The following should give you a bit of a sampling of the types of test questions I may ask and serve as a review for the topics we've discussed so far this semester. On the test I will supply you with any tables of data, equations, or constants that you could need to complete the questions. For the sake of this review, I'm assuming you can use your book to look these types of things up. You'll likely want to work these through on your own paper except where you need to draw on an image, as I didn't leave you much room. . .

1. The core of the Sun is:
   - A. at the same temperature and density as its surface.
   - B. at the same temperature but much denser than its surface.
   - **C. much hotter and much denser than its surface.**
   - D. constantly rising to the surface through convection.
   - E. composed of iron.

2. What keeps the Sun's outer layers from continuing to fall inward from gravitational collapse?
   - **A. Outward pressure due to super-heated gas**
   - B. The strong force between protons
   - C. Electromagnetic repulsion between protons
   - D. Neutrinos produced by nuclear fusion drag gas outward

3. What is the only force that can overcome the repulsion between two positively charged nuclei to bind them together into an atomic nucleus?
   - **A. The strong force**
   - B. The weak force
   - C. The electromagnetic force
   - D. The gravitational force
   - E. The Coriolis force

4. List the different layers of the Sun, and write a short description of what is happening or what is special about each.

Solution:

The Core: where the fusion happens

The Radiation Zone: where energy is moved outward via radiation (like a hot stove burner)

The Convection Zon: where energy is moved outward via convection currents (like boiling water)

The Photosphere: the "surface" of the Sun. Where light originates from.

The Chromosphere: closest "atmosphere" layer to the Sun. Emits ultraviolet light.

The Corona: outermost "atmosphere" layer. Very hot, and emits x-rays.

5. How does the Sun primarily produce energy?
   - **A. Nuclear fusion through a proton-proton chain**
   - B. Nuclear fusion through the CNO cycle
   - C. Nuclear fission

D. The burning of highly flammable hydrogen

6. Suppose the Sun ran out of fuel and stopped energy production. How long would it take the last neutrinos to reach Earth? How long would it take the last bits of sunlight to reach Earth?

> **Solution:** Neutrinos do not interact with much, so they can leave the core of the Sun immediately with no issue. Thus we would detect a stop in the neutrino production fairly quickly (within minutes to hours). It takes the energy released in the core hundreds of thousands of years to make it to the Sun's surface however, so the Sun could keep shining for maybe another 100,000 years!

7. How many hydrogen atoms does it take to create one helium atom via the proton-proton chain? What else is created in the process?

> **Solution:** It takes 4 hydrogen atoms to create 1 helium atom. In the process, neutrinos and gamma rays are also emitted (2 of each).

8. What would happen in the Sun if the temperature of the core decreased?
   A. The fusion rate decreases, then the core shrinks and heats
   B. The fusion rate decreases, then the core expands and heats
   C. The fusion rate increases, then the core expands and cools
   D. The fusion rate increases, then the core shrinks and heats

9. What is the solar wind?

> **Solution:** An outflowing of charged particles that moves away from the Sun.

10. A computer salesman attempts to convince you to purchase a "solar neutrino" shield for your new computer. Why do you turn down this offer?
    A. Neutrinos rarely, if ever, interact with your computer
    B. There is no such thing as a solar neutrino
    C. Solar neutrinos are generated by solar winds, but we are in a solar minimum currently, so the risk of damage is very low
    D. The Earth's magnetic field already offers excellent protection against the onslaught of solar neutrinos

11. Star A has an apparent magnitude of 5.6 while Star B has an apparent magnitude of 7.1.
    (a) Which star appears brighter in the sky?

    > **Solution:** Star A

    (b) Which star has a higher luminosity?
    A. Star A
    B. Star B
    C. The have the same luminosity
    D. It is impossible to tell

12. What are the standard units for apparent *brightness*?
    - A. Watts
    - B. Joules
    - C. Newtons
    - D. Watts per second
    - **E. Watts per square meter**
13. What are the standard units for luminosity?
    - **A. Watts**
    - B. Joules
    - C. Newtons
    - D. Watts per second
    - E. Watts per square meter
14. Sirius has an apparent magnitude of about -1.46. How many times brighter does Sirius appear in the sky than the star Vega?

    Solution: 3.84 times brighter than Vega

15. You measure the parallax angle of the Star Arcturus to be $0.0889''$. How far away is Arcturus in light-years?

    Solution: 11.24 parsecs, which equates to 36.67 light years.

