Astronomy 104 PRACTICE Final Exam Solutions

Spring Semester 2009

WARNING!

This practice final contains questions focused only on recent material. The real final may contain material covered on earlier exams. Study those as well!

You really don't want to look at these solutions until you have attempted the practice final exam, since the final exam questions will be different than on the practice exam, "memorizing" these solutions is somewhat worthless.

Multiple Choice Questions:

1. What do astronomers mean when they say that we are all "star stuff"?
   a. that Earth formed at the same time as the Sun
   b. that the Universe contains billions of stars
   c. that life would be impossible without energy from the Sun
   d. that the Sun formed from the interstellar medium: the "stuff" between the stars
   e. that the carbon, oxygen, and many elements essential to life were created by nucleosynthesis in stellar cores

2. Where is the Sun in the range of masses for stars?
   a. high-mass star
   b. intermediate-mass star
   c. low-mass star

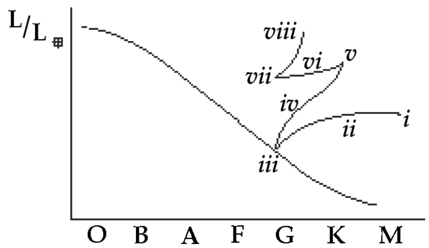
3. What happens when a star exhausts its core hydrogen supply?
   a. Its core contracts, but its outer layers expand and the star becomes bigger and brighter.
   b. It contracts, becoming smaller and dimmer.
   c. It expands, becoming bigger but dimmer.
   d. Its core contracts, but its outer layers expand and the star becomes bigger but cooler and therefore remains at the same brightness.
   e. It contracts, becoming hotter and brighter.

4. Compared to the star it evolved from, a red giant is
   a. cooler and dimmer.
   b. hotter and dimmer.
   c. hotter and brighter.
   d. cooler and brighter.
   e. the same temperature and brightness.

5. Why does a star grow larger after it exhausts its core hydrogen?
   a. Helium fusion in the core generates enough thermal pressure to push the upper layers outward.
   b. Hydrogen fusion in a shell outside the core generates enough thermal pressure to push the upper layers outward.
   c. The internal radiation generated by the hydrogen fusion in the core has heated the outer layers enough that they can expand after the star is no longer fusing hydrogen.
   d. The outer layers of the star are no longer gravitationally attracted to the core.
   e. Helium fusion in a shell outside the core generates enough thermal pressure to push the upper layers outward.

6. What is a planetary nebula?
   a. a disk of gas surrounding a protostar that may form into planets
   b. what is left of the planets around a star after a low-mass star has ended its life
   c. the expanding shell of gas that is no longer gravitationally held to the remnant of a low-mass star
   d. the expanding shell of gas that is left when a white dwarf explodes as a supernova
   e. the molecular cloud from which protostars form

The following questions refer to the H-R diagram below that shows the life track of a 1-solar-mass star, with various stages labeled with Roman numerals.



7. During which stage is the star's energy supplied ***only*** by gravitational contraction?
a. ii
b. vi
c. v
d. iii
e. viii

8. Which stage lasts the longest?
a. iii
b. vi
c. viii
d. i
e. iv

9. What will happen to the 1-solar-mass star after stage viii?
a. It will explode in a supernova.
b. It will collapse to make a neutron star.
c. It will gain mass until it collapses under its own weight.
d. It will eject a planetary nebula.
e. It will begin burning carbon in its core.

10. Which of the following sequences correctly describes the stages of life for a low-mass star?
a. white dwarf, main-sequence, red giant, protostar
b. protostar, main-sequence, white dwarf, red giant
c. protostar, main-sequence, red giant, white dwarf
d. protostar, red giant, main-sequence, white dwarf
e. red giant, protostar, main-sequence, white dwarf

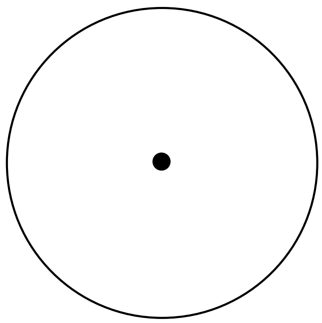
11. Which element has the lowest mass per nuclear particle and therefore cannot release energy by either fusion or fission?
a. hydrogen
b. silicon
c. iron
d. oxygen
e. uranium

