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1. At what location in the space around a black hole does the escape velocity become equal to the speed of light?
   A. at the point where escaping X rays are produced
   B. at the point where clocks are observed to slow down by a factor of 2
   C. *at the event horizon
   D. at the singularity

2. Why are the majority of stars in the sky in the main-sequence phase of their lives?
   A. *This is the longest-lasting phase in each star’s life
   B. Most stars die at the end of the main-sequence phase
   C. This is the only phase that is common to all stars
   D. Most stars in the sky were created at about the same time, so they are all in the same phase of their lives

3. What is a red giant?
   A. a large, red star burning hydrogen into helium in its core
   B. a protostar in the “upper right” part of the Hertzsprung-Russell diagram
   C. a large emission nebula
   D. *a star burning hydrogen into helium in a shell around the core
4. After the helium flash in a red giant, the stars contracts because
   A. energy radiated to space during the helium flash cools the entire star, making it contract.
   B. The electrons in the core become degenerate during the helium flash, reducing the volume occupied by the core
   C. The helium flash uses most of the helium in the star’s core, reducing the energy produced in the core
   D. *The star’s deep interior expands and cools during the helium flash, reducing the energy produced by the hydrogen burning shell

5. An astronomer studying a globular cluster plots its stars on a Hertzsprung-Russel diagram and finds that certain stars in the cluster lie on the horizontal branch. What does this astronomer immediately know about these stars?
   A. They are still contracting toward the main sequence
   B. They are burning hydrogen into helium in their cores
   C. *They are burning helium into carbon and oxygen in their cores
   D. They are burning helium into carbon and oxygen in a shell around their cores

6. In the process of helium shell fusion in low-mass stars near the end of their lives, the stars moves upward and to the right on the asymptotic giant branch of the Hertzsprung-Russell diagram. In this process, the star is
   A. contracting, cooling, and hence becoming less luminous
   B. expanding, heating, and becoming more luminous
   C. *expanding, cooling, and becoming more luminous
   D. contracting, becoming hotter and much less luminous

7. The event that follows the asymptotic giant branch (AGB) phase in the life of a low-mass star is:
   A. *the ejection of a planetary nebula
   B. core collapse and a supernova explosion
   C. helium flash and the start of helium burning in the core
   D. the onset of hydrogen burning in the core

8. The major source of light in the expanding shell of gas in a planetary nebula is
   A. *fluorescence of the atoms, caused by UV light from the hot central white dwarf star
   B. reflection and scattering of the light of the central white dwarf star from dust and gas in the shell
   C. thermal heating of the dust grains by radiation from the hot central star
   D. thermonuclear reactions in this hot gas, caused by the underlying explosion

9. The stars that eventually become white dwarfs are those that start life with masses of less than
   A. 1.4 solar masses
   B. 3 solar masses
   C. 25 solar masses
D. *4 solar masses

10. Which of the following stars would you classify as a population II star?
   A. a star with approximately the same abundance of heavy elements as the Sun
   B. any member of an open star cluster
   C. *a star with very low abundance of heavy elements
   D. a star with a much higher abundance of heavy elements than the Sun

11. Which of the following processes is NOT involved in the supernova explosion of a massive star?
   A. passage of a shock wave through the star’s envelope
   B. *helium flash in the star’s core, when 3 helium nuclei combine
   C. photodisintegration of nuclei by gamma rays
   D. collapse of the star’s core

12. A pulsar is most probably formed
   A. in the core of a star as it evolves through its main sequence phase
   B. *in the center of a supernova explosion
   C. within a huge gas cloud, by collisions between stars
   D. just after the formation of a protostar by gravitational condensation

13. The main reason for the observed slowdown of Crab pulsar is
   A. the slow expansion and redistribution of mass, similar to a spinning skater who spreads her arms outward
   B. a slow buildup of the magnetic field as rotational energy is transferred to magnetic energy
   C. *the loss of rotational energy through the emission of beams of charged particles
   D. friction between the stellar surface and the surrounding nebular material.

14. Glitches are occasionally observed by astronomers studying pulsars. What are these glitches?
   A. clumps of denser material in the jets emitted along the magnetic poles
   B. sudden flares caused by matter falling onto the surface of the neutron star
   C. secondary pulses of radiation occasionally interspersed with the primary pulses
   D. *sudden increases in rotation rate

15. In some binary star systems, such as Algol, the less massive star is a red giant and the more massive star is on the main sequence. This is evidence that
   A. *mass transfer has occurred from one star to another
   B. the more massive star formed later, from a disk of gas surrounding the less massive star.
   C. The more massive star captured the other one into orbit some time after the two stars had formed
   D. Stars evolve differently in binary star systems, with less massive stars evolving faster than more massive stars
16. The difference between a nova and an X-ray burst is that
   A. a nova involves an explosion on the surface of a neutron star, whereas an X-ray burst involved an explosion on the surface of a white dwarf
   B. a nova involves an explosion on the surface of a neutron star, whereas an X-ray burst involves the complete collapse of a neutron star to form a black hole
   C. *a nova involves an explosion on the surface of a white dwarf, whereas an X-ray burst involves an explosion on the surface of a neutron star
   D. a nova involves the complete explosive destruction of a white dwarf, whereas an X-ray burst involves an explosion on the surface of the white dwarf.