16. What are the two different methods to calculate a star's luminosity? (*Hint: one depends on its apparent brightness here at Earth and one depends on its temperature*)

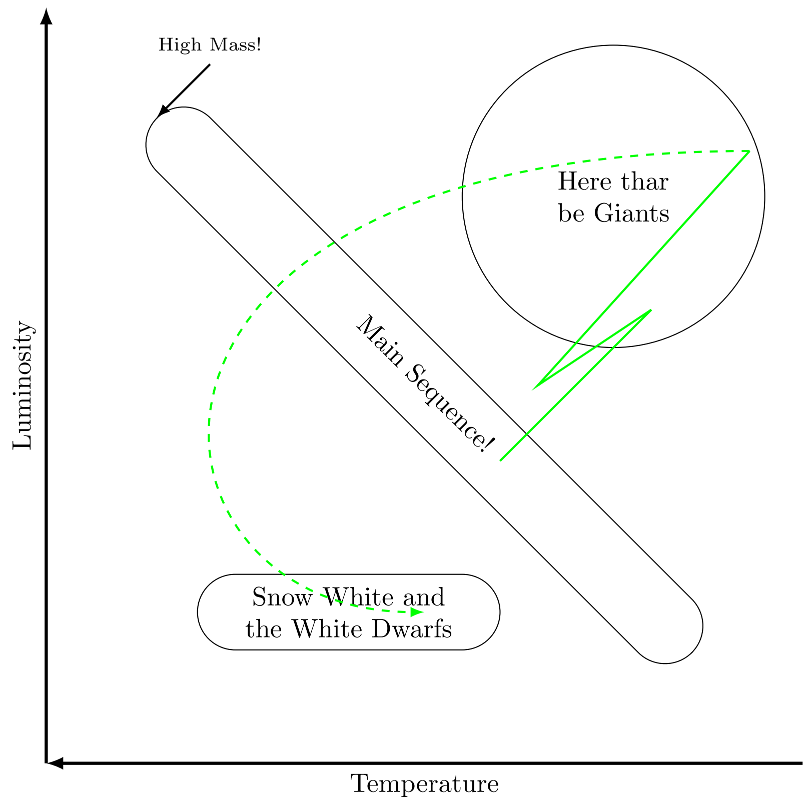
    Solution:
    $$L = \sigma T^4 \times 4\pi R^2 \qquad \text{and} \qquad L = 4\pi d^2 \times B$$

17. What are the major spectral types, in order from hottest to coldest?

    Solution: OBAFGKM

18. Sketch an HR diagram, and mark and label the following areas:
    - (a) Main sequence stars
    - (b) Giants
    - (c) White dwarfs
    - (d) Where are high mass stars on the main sequence?
    - (e) The path a G-type star would follow throughout its lifetime

Solution:



19. How can you tell the age of a star cluster?

Solution: By its main-sequence turn-off point!

20. What is the source of luminosity for proto-stars that have not yet become hot enough for fusion in their cores?
    A. Fission from concentrated radioactive elements
    B. Light absorbed from nearby stars
    C. Energy released by in-falling matter
    D. Fusion in their low-density outer layers

21. What is the minimum mass a proto-star can have to start fusion and become a main sequence star?

Solution: About 8% the mass of the Sun, or $0.08M_\odot$

22. What is the fate of an isolated brown dwarf?
    A. It will become a white dwarf.
    B. It will become a neutron star.

C. It will become a black hole.

D. It will remain a brown dwarf.

23. Describe degeneracy pressure and how it differs from gas pressure. How do both depend on temperature?

Solution: Degeneracy pressure is the pressure that arises from trying to pack electrons or neutrons too tightly into a space. There are so many allowed states for the electrons or neutrons to occupy, so having an excess of electrons/neutrons trying to occupy those spaces results in a sort of traffic jam, and gives the star an outward pressure. This is completely independent of temperature!

Gas pressure on the other hand arises from atoms moving around energetically and bouncing off each other. A higher temperature means they are moving faster, and thus they collide with more force, exerting more pressure. So gas pressure intrinsically depends on the temperature.

24. What happens when a star like the Sun exhausts its core hydrogen supply?

A. Its core contracts, but its outer layers expand and the star becomes bigger and brighter

B. It contracts, becoming smaller and dimmer

C. It contracts, becoming hotter and brighter

D. It expands, becoming bigger but dimmer

E. It contracts, but its outer layers expand and the star becomes bigger but cooler and therefore remains at the same brightness