12. What types of stars end their lives with supernovae?
a. all stars that are red in color
b. stars that have reached an age of 10 billion years
c. stars that are at least several times the mass of the Sun
d. stars that are similar in mass to the Sun
e. all stars that are yellow in color

13. Which event marks the beginning of a supernova?
a. the onset of helium burning after a helium flash in a star with mass comparable to that of the Sun
b. the beginning of neon burning in an extremely massive star
c. the sudden collapse of an iron core into a compact ball of neutrons
d. the expansion of a low-mass star into a red giant
e. the sudden outpouring of X rays from a newly formed accretion disk

14. What happens to the core of a star after a planetary nebula occurs?

- **a. It becomes a white dwarf.**
- b. It breaks apart in a violent explosion.
- c. It contracts from a protostar to a main-sequence star.
- d. It becomes a neutron star.
- e. none of the above



15. A drawing of a red giant is above. The dot in the center is the core of the sun. The amount of hydrogen *in the core* is

- a. zero
- **b. small, about 10%**
- c. large, around 75%

16. The amount of hydrogen *in the outer layers* of the red giant is

- a. zero
- b. small, around 10%
- **c. large, around 75%**

17. White dwarfs are so called because

- a. it amplifies the contrast with red giants.
- b. they are the end-products of small, low-mass stars.
- c. they are supported by electron degeneracy pressure.
- **d. they are both very hot and very small.**
- e. they are the opposite of black holes.

18. Which of the following is closest in mass to a white dwarf?

- a. Earth
- b. Jupiter
- **c. the Sun**
- d. the Moon

19. You discover a binary star system in which one member is a $15M_{sun}$ main-sequence star and the other star is a $10M_{sun}$ giant. Why should you be surprised, at least at first?

- a. A star with a mass of $15M_{sun}$ is too big to be a main-sequence star.
- **b. The two stars should be the same age, so the more massive one should have become a giant first.**
- c. It doesn't make sense to find a giant in a binary star system.
- d. The two stars in a binary system should both be at the same point in stellar evolution; that is, they should either both be main-sequence stars or both be giants.

20. Which of the following is closest in size (radius) to a neutron star?

- a. a basketball
- b. the Sun
- c. a football stadium
- **d. a city**
- e. the earth

21. What is the basic definition of a black hole?

- a. any object made from dark matter
- **b. any object from which the escape velocity exceeds the speed of light**
- c. a dead galactic nucleus
- d. any compact mass that emits no light
- e. a dead star that has faded from view

22. ________________ stars lose a significant amount of mass after leaving the main sequence.

- a. No
- b. A few
- **c. All**

23. Pulsars are composed of
   a. hydrogen
   b. carbon and oxygen
   c. neutrons
   d. neutrinos

24. [This may go beyond what was covered in lecture.] How does the gravity of an object affect light?
   a. Light coming from a compact massive object, such as a neutron star, will be redshifted.
   b. Visible light coming from a compact massive object, such as a neutron star, will be redshifted, but higher frequencies such as X rays and gamma rays will not be affected.
   c. Light coming from a compact massive object, such as a neutron star, will be blueshifted.
   d. Light doesn't have mass; therefore, it is not affected by gravity.
   e. Less energetic light will not be able to escape from a compact massive object, such as a neutron star, but more energetic light will be able to.

25. Which if the following lengths is closest to the diameter of the disk of the Milky Way?
   a. 1,000 light years
   b. 100 light years
   c. 1,000,000 light years
   d. 100,000 light years
   e. 10,000 light years

26. Approximately how far is the Sun from the center of the galaxy?
   a. 28 light-years
   b. 280 light-years
   c. 28 million light-years
   d. 28,000 light-years
   e. 2,800 light-years

27. Imagine two galaxies, I and II. Galaxy II is twice as far away from us as galaxy I. That means the speed at which Galaxy II is moving away from us is roughly ______ the speed of Galaxy I.
   a. two times
   b. the same as
   c. half

28. The Doppler effect is a change in the __________ a spectra caused by the motion of the light source.
   a. wavelength of spectral lines in
   b. apparent brightness of
   c. luminosity of
   d. speed of the light coming from

29. Why are Cepheid variables important?
   a. Cepheids are supermassive stars that are on the verge of becoming supernovae and therefore allow us to choose candidates to watch if we hope to observe a supernova in the near future.
   b. Cepheids are pulsating variable stars, and their pulsation periods are directly related to their true luminosities. Hence, we can use Cepheids as "standard candles" for distance measurements.
   c. Cepheids are a type of young galaxy that helps us understand how galaxies form.
   d. Cepheid variables are stars that vary in brightness because they harbor a black hole.