17. The X-rays from pulsating X-ray sources are believed to arise from
   A. hot spots in an accretion disk around a rapidly precessing neutron star, created when the jets of charged particles from the neutron star’s poles pass across the accretion disk
   B. a hot spot on a normal star, caused by intense radiation from an orbiting neutron star
   C. hot spots on neutron star’s equator, caused by matter falling inward from an accretion disk around the neutron star
   D. *hot spots at the magnetic poles of a neutron star, caused by matter from a companion star traveling down the neutron star’s magnetic field.

18. Suppose you are on board a spaceship that is passing the Earth at 80% the speed of light. You see a clock on the Earth tick off five seconds. How much time elapsed on your clock while this was happening?
   A. 5 seconds-the same as on the Earth’s clock
   B. less than 5 seconds if you are approaching the Earth, or more than 5 seconds if you are moving away
   C. less than 5 seconds
   D. *more than 5 seconds

19. A clock is moving across your line of sight with its face turned toward you. Each of the following statement about this clock, as seen by you, is true except one. Which statement is incorrect?
   A. The clock will run slow compared to a clock in your hand
   B. The clock will appear shorter than it would if it were at rest
   C. *The clock will appear thinner, front to back, than it would if it were at rest
   D. The clock will appear more dense than it would if it were at rest

20. How does a gravitational field affect the passage of time?
   A. Gravity has no effect on the passage of time
   B. Clocks in a gravitational field run faster than clocks outside the field
   C. Gravity makes time stop
   D. *Clocks in a gravitational field run slower than clocks outside the field

21. According to general relativity, why does the Earth orbit the Sun?
   A. *Space around the Sun is curved and the Earth follow this curved space
B. The Sun exerts a gravitational force on the Earth across empty space
C. Matter contains quarks, and the Earth and Sun attract each other with the “color force” between their quarks
D. The Earth and Sun are continually exchanging photons of light in a way that holds the Earth in orbit

22. How does the diameter of a black hole (size of the event horizon) depend on the mass inside the black hole?
   A. the greater the mass, the smaller the diameter
   B. the greater the mass, the greater the diameter up to the mass limit for a black hole; above that mass the black hole collapses
   C. the diameter does not depend on the mass
   D. *the greater the mass, the greater the diameter

23. How many properties of the matter inside a black hole can be measured from outside the black hole?
   A. 4
   B. only 1
   C. *3
   D. 6

24. How do rotating black holes DIFFER from nonrotating black holes?
   A. Rotating black holes have a region just inside the event horizon in which nothing can be at rest
   B. *Rotating black holes have a region juts outside the event horizon in which nothing can be at rest
   C. Rotating black holes have a magnetic field due to the spin of electrically charged matter
   D. Not at all-the only property that distinguishes one black hole from another is mass, not spin

25. Rotating Black Holes can have accretion disks. Magnetic field lins connect the black holes with the disk. What, if anything, can be transferred between the rotating black hole and its accretion disk?
   A. *Particles and energy can be transferred, but only from the disk to the black hole, never from the hole to the disk
   B. Particles and energy can be transferred in either direction
   C. Rotational energy and angular momentum can be transferred from the black hole to the accretion disk
   D. Nothing will change

26. Harlow Shapley determined the position of the Sun in the galaxy by measuring the distances to 93 globular clusters of stars. How did Shapley obtain the distances to these very distant clusters?
   A. *He measured the apparent brightness and pulsation periods of RR Lyrae stars in the clusters
B. He plotted the apparent brightness and spectral classes of a sample of the stars in each cluster on a Hertzsprung-Russell diagram.
C. He measured the proper motion and radial velocity of each globular cluster.
D. He measured the apparent brightness of the brightest red giant stars in each cluster.

