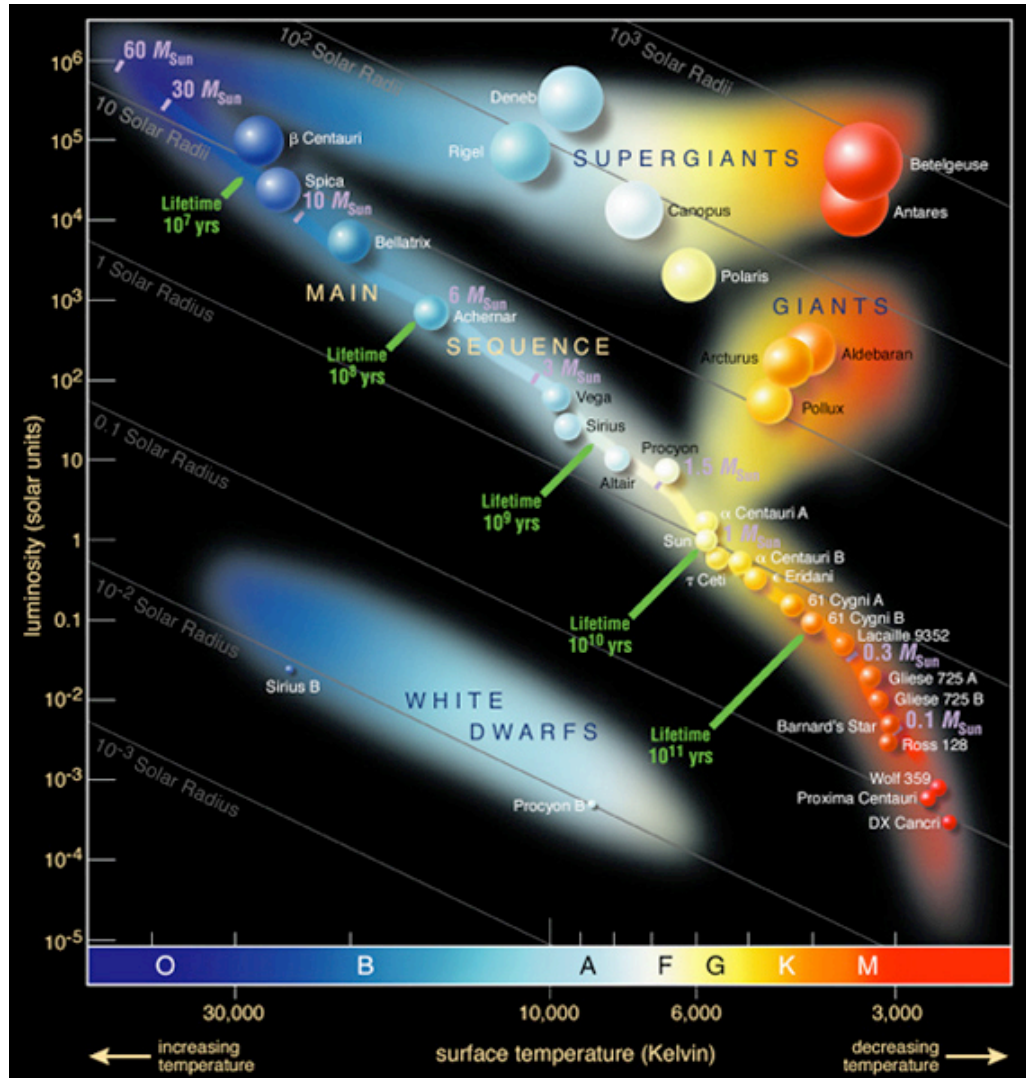
3. That heavy stars are bluer and brighter, and have shorter lifetimes (down to a million years or less). You can then tell the **age of a cluster** by the lifetime of the heaviest star still on the main sequence in the H-R diagram for the group. (heavier stars will have blown up)

4. That smaller stars are **redder and cooler**, and have very long lifetimes (up to hundreds of billions of years).

5. That very small objects (size of Jupiter up to about 20 Jupiter masses) don't have enough mass to start Hydrogen burning. Such small objects are called "planets" if they are around a star; are called "**brown dwarfs**" if they are not.

