1. In which phase of a star's life are thermonuclear reactions converting hydrogen into helium in the core of a star?
   (a) the main-sequence phase

2. Which group of stars in the H-R diagram would be labeled “zero-age main sequence”?
   (d) stars that have just started converting hydrogen to helium in their cores

3. What causes the core of a star to contract during the main-sequence phase of the star's life?
   (a) The conversion of hydrogen into helium reduces the number of particles in the core.

4. Which of the following statements about the mass and lifetime of a star is true?
   (b) The more massive the star, the faster it will evolve through its life.

5. When a star leaves the main sequence and expands toward the red giant region, what is happening inside the star?
   (a) Hydrogen burning is taking place in a spherical shell just outside the core; the core itself is almost pure helium.

6. Why does it require higher gas temperatures in the core of a star to produce nuclear fusion of helium compared to that required for hydrogen?
   (c) Higher collision speeds are needed to overcome the extra electrostatic repulsion between doubly charged He nuclei.

7. Electron degeneracy, a result of the Pauli exclusion principle that prevents electrons from becoming crowded together beyond a certain limit, is important in
   (a) the core of a low-mass star just before the start of core helium burning.

8. After the start of helium nuclear reactions in its core, what are the conditions in a star compared to those just before these reactions began?
   (d) The star is smaller and hotter.

9. In describing a star, what does the adjective “metal-poor” mean?
   (d) The star has a low abundance of all elements heavier than hydrogen and helium in its spectrum.

10. What is the most important use of Cepheid variables for astronomers?
    (b) The distance to a Cepheid variable can be found very easily.

11. In terms of a star's evolutionary life, an asymptotic giant branch (AGB) star is in the
    (b) helium shell-burning phase.
12. An astronomer plots the HR diagram of a star cluster and finds that it contains hot B-type stars on the main sequence and cooler G- and K-type stars noticeably above the main sequence. This cluster is
(a) very young, because the G and K stars are still evolving toward the main sequence.

13. A planetary nebula is
(c) an expanding gas shell surrounding a hot, white dwarf star.

14. A white dwarf star is generating energy from what source?
(d) It no longer generates energy but is cooling slowly.

15. Which physical phenomenon keeps a white dwarf star from collapsing inward on itself?
(c) electron degeneracy pressure

16. As a white dwarf evolves, the direction of its motion on the Herzsprung-Russell diagram below the main sequence is upper left to lower right, which means that
(c) its size or radius remains constant as it cools and becomes less luminous.

17. Thermonuclear fusion reactions release energy because
(c) the “ash” nucleus produced is more tightly bound than the “fuel” nucleus.

18. Carbon fusion in massive stars combines helium and carbon to produce oxygen. This is followed by oxygen fusion in which oxygen is burned to produce sulfur. Why is a higher temperature required for oxygen fusion than for carbon fusion?
(b) Larger nuclei, like oxygen, have more protons and are therefore repelled more strongly from other nuclei. Thus faster speeds (at higher temperatures) are required to bring these nuclei together than are required for smaller nuclei.

19. Which of the following processes does not happen as a result of core collapse at the end of the life of a massive star?
(c) The helium flash.

20. It is now thought that most elements in the universe heavier than iron in the periodic table
(b) are produced by endothermic nuclear reactions in the shock wave regions surrounding supernova explosions.

21. Which of the following is not true for supernova SN 1987A?
(b) The pulsar in its center is the most rapidly rotating pulsar yet found.

22. The Crab Nebula is a nearby example of what type of physical phenomenon?
(b) remnant of a supernova explosion
23. Type II supernovae show prominent lines of hydrogen in their spectra, whereas hydrogen lines are absent in spectra of Type Ia supernovae. Why is this?  
(b) Massive stars contain large amounts of hydrogen, whereas white dwarfs are mostly carbon and oxygen.

24. What is the relationship between neutron stars and the Chandrasekhar Limit?  
(b) The Chandrasekhar Limit applies only to systems stabilized by degenerate electrons. Neutron stars are stabilized by neutron degeneracy pressure.

25. Neutron stars are believed to be created by  
(b) Type II supernovae.

26. A pulsar’s pulses are produced by  
(d) the rapid rotation of a neutron star that is producing two oppositely directed beams of radiation.

27. The fastest pulsars, called millisecond pulsars, have periods of about 1/1000 second. The reason they pulse so much faster than (for example) the Crab and Vela pulsars is that they  
(d) were spun up by mass transferred on to them from a companion in a binary star system.

28. Glitches are occasionally observed by astronomers studying pulsars. What are these glitches?  
(d) sudden increases in rotation rate

29. The first pulsar was discovered by  
(b) British graduate student, Jocelyn Bell, in 1967.

30. What is “special” about the special theory of relativity?  
(b) It deals only with objects moving in a straight line at constant speed.

31. The Michelson-Morley experiment demonstrated that  
(b) the “ether” did not exist and the speed of light was constant.

32. You are standing on the gangplank of your spaceship on Mars when you see an identical spaceship go past Mars at 90% of the speed of light. When you look closely at this spaceship, how do you find that it compares to your own spaceship?  
(a) The moving spaceship looks shorter, and time on it appears to run more slowly than on yours.

33. Einstein's principle of equivalence in his general theory of relativity asserts that  
(c) being at rest in a gravitational field is equivalent to being in an upwardly accelerated frame of reference in a gravity-free environment.
34. According to general relativity, why does Earth orbit the Sun?  
(c) Space around the Sun is curved and Earth follows this curved space.

