Contents

Big ideas

- What produces energy in the sun?
- What will be the sun's future? What is earth's future?
- Luminosity (or size) and temperature determine a star's location on the Hertzsprung-Russell Diagram. Mass and history explain its location.
- Main-sequence stars burn hydrogen like the sun.
- Giants are dying stars. They burn hydrogen in a shell or helium, or heavier elements.
- Some giants spew elements out that eventually form new stars.
- White dwarfs are earth-sized, dead stars. Degenerate electrons produce the pressure.
- Neutron stars are Lansing-sized stars made of degenerate neutrons
- Black holes are so compact that light cannot escape from them.
- Exploding stars, supernovae, spew elements into space.
- Planets form near other stars.
- I am made of primordial hydrogen and material ejected by dying stars.

Not so big ideas on the sun

- Fusion of hydrogen into helium produces energy in the sun.
  - Einstein: E=mc2
  - 1/1,000,000,000 of mass changes into energy in a chemical reaction
  - 4H→He changes 0.7% of mass into energy.
  - Sun burns 10% of its hydrogen in 10 Byr.
- Hans Bethe figured out nuclear reactions in stars in 1930s.
- Parts of the sun (look them up)
- Knowledge of sun's interior comes from observations and models based on physics and observations.
  - GONG probed the solar interior by observing sound waves on the surface that travel into the interior.
  - Center: Energy is produced, T=16MK, density is 160 that of water, depleted H, extra He.
- Sun's magnetic field shows in flares and sun spots.

NSB ideas on Hertzsprung-Russell diagram

- Hertzsprung-Russell Diagram is a plot of stars. Hotter stars are on the left; luminous stars are up.
  - Luminosity depends only on the star. Flux depends on how far we are from the star.
- Hot-plate model of a star: The key physical parameters of a star are temperature and size. A star produces black-body radiation (p114-116)
- Spectral classes OBAFGKM indicate temperature
- Stars come in three types.
- Stars spend most of their life burning hydrogen in the core as main-sequence stars (also called dwarfs).
- Dwarfs are about the same size as the sun

- When stars run out of hydrogen in the core, their internal state changes. They grow in size. They are called giants.
  - Giants are big, sometimes 100 times as big as the sun.
  - Giants burn hydrogen in a shell, helium, or other elements
- White dwarfs are earth-sized, dead stars.
- Main sequence is a mass sequence
  - O stars are massive
  - M stars have least mass
- Hot massive stars live a short life and cool stars live a long time
  - Lifetime=mass/luminosity
  - Comparison: If sun lives 80 years,
  - $30M_{\odot}$ O star lives 4 days
  - Barnard's star ($0.1M_{\odot}$ M star) lives 20,000 yr.
- HR diagram of a star cluster is a snapshot of 100,000 stars born at the same time.
  - Young cluster has hot O stars
  - As a cluster ages, O stars die, then B stars, then A star, etc.
- Life of the sun
  - MS for 10 Byr
  - Giant for 1 Byr
  - Planetary nebula
  - WD
- What will earth be as sun ages?

NSB ideas about white dwarfs, neutron stars, and black holes

1. The more massive a white dwarf is, the smaller it is in diameter.
2. The escape speed from the surface of an object increases with increasing mass and/or decreasing diameter.
3. Pulsars are believed to be rapidly rotating neutron stars.
4. The upper mass limit for a white dwarf star is about 1.4 solar masses. The upper mass limit for a neutron star is about 3 solar masses. There is no upper mass limit for a black hole.
5. Pressure caused by degenerate electrons or degenerate neutrons does not depend upon temperature in the way that ordinary gas pressure does.
6. Mass bends spacetime.

Questions on Chapter 10

1. At the center of the sun, fusion converts hydrogen into ___.
2. Fusion in the sun requires a temperature of thousands, millions, billions Kelvin.
3. The sun is losing mass because___.
4. The sun will use up its hydrogen in thousands, millions, billions, trillions of years.
5. There is more helium in the center of the sun than the surface because__.
6. Will a lead ball sink into the sun (if it did not melt)? Look on p 4 of slides of 3/4/05.
7. Does matter move from the center of the sun to the surface?
8. Is the sun producing carbon now?
9. Why is hot gas in Figure 10.14b confined in loops?
10. What are characteristics of the core, radiation zone, convection zone, photosphere, chromosphere, corona, and solar wind? In which region is Venus?
11. If I shine a flashlight toward the sun, would the light go through the corona?