6. That the reason it takes high pressure, high density to have nuclear fusion is because of the **electrical repulsion** of the nuclei. The attractive nuclear force (**strong force**) is very short range (less than a nm), but that electrical repulsion increases as the distance is compressed, squared.

7.   The smallest stars that have nuclear burning are "**red dwarfs**". They have good mixing in their interiors so will continue nuclear burning until all their Hydrogen is converted into Helium (many billions of years).

8.   **Spectral type** of stars on the main sequence is determined mostly by their **color** (OBAFGKM = Oh, Be A Fine Girl, Kiss Me) (sorry, I didn't make that up).   Can tell Red Giants from Red dwarfs by their spectrum.

9.   **Atomic number** (Z): number of protons in the nucleus. Determines the kind of element (1 = H, 2 = He; 3 = Li; 4 = Be; 5= B; 6= C; 7 = N; 8= O, etc.

10. **Atomic weight** (A): number of protons plus neutrons in the nucleus. **Isotope** = two nuclei having different numbers of neutrons for the same number of protons. Isotopes are chemically the same (i.e. O^{12} has the same chemistry as O^{13}. But because it is heavier, there is less O^{13} in the atmosphere than O^{12}.) An atom is then shown as $_Z Sy^A$, where Sy is the atomic symbol of the element (e.g. C, O, Fe), and Z is the atomic number and A the atomic weight. (Z is really unnecessary because all isotopes of a given element have the same Z).

11. **Chemistry** depends on the electron shells around each element … see the **periodic table**.

(obviously you don't need to memorize the periodic table, but here it is…)
from   http://www.dayah.com/periodic/Images/periodic%20table.png

12. **H-Process nuclear fusion**: changes 4 H nuclei to 1 He nucleus (called an "**alpha particle**") plus two e^+ (positrons = anti-electrons), two neutrinos, plus energy. Positrons allow balance of charge; neutrinos allow balance of energy and momentum. Sometimes called "nuclear burning" but is not really a burning process… burning is oxidation which is chemical, not nuclear. This fusion can proceed in several ways; depending on temperature, etc.

　　see http://hyperphysics.phy-astr.gsu.edu/Hbase/astro/astfus.html

　　or　http://zebu.uoregon.edu/textbook/energygen.html

proton-proton chain: (for cooler stars like our Sun)

$${}_1H^1 + {}_1H^1 \rightarrow D + e^+ + \nu + \gamma \qquad \text{(need two of these reactions)}$$

$${}_1H^1 + {}_1D^2 \rightarrow {}_2He^3 + \gamma \qquad\qquad \text{(need two of these reactions)}$$

$${}_2He^3 + {}_2He^3 \rightarrow {}_2He^4 + {}_1H^1 + {}_1H^1 + \gamma$$

for heavier, hotter stars (or later in their lifetime): **Carbon Chain or CNO cycle** (carbon as catalyst)

$${}_1H^1 + {}_6C^{12} \rightarrow {}_7N^{13} + \gamma$$

$${}_7N^{13} \rightarrow {}_6C^{13} + e^+ + \nu \text{ (decay)}$$

$${}_1H^1 + {}_6C^{13} \rightarrow {}_7N^{14} + \gamma$$

$${}_1H^1 + {}_7N^{14} \rightarrow {}_8O^{15} + \gamma$$

$${}_8O^{15} \rightarrow {}_7N^{15} + e^+ + \nu \text{ (decay)}$$

$${}_1H^1 + {}_7N^{15} \rightarrow {}_6C^{12} + {}_2He^4 + \nu$$
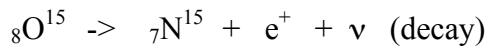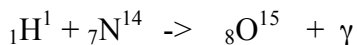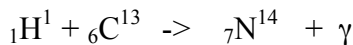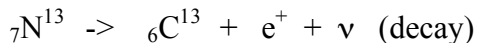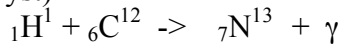
(Both end up changing 4 Hydrogens to one Helium, plus two positrons and neutrinos and gamma rays for energy)