30. What is Hubble's law?
   a. The faster a spiral galaxy's rotation speed, the less luminous it is.
   b. How fast a galaxy is moving away from us is directly proportional to its distance from us.
   c. The longer the time period between peaks in brightness, the greater the luminosity of the Cepheid variable star.
   d. The faster a spiral galaxy's rotation speed, the more luminous it is.
   e. The recession velocity of a galaxy is inversely proportional to its distance from us.

31. What is the most accurate way to determine the distance to a nearby star?
   a. main-sequence fitting
   b. Hubble's law
   c. radar ranging
   d. stellar parallax
   e. using Cepheid variables

32. What is the most accurate way to determine the distance to a nearby galaxy?
   a. stellar parallax
   b. radar ranging
   c. using Cepheid variables
   d. Hubble's law

33. What is the most accurate way to determine the distance to a distant galaxy (farther than 50 million parsecs)?
   a. stellar parallax
   b. radar ranging
   c. using Cepheid variables
   d. Hubble's law

   [NOTE: Because all galaxies are moving, the amount of velocity due to the expansion of the universe has to exceed the galaxy's velocity relative to its neighbors before Hubble's law becomes useful.]

34. What kinds of atomic nuclei formed during the era of nucleosynthesis?
   a. only hydrogen
   b. hydrogen and helium and trace amounts of lithium, beryllium, and boron
   c. roughly equal amounts of each of the following: hydrogen, helium, lithium, beryllium, and boron
   d. nuclei of all the chemical elements
   e. only helium

35. Which of the following statements about the cosmic background radiation is not true?
   a. It has a temperature of about 3 degrees K above absolute zero.
   b. It appears essentially the same in all directions (it is isotropic).
   c. It was discovered by Penzias and Wilson in the early 1960s.
   d. It is the result of a mixture of radiation from many independent sources, such as stars and galaxies.
   e. It had a much higher temperature in the past.

36. What are the two key observational facts that led to widespread acceptance of the Big Bang model?
   a. the cosmic background radiation and the expansion of the universe
   b. the predominance of matter over antimatter and the near-critical density of the universe
   c. the cosmic background radiation and the near-critical density of the universe
   d. the predominance of matter over antimatter and the large scale structure of galaxies
   e. the cosmic background radiation and the high helium content of the universe

37. **[This one may go a bit beyond what we covered in class]** Evidence that the cosmic background radiation really is the remnant of a Big Bang comes from predicting characteristics of remnant radiation from the Big Bang and comparing these predictions with observations. **Four of the five statements below are real. Which one is fictitious?**
   a. The cosmic background radiation is expected to have a perfect thermal spectrum, and observations from the COBE spacecraft verify this prediction.
   b. The cosmic background radiation is expected to contain spectral lines of hydrogen and helium, and it does.
   c. The cosmic background radiation is expected to look essentially the same in all directions, and it does.
   d. The cosmic background radiation is expected to have a temperature just a few degrees above absolute zero, and its actual temperature turns out to be about 3 K (actually 2.7 K).
   e. The cosmic background radiation is expected to have tiny temperature fluctuations at the level of about 1 part in 100,000. Such fluctuations were found in the COBE data.

Sketched out Solutions for Discussion Questions on the PRACTICE Final:

Don't assume these solutions would get you 100%. I am just sketching out the key points that would have to be included in a solution.

1. Answer these questions about stellar evolution.
   a. Briefly summarize the stages of life for a low-mass star.

      Protostar → Main Sequence → Red Giant → Planetary Nebula → White Dwar
      I would probably at least briefly describe each stage and maybe state that the main sequence lasts much longer than all the others.

   b. Briefly summarize the stages of life for a high-mass star.

      Protostar → Main Sequence → Red Giant → Supernova → Neutron Star/Black Hole/Nothing?
      I would probably at least briefly describe each stage and maybe state that the main sequence lasts much longer than all the others.

   c. Briefly explain why high-mass stars have shorter lifetimes than low-mass stars.