Questions on Chapter 11

1. Is Rigel (Figure 11.10) a dwarf?

2. If a giant hand replaced the sun with Polaris (Figure 11.10), how would our new sun look different?
3. If a giant hand ripped away half the mass of the sun, how would our new sun look different?
4. Will the sun ever be star like Vega (Figure 11.10)? … like Sirius B?
5. Suppose the sun formed in a star cluster 5 Byrs ago. Sketch the HR diagram 4 Byrs ago. You can use Fig 11.10.
6. If a giant hand moved Vega twice as far as it is, it moves down on the HR diagram. True or false.
7. A dwarf star has twice the mass and 8 times the luminosity as the sun. It will live ___ as long as the sun.
8. Suppose star A and star B are both main sequence stars of the same temperature. Star A is 100 times fainter than star B. Compare the stars' luminosities and distances.
9. On a HR diagram, where are the stars with the largest radii?
10. Two stars, Betty and Wilma, are two main-sequence stars in a cluster. Betty is more luminous. Which is hotter? Which is more massive? Which will die first?
11. Algol is a binary star with a 4-$M_{\odot}$ main-sequence star and a 1-$M_{\odot}$ giant. The two stars formed at the same time. Why is this surprising?

Questions on Chapter 12

1. Why do the oxygen molecules in air move?
2. Why do the electrons in a white dwarf move?
3. A white dwarf has about the same mass as the sun and the same size as the earth. True or false?
4. A neutron star has about the same mass as the sun and the same size as the earth. True or false?
5. If the temperature of the sun cooled suddenly, would the size change?
6. If the temperature of the white dwarf Sirius B cooled suddenly, would its size change?
7. How did the neutron star in the Crab Nebula form?
8. Will the sun become a supernova?
9. Will Spica, which has 12$M_{\odot}$, become a supernova? (See Fig 11.10)
10. Which was a supernova that was visible to the naked eye? 1987A, 1987B, 1054, 1604.
11. Why is having an iron core a disaster for a massive star?
12. What event marks the beginning of a supernova?
13. You ISP205 buddy says, "Betelgeuse (the bright star in the constellation Orion) has become a supernova." What did she see?
14. The sun is a main-sequence star for 10 Byr. How long will it be in the giant phase? How long will it be a in the white dwarf phase?
15. Why are elements with 12, 16, 20, 24, 28 nuclei more abundant in the universe?
16. When will the earth be too hot for humans?

Questions on Chapter 13

1. A compact object with a mass of 1.0 solar mass is likely to be __________.
2. The X-rays seen to come from Cygnus X-1 come from inside the black hole event horizon? T or F?
3. White dwarf stars in close binary star systems can sometimes explode as supernovae? T or F?
4. If you fell inside the event horizon of a black hole, how could you communicate with the outside world?
5. If the sun became a black hole, how would the length of a year on the earth change?
6. Can a neutrino escape from inside the event horizon of a black hole?
7. Which would be bigger in diameter, a white dwarf with a mass of 0.6 solar masses or a white dwarf with a mass of 1.2 solar masses?
8. A pulsar is seen to pulse 20 times a second. How many times a second does that pulsar spin around?

Answers & questions for chapter 10

1. At the center of the sun, fusion converts hydrogen into helium.
2. Fusion in the sun requires a temperature of millions Kelvin.
3. The sun is losing mass because it is changing into energy.
4. The sun will use up its hydrogen in billions of years.
5. There is more helium in the center of the sun than the surface because hydrogen has fused to become helium.
6. Will a lead ball sink into the sun (if it did not melt)? Look on p 4 of slides of 3/4/05. It will sink more than halfway in; at halfway point, density is that of water.
7. Does matter move from the center of the sun to the surface? No; convection zone (where matter moves) does not extend to the center.
8. Is the sun producing carbon now? No
9. Why is hot gas in Figure 10.14b confined in loops? Matter moves parallel to magnetic field lines.
10. What are characteristics of the core, radiation zone, convection zone, photosphere, chromosphere, corona, and solar wind? Read book In which region is Venus? Solar wind
11. If I shine a flashlight toward the sun, would the light go through the corona? Yes; light would reach the photosphere, where it scatters.