27. Approximately how far is the Sun from the center of our galaxy?
   A. 49 kpc
   B. 2 kpc
   C. *8 kpc
   D. 160 kpc

28. Where would you look in our galaxy to find older, metal-poor stars?
   A. in the disk and spiral arms
   B. everywhere in the galaxy
   C. *in the globular clusters in the galactic halo
   D. only at the galactic center

29. In our galaxy, young metal-rich stars are found
   A. *in the disk and spiral arms
   B. everywhere is the galaxy
   C. only at the galactic center
   D. in the globular clusters, in the galactic halo

30. Which of the following components best outline the spiral arms of the galaxy?
   A. *young O and B stars, dust and gas
   B. globular clusters
   C. predominantly solar-type stars
   D. white dwarf stars

31. The Sun’s location in our galaxy is
   A. *in the disk of the galaxy, inside a spiral arm or segment of a spiral arm
   B. in the disk of the galaxy, between and well away from any spiral arm
   C. we cannot tell where we are located because our view is too severely blocked by interstellar dust
   D. in the halo, somewhat above and outside of the spiral arms

32. The possible presence of a very large amount of unseen (“dark”) matter in the halo of our galaxy is deduced from
   A. the unexpected absence of luminous matter (stars, etc.) beyond a certain distance
   B. *the rotation curve of our galaxy, which indicates higher than expected orbital speeds in the outer regions of the galaxy
   C. the rotation curve of our galaxy, which shows that orbital speeds in the outer parts of the galaxy decrease in a way that follows Kepler’s law
   D. the unexpected high amount of interstellar absorption in certain directions
33. What is a Cepheid variable star?
   A. *a high mass star that pulsates regularly in brightness
   B. one of several classes of stars that pulsate randomly in brightness
   C. a star that normally remains constant in brightness but occasionally flares up in brightness by several magnitudes
   D. a low-mass horizontal-branch star that pulsates regularly in brightness

34. One difficulty with the density wave theory is that
   A. the theory fails to explain why a given spiral pattern lasts only a small fraction of the lifetime of a galaxy
   B. it fails to provide a mechanism for star formation
   C. *there is no mechanism proposed to provide the energy output necessary to sustain the density wave
   D. it fails to explain the distribution of Population I and Population II stars in the galaxy

35. The center of our Milky Way Galaxy can be observed most easily at which of the following wavelengths?
   A. Ultraviolet light
   B. Hydrogen Balmer Hα light
   C. *Infrared and radio radiation
   D. Highly penetrating gamma rays

36. Much of the mass of our galaxy appears to be in the form of “dark matter” of unknown composition. At present this matter can be detected only because
   A. it bends light from distant galaxies and quasars
   B. it emits synchrotron radiation
   C. *its gravitational pull affects orbital motions of matter in the galaxy
   D. it blocks out the light from distant stars in the plane of our galaxy

37. In a star like our Sun, the final phase of the life cycle will be a
   A. black hole
   B. neutron star
   C. *white dwarf
   D. any of the above is possible
   E. pulsar

38. One of the conclusions from the mass-luminosity relationship is that
   A. *bright main sequence stars are more massive than faint main sequence stars
   B. giants are more massive than main sequence stars
   C. giants are more massive than white dwarfs
   D. main sequence stars are more massive than white dwarfs
   E. all of the above are true

39. Neutron stars
   A. are among the brightest stars we know of
B. obey the mass-luminosity relation  
C. obey the period-luminosity relation  
D. *often emit radio waves in two narrow beams  
E. none of the above

40. An astronomer observing a star cluster in the Galaxy could do which of the following to determine the age of the cluster?  
A. *construct an HR diagram for the cluster  
B. count the number of cepheids in the cluster  
C. measure the Doppler shifts of many stars in the cluster  
D. wait for a supernova in the cluster and measure its light curve  
E. check the radial and transverse velocities

41. After a second red giant stage, an old solar-mass star will gently eject its outer layers, leaving behind a hot, small stellar  
A. nova  
B. *planetary nebula  
C. pulsar  
D. supernova remnant  
E. T Tauri

42. A B-type star leaves the main sequence due to  
A. exploding as a supernova  
B. *the depletion of hydrogen in its core  
C. the onset of helium burning  
D. the onset of the CNO cycle  
E. none of the above

43. Unlike low-mass stars, more massive stars  
A. do not run out of hydrogen in their cores before they die  
B. *eventually burn carbon in their cores  
C. never burn helium in their cores  
D. never burn hydrogen in their cores  
E. end their lives by fissioning the of Uranium

44. Horizontal-branch stars, which have a range of temperatures with luminosities between 50 and 100 times that of the Sun, are in what stage of their lives?  
A. hydrogen shell burning, with a degenerate helium core  
B. *core helium burning  
C. gravitational contraction before the start of core hydrogen burning  
D. core hydrogen burning

45. Interstellar dust obscures our view of distant regions of space at optical wavelengths. Which of the following statements is true concerning this dust obscuration?  
A. *Distant regions are severely obscured only in the plane of the galaxy  
B. Distant regions are obscured roughly uniformly over the whole sky
C. Distant regions are obscured randomly over the whole sky, individual absorbing dust clouds showing no preference for one particular directions or plane
D. Distant regions are obscured the least in the plane of the galaxy, and are strongest when we look out in the galactic halo, at right angles to this plane.

46. Which of the following is not a characteristic of the stars of the disk component of our galaxy?
   A. circular orbits
   B. randomly inclined orbits
   C. higher metal abundance
   D. young stars
   E. star formation regions