10. Stars the mass of the Sun burn their Hydrogen in a central hot **core** with a **radiative zone** (energy mostly in gamma rays) then a **convective zone** bringing the energy up to the surface, where it is radiated away as visible light at the **photosphere**. This ends up using up all the burning hydrogen in the core, while there is still plenty unburned around it. Dark areas on the photosphere are called **sunspots** and are related to strong **magnetic fields**.

On the Sun, sunspots have an 11-year cycle from max to min and back again; more sunspots is related to more solar activity and more flares. The magnetic field reverses every 11 years, resulting in a 22-year magnetic
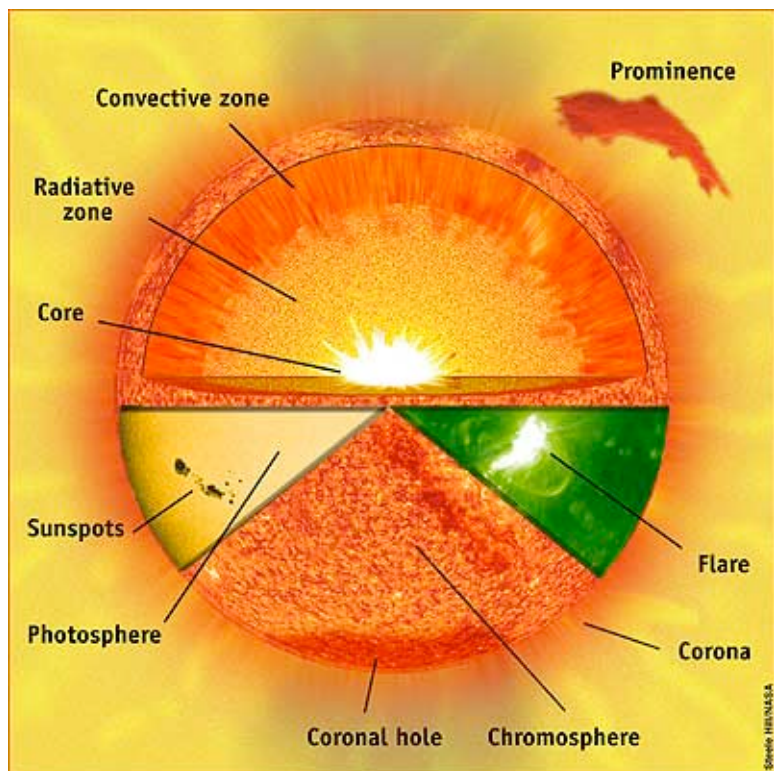
cycle for the Sun.

11. The red colored layer (red from Hydrogen-alpha radiation, 656.3 nm) is the **chromosphere**; the outer very hot (millions of deg K) halo is the **corona**. The long-lived red eruptions are called **prominences** and are seen in H-alpha on the surface as dark **filaments**.