      Since the mass in high mass stars pushes down on the core (gravitationally) so much more than in low mass stars, the core has to counter by heating up a lot more to produce a balancing outward radiation pressure. Since the core is at a much higher temperature, it fuses the hydrogen <u>much</u> more quickly.

2. Suppose you discovered a star made purely of hydrogen and helium. Would the star be young (like the stars in the disk of the Milky Way), old (like the stars in the halo of the Milky Way), or very old (very old meaning almost the age of the universe)? How old do you think it would be? *Explain.*

   Since we know more recent stars are made of gas consisting at least in part of gas ejected from previous generations of stars, we know recent stars have more heavy elements in them than previous generations of stars. A star with NO heavy elements would have to be a first generation star and exceptionally old.

   SIDE NOTE: It turns out for reasons a bit beyond the scope of the course, these first stars were all MUCH more massive than modern stars (since pure hydrogen and helium don't cool off as easily as hydrogen and helium with a few tenths percent heavier elements), so the gas clouds that collapse to form the first stars have to be huge. Therefore, there are no "first stars" left today.

3. Imagine you observe a white dwarf supernova.

    a. What kind of spectrum (continuous, emission, absorption, or a combination) do you think you will observe, and why? Assume there is nothing between you and the white dwarf.

    Since a white dwarf is very dense, you will initially have a continuous spectrum. As the debris goes outward, the hot dense surface (still producing a mostly continuous spectrum) will be visible through the thinner gas of the ejected material. This thinner gas, made mostly of carbon and oxygen, will cause carbon and oxygen absorption lines to appear in the spectrum. Clever students might realize the absorption lines would be blueshifted, since the material doing the absorption is moving towards us.

    b. How would your answer change if there was a cloud of cold hydrogen gas between you and the supernova?

    You would immediately see hydrogen absorption lines in the spectrum of the supernova. Beyond the scope of what we would expect students to know, but as a clarification, astronomers can distinguish between absorption lines due to material ejected from the star and a gas cloud between us and the white dwarf by examining the redshifts of the spectral lines.

4. Do you think it is possible that a 10-solar-mass main-sequence star could harbor an advanced civilization? *Explain your reasoning.*

    A 10 solar-mass star would have a very short lifetime, probably too short for life to evolve on a planet orbiting it. Since it took about 4.5 billion years for "intelligent life" (assuming you want to call humans "intelligent") to evolve on Earth, you probably need at least a significant fraction of that amount of time for an advanced civilization to evolve on a planet, so you need a low mass star.

5. Explain how it is possible to determine the shape of the Milky Way galaxy when we reside inside it and can't travel outside it.

    Basically, we can count the numbers of stars of various brightness in different directions. Assuming all stars are of similar luminosity (astronomers can correct for this incorrect assumption, but the point is the same), we can know if there are many faint stars that the galaxy extends for quite a distance in that direction. We can also count the total number of stars in various directions to get an idea of the extent of the galaxy.

6. Summarize the links in the distance ladder that allow us to estimate distances to the farthest reaches of the universe.

   The distance ladder is a technique by which we use distance measuring techniques that work closer to earth to bootstrap our way to farther distances. The techniques we used (in order from closest to farthest) are:

   parallax → main sequence fitting (spectroscopic parallax) → Cepheids → Supernova Type Ia → Hubble's Law

7. Explain how the existence of Hubble's law leads us to argue for the existence of a Big Bang or at least for a period where the Universe was much denser than it is today.

   Hubble's Law suggests the universe is currently expanding, that is that it is getting less dense. If we run that clock backwards, it becomes clear the universe was denser in the past. About 13.7 billion years ago, the entire visible universe was within a very tiny volume, so the universe was much denser about 13.7 billion years ago than today.

8. Where did the hydrogen in your body (in the water molecules, mostly) originate and how did it get in your body? How is this story different for carbon? How about for the iron in your blood?

   Hydrogen and Helium → originate in Big Bang
   Carbon, Nitrogen, Oxygen → originate in low mass stars (the CNO in high-mass stars is converted to heavier elements)
   Phosphorus, Iron → originate in high mass stars (where carbon burning and neon burning and silicon burning occur)
   Elements lower down periodic table than Iron (for example, silver and gold) → Originate during supernovas of high mass stars.