Answers & questions for chapter 11

1. Is Rigel (Figure 11.10) a dwarf? Rigel is a giant
2. If a giant hand replaced the sun with Polaris (Figure 11.10), how would our new sun look different? It is a little hotter and a lot bigger and brighter.
3. If a giant hand ripped away half the mass of the sun, how would our new sun look different? The sun would become a K star, which is redder and fainter.
4. Will the sun ever be star like Vega (Figure 11.10)? No; stars do not evolve and move along the main sequence. Will the sun ever be a star like Sirius B? Yes; sun will become a white dwarf.
5. Suppose the sun formed in a star cluster 5 Byrs ago. Sketch the HR diagram of the star cluster 4 Byrs ago. You can use Fig 11.10. HR diagram has stars hotter than the sun up to the tic labeled "Lifetime 1Byr."
6. If a giant hand moved Vega twice as far as it is, it moves down on the HR diagram. True or false. False. Luminosity is an intrinsic property of stars.
7. A dwarf star has twice the mass and 8 times the luminosity as the sun. It will live 2/8=1/4 as long as the sun.
8. Suppose star A and star B are both main sequence stars of the same temperature. Star A is 100 times fainter than star B. Compare the stars' luminosities and distances. Luminosities are same, since temperature is same. For star A to be fainter, it is 10 times as far as B. $Flux=L/D^2$
9. On a HR diagram, where are the stars with the largest radii? Upper right.
10. Two stars, Betty and Wilma, are two main-sequence stars in a cluster. Betty is more luminous. Which is hotter? Which is more massive? Which will die first? Betty for all three.
11. Algol is a binary star with a $4\text{-}M_{\odot}$ main-sequence star and a $1\text{-}M_{\odot}$ giant. The two stars formed at the same time. Why is this surprising? The more massive star should have become a giant first.

Answers & questions for chapter 12

1. Why do the oxygen molecules in air move? They move because they are hot.
2. Why do the electrons in a white dwarf move? They move because they are confined.
3. A white dwarf has about the same as the sun and the same size as the earth. True or false? T
4. A neutron star has about the same as the sun and the same size as the earth. True or false? F; neutron star is same size as Lansing.
5. If the temperature of the sun cooled suddenly, would the size change? Y; pressure would drop.
6. If the temperature of the white dwarf Sirius B cooled suddenly, would its size change? N; pressure stays the same.
7. How did the neutron star in the Crab Nebula form? It formed in a supernova.

8. Will the sun become a supernova? No; not enough mass.
9. Will Spica, which has $12M_{\odot}$, become a supernova? (See Fig 11.10) Yes; it has more than $8M_{\odot}$.
10. Which was a supernova that was visible to the naked eye? 1987A, 1987B, 1054, 1604. All except 1987B.
11. Why is having an iron core a disaster for a massive star? They is no more fuel to burn to supply pressure.
12. What event marks the beginning of a supernova? Collapse of iron core.
13. You ISP205 buddy says "Betelgeuse (the bright star in the constellation Orion) has become a supernova." What did she see? The star, still a dot in the sky, became extremely bright.
14. The sun is a main-sequence star for 10 Byr. How long will it be in the giant phase? How long will it be a in the white dwarf phase? Sun will be a giant for 1 Byr, and then it will be a white dwarf forever.
15. Why are elements with 12, 16, 20, 24, 28 nuclei more abundant in the universe? They are made by adding helium4 to the parent nucleus.
16. When will the earth be too hot for humans? In 1-4Byr, when sun is still a MS star.

Answers and questions on Chapter 13

1. A compact object with a mass of 1.0 solar mass is likely to be a white dwarf.
2. The X-rays seen to come from Cygnus X-1 come from inside the black hole event horizon? F, they come from the accretion disk outside the event horizon.
3. White dwarf stars in close binary star systems can sometimes explode as supernovae? T
4. If you fell inside the event horizon of a black hole, how could you communicate with the outside world?
1. You would be unable to communicate with the outside world if that happened to you.
5. If the sun became a black hole, how would the length of a year on the earth change? The length of a year would be unchanged.
6. Can a neutrino escape from inside the event horizon of a black hole? No, nothing that we know of can go faster than the escape speed of a black hole.
7. Which would be bigger in diameter, a white dwarf with a mass of 0.6 solar mass or a white dwarf with a mass of 1.2 solar masses? The 0,6 solar mass white dwarf would be bigger in diameter.
8. A pulsar is seen to pulse 20 times a second. How many times a second does that pulsar spin around? Also about 20 times a second.