25. What is a planetary nebula?

A. A disk of gas surrounding a proto-star that may form into planets

B. What is left of its planets after a low-mass star has ended its life

C. The expanding shell of gas that is no longer gravitationally bound to the remnant of a low-mass star

D. The molecular cloud from which proto-stars form

E. The expanding shell of gas that is left when a white dwarf explodes as a supernova

26. Compared to the star it evolved from, a white dwarf is:

A. hotter and brighter.

B. hotter and dimmer.

C. cooler and brighter.

D. cooler and dimmer.

E. the same temperature and brightness.

27. Describe in words the life-cycle of a high mass star, from beginning to end.

Solution: In the beginning, the star is without form. Gravity collapses a cold and dense molecular cloud until the center is dense and hot enough to support hydrogen fusion. At this point the star enters the main sequence. Here it will happily burn for the bulk of it's (admittedly short) life. When the core of the star (where the fusion occurs) runs out of hydrogen, it begins to collapse. This collapse of the core brings a shell of surrounding hydrogen into fusionable temperatures. The energy from the fusing shell puffs up the outer layers of the star even as the core collapses. The star gets cooler and larger, but in such a way that its luminosity stays roughly constant. At some point the core will become hot enough to start fusing helium. Once this occurs, the core will stabilize and the shell burning will reduce, causing the star to shrink some. This continues until the star runs out of helium, at which point its core begins to collapse again. This time, shells of both fusing helium and hydrogen and activated, puffing the outer layers of the star up even larger. Once the core reaches the temperature for the fusion of carbon, it again stabilizes, reduces the shell fusion, and the star shrinks again. This puffing up and shrinking continues again each time the star runs out of fuel in its core. At some point the star will have fused its way all the way up to iron. This is the stopping point, as it is impossible for the star to fuse iron and output energy. Thus, when the core is entirely iron it begins to collapse again, in the hope of igniting a new stage of fusion. But such a stage does not exist, and thus the core keeps on shrinking. The star has enough mass to overcome electron degeneracy pressure, and so at some point in the collapse the core becomes composed entirely of neutrons. Depending on the mass of the star, it may or may not have enough mass to also overcome neutron degeneracy pressure. If it does, then the star will become a black hole, otherwise it will become a neutron star. In the process of the collapse, a terrific amount of energy is radiated outward, taking the outer layers of the star along with it. This outward moving explosion is known as a supernova. So the end state of the high mass star is a supernova remnant, with either a tiny neutron star or black hole at the center.

28. Suppose the star Betelgeuse were to become a supernova tomorrow (as seen here on Earth). What would it look like to the naked eye?

    A. Because the supernova destroys the star, Betelgeuse would disappear from view

    B. We'd see a cloud of gas expanding away from where Betelgeuse used to be. Over a few weeks, this cloud would grow to fill our entire sky.

    C. Betelgeuse would remain a dot of light, but would suddenly become so bright that, for a few weeks, we'd be able to see this dot in the daytime

    D. Betelgeuse would suddenly appear to grow larger in size, soon reaching the size of the full moon. It would also be about as bright as the full moon.

29. How and from what process do we get elements heavier than Iron?

    Solution: Stars can not fuse anything heavier than Iron in their core, so the only time the conditions are reached for heavier elements to be formed is in the massive energies and pressures of a supernova. So everything heavier than iron was once part of a supernova!

30. Why is Iron the end of the road for fusion in massive stars?

    Solution: Iron is the peak of the binding energy curve, which means that energy is released by fusion for lighter elements or by fission for heavier elements. Because stars rely on fusion to produce energy, it is impossible for them to fuse iron into anything heavier and get out energy. Thus iron is the end of the road.

31. Describe two possible events for a white dwarf in a binary system that is stealing mass from another star. What triggers each event?

Solution: When a star is stealing mass from another, most of that mass is going to be in the form of hydrogen. Thus, as the white dwarf steals mass, it is overlaying a thin shell of hydrogen across its surface. As the thickness of the shell increases, so does the temperature of the bottom layer of the shell. At some point, it can become hot enough for hydrogen fusion to take place, and the white dwarf undergoes a nova, shining brightly for several weeks. The star then returns to accreting more mass.

If the star should manage to accrue so much mass that it reaches the Chandrasekhar limit, then it actually becomes hot enough to fuse carbon. Since the entire white dwarf is composed of carbon, this fusion happens nearly instantly throughout the entire star. This causes the white dwarf to explode in a Type I supernova, one of the brightest events in the known universe.

32. White dwarfs are supported against gravity primarily by:
    A. electron degeneracy pressure
    B. neutron degeneracy pressure
    C. gas pressure
    D. rotational pressure

33. Which of the following is closest in size (radius) to a neutron star?
    A. The Sun
    B. The Earth
    C. A city
    D. A football stadium
    E. A basketball

34. Explain what causes the radio pulses that we detect from a pulsar.

Solution: A pulsar is a neutron star whose outgoing radiation has been focused into a narrow beam by its magnetic fields. This beam is similar to the light beam of a lighthouse. Similar to the lighthouse, the neutron star also rotates, causing its beam to sweep across the sky. If the beam should cross the Earth, we see a pulse. Since the neutron star spins at a very reliable (mostly constant) rate, we see pulses at a very regular interval.

35. Which of the following statements about black holes is not true?
    A. If you watch someone else fall into a black hole, you will never see them cross the event horizon. However, they will fade from view as the light they emits becomes more and more redshifted.
    B. If we watch a clock fall toward a black hole, we will see it tick slower and slower as it falls toward the black hole.
    C. The event horizon of a black hole represents a boundary from which nothing can escape
    D. If the Sun magically disappeared and was replaced by a black hole of the same mass, the Earth would soon be sucked into the black hole.
    E. If you fell into a supermassive black hole (so that you could survive the tidal forces), you would experience time to be running normally as you plunged across the event horizon.