35. The Hulse-Taylor binary pulsar shows the existence of  
(c) gravitational waves.

36. If a black hole is truly black and has an escape velocity greater than the speed of light such that no light can escape it, where do the X-rays come from in the black hole candidates so far identified?  
(d) from the matter surrounding the black hole, which is highly condensed and hence very hot because of the intense gravitational field

37. Each of the following is important in detecting stellar-sized black holes in binary systems, except one. Which is the exception?  
(d) The system must rotate at nearly the speed of light.

38. What is the event horizon of a black hole?  
(a) the “surface” from the inside of which nothing can escape

39. The words “Schwarzschild radius” refer to  
(b) the distance from the center of a black hole to where the escape velocity becomes equal to the speed of light.

40. Suppose you were able to lower toward the event horizon of a black hole a clock that emitted a green pulse every second. What would you see as the clock got closer and closer to the event horizon?  
(c) The pulses would slow down and turn red.

41. The unknown factor that misled Herschel into concluding that the stars of the Milky Way were distributed with the Sun at the center of the galaxy was  
(d) the presence of significant interstellar dust, which obscured the more distant stars and thereby localized his observations.

42. The dimensions of the disk of our Milky Way galaxy are  
(d) diameter 160,000 light-years (50 kpc); thickness 2,000 light-years (0.6 kpc).

43. The central bulge of the Milky Way contains  
(c) both Population I and Population II stars, but no young blue stars.

44. The possible presence of a very large amount of unseen (“dark”) matter in the halo of our galaxy is deduced from  
(b) the rotation curve of our galaxy, which indicates constant high orbital speeds in the outer regions of the galaxy.
45. The 21 centimeter line is one of the most important wavelengths in radio astronomy. It is produced mainly in
(a) neutral hydrogen.

46. Harlow Shapley was able to determine the size of the Milky Way and the position of the Sun within it by studying
(c) RR Lyrae variables in globular clusters, thereby determining the distribution of those clusters in the galactic halo.

47. Which of the following is not useful for mapping the locations and shapes of the spiral arms of our galaxy?
(a) the distribution of globular clusters

48. Which of the following statements correctly describes the rotation of our galaxy?
(d) The disk rotates differentially (objects further from the center take longer to complete an orbit than objects closer to the center), and the halo objects have random orbits with no net rotation of the halo about the center of the galaxy.

49. What is microlensing?
(a) the focusing of starlight by the gravitational fields of massive compact halo objects

50. The possible presence of a supermassive black hole at the center of our galaxy has been deduced from
(d) the very high orbital speeds of stars close to the galactic center.
1. Calculate the main-sequence lifetimes of (a) a 10-\(M_\odot\) star and (b) a 0.5-\(M_\odot\) star. Compare these lifetimes with that of the Sun.

**For a star with a mass of 10-\(M_\odot\), its main-sequence lifetime is**

\[ t = \frac{1}{M^{2.5}} = \frac{1}{(10)^{2.5}} = 0.003 \text{ times the main sequence lifetime of the Sun.} \]

**For a star with a mass of 0.5-\(M_\odot\), its main-sequence lifetime is**

\[ t = \frac{1}{M^{2.5}} = \frac{1}{(0.5)^{2.5}} = 5.7 \text{ times the main sequence lifetime of the Sun.} \]

2. The distance to the LMC is about 50,000 pc. The absolute magnitude of SN1987A at its brightest was about \(-15\). What was its apparent magnitude when it was at its brightest? The naked-eye limit is about apparent magnitude = 6. According to your calculations should SN1987A have been visible to the naked-eye?

\[ m = M + 5 \log d - 5 = (-15) + 5 \log (50,000) - 5 = 3.5 \]

Since this is brighter than the naked-eye limit, yes, it was visible to the naked-eye.

3. A pulsar’s period is \(6 \times 10^{-1}\) sec and it is increasing at a rate of \(3 \times 10^{-12}\) s/s. Calculate the approximate age of this pulsar. Could Galileo (1564-1642) have seen the supernova that created this pulsar?

\[ T = \frac{P}{2R} = \frac{(6 \times 10^{-1} \text{ sec})}{(2 \times 3 \times 10^{-12} \text{ s/s})} = 1 \times 10^{11} \text{ sec} = 3175 \text{ years} \]

The supernova occurred thousands of years ago, so, no, Galileo could not have seen it.
4. If a black hole were to have the same size as the Earth ($R_E = 6,378$ km), how massive would it be?

$$R_{sch} = \frac{(2GM)}{c^2} = 3 \text{ km} \ (M/M_\odot),$$
so $M/M_\odot = \frac{R_{sch}}{3 \text{ km}} = \frac{6,378 \text{ km}}{3 \text{ km}} = 2126$

The black hole would be 2126 $M_\odot$.

5. A gas cloud located in the spiral arm of a distant galaxy is observed to have an orbital velocity of 400 km/s. If the cloud is 20,000 pc from the center of the galaxy and is moving in a circular orbit, what is the mass of the galaxy contained within the cloud’s orbit?

$$v = 400 \text{ km/s} = 4 \times 10^5 \text{ m/s} \text{ and } R = 20,000 \text{ pc} = 6.2 \times 10^{20} \text{ m}$$

$$M = \frac{(Rv^2)}{G}$$
$$= \frac{(6.2 \times 10^{20} \text{ m})(4 \times 10^5 \text{ m/s})^2}{(6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2})}$$
$$= 1.5 \times 10^{42} \text{ kg} = 7.4 \times 10^{11} M_\odot$$