12. **Solar flares** are very energetic eruptions that spew both energetic particles and photons, and release large chunks of the corona in a **Coronal Mass Ejection** (CME). The solar energetic particles (SEP's) arrive at nearly the speed of light; the less energetic but denser CME plasma arrives about 2 days later. Both can be a danger to humans in space, but only the CME contributes to the disruption of the Earth's magnetic field. This area of research is called **space weather**. (See the Space Weather section of your Space Update CD).
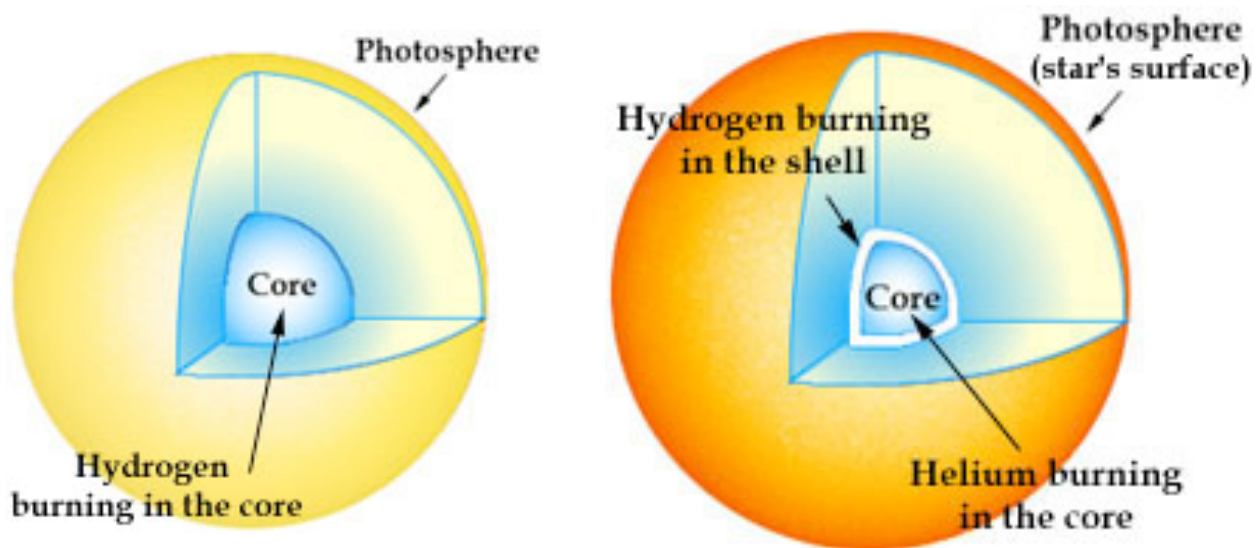
13. **Stellar evolution**: the birth, life, and death of stars.
http://observe.arc.nasa.gov/nasa/space/stellardeath/stellardeath_opening.html
When the hydrogen in the core is consumed, the central pressure falls because fusion stops. This allows the star to collapse, making the core heat up and start to burn heavier nuclei. Helium can be burned to Carbon (called the **triple-alpha process**, because it changes three alpha particles to one Carbon). This burns a LOT hotter and sets the outer zones to Hydrogen burning. This turns the Sun into a Red Giant. Eventually the He in the inner core and the H in the outer core is exhausted, leaving the inner part a **white dwarf**. Further collapse is prevented by something called "electron degeneracy pressure" (the electrons are as tightly packed as they can be). A white dwarf would be about the size of the Earth.
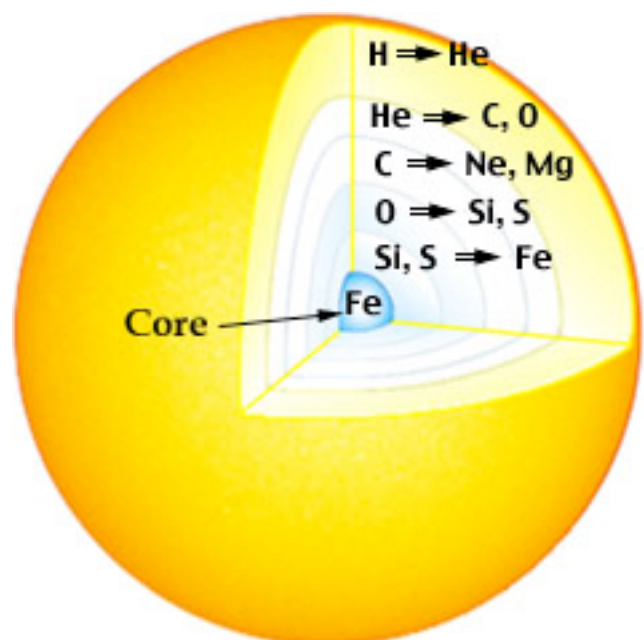
14. Stars a bit heavier than the Sun do a similar thing but become a **red supergiant**. The hot white dwarf is left behind. If material then falls onto it, it can burn the hydrogen quickly as a **nova**. The expanding envelope of material eventually is called a **planetary nebula**.

15. Stars a lot heavier than the Sun (starting about 8 solar masses) also go through a giant stage, until the Helium in their inner core is exhausted. When their helium in their inner core is used up, the core collapses again and starts burning Carbon into iron. The fusion in the core even goes deeper, changing Fe into heavier elements. But since iron is the most stable element, additional fusion takes energy not releases it, so the core collapses faster and the explosion even more incredible, spewing heavy elements into its vicinity. The outer layers start hydrogen and helium burning. This is extremely fast (since very hot and high pressure), causing the outer areas to expand rapidly. Boom! Supernova! A star can be as bright as an entire galaxy. The remnant is a **neutron star**, about the size of the 610 loop. All the electrons are basically pushed into the protons, making the core all neutron matter. Further collapse is prevented by **neutron degeneracy pressure**. If a neutron star has a magnetic field and is rotating, it will become a **pulsar**, sending out beeps of radio noise once per spin (and the spin can be less than a second!). (The Crab nebula, 7000 light years away, is the supernova of 1054, which has a pulsar inside it and pulses in all wavelengths of light, even visible!). The blast of particles from the rapid fusion can make all the elements, even the ones heavier than iron.

16. Stars even more massive than that, cannot hold up their core against neutron degeneracy. The end result is a **black hole**, when the density approaches infinity.

17. A **black hole** becomes so dense that the escape velocity (sqrt(2GM/R)) is greater than the speed of light. The radius where that happens is called the **Schwarzschild radius**, and is about a few km for a remnant the mass of the Sun. This is also the **event horizon**. As material falls into a black hole, it gets traveling faster and faster, emitting X-ray radiation (synchrotron radiation, named after the radiation emitted by energetic particles going in a circle in a particle accelerator). Once the material falls inside the event horizon, we will never see it again (and we can no longer influence its behavior). It's GONE.

18. Know which wavelength bands (of light) get stopped by our atmosphere, so we need to go to outer space to study distant stars and galaxies. Be able to name at least one spacecraft studying the Universe, and which wavelength it is measuring.

19. History: Know that most of the stars and constellations were named by the ancient Babylonians.

20. Know that the radius of the Earth was calculated two thousand years ago, and how. Erasthosthenes knew that the the sun went straight down at well at Syene on the summer solstice (Syene is at 23.5 latitude). He then measured the angle of the sunlight at noon at Alexandria and calculated the radius of the earth by theta/360 = (distance from Syene to Alexandria) / circumference of the Earth – for the graph see http://astrosun2.astro.cornell.edu/academics/courses//astro201/eratosthenes.htm

21. Know what Copernicus's theory was, and how it differed from the accepted model of the Universe of his time. What is an epicycle?

22. Know what four observations of Galileo supported the Copernican theory.   Know why the phases of Venus prove that Venus goes around the Sun.

23. Know that Kepler's laws of planetary motion were empirically discovered but that they can be derived from Newton's laws.

24. Know that the wobble of the Earth's axis is called **precession**, makes the direction of the north pole drift around once in 23,000 years. The direction of the vernal equinox is now in the constellation Pisces, heading to Aquarius (to the ancients it was in Ares). This contributes to the ice ages. This also means that the astrology signs are almost a full month off. The pole star presently is Polaris but for the pyramid builders was Thuban.

25. Know the wavelength bands of light that the major space observatories are studying the universe in (i.e. were you listening to the presentations??)

Be able to calculate:
1. If the Sun puts out 4 E26 Watts of energy (1 W = 1 J/s), how many kg of Hydrogen are being turned into Helium every second?   (don't forget that only 0.007 of the Hydrogen mass is converted to energy)
2. If only 10% of the mass of the Sun is fused in the core, how long will the Sun last before it is used up?
3. If a CME leaves the Sun at 1000 km/s, and doesn't change speed significantly, how long will it take to reach the Earth?
4. What is the escape velocity of the Sun (today) ? = sqrt (2GM/R)