**The Bizarre Stellar Graveyard**

18.1 Multiple-Choice Questions

1) Degeneracy pressure is the source of the pressure that stops the crush of gravity in all the following *except*

A) a brown dwarf.

B) a white dwarf.

C) a neutron star.

D) a very massive main-sequence star.

E) the central core of the Sun after hydrogen fusion ceases but before helium fusion begins.

Answer: D

2) White dwarfs are so called because

A) they are both very hot and very small.

B) they are the end-products of small, low-mass stars.

C) they are the opposite of black holes.

D) it amplifies the contrast with red giants.

E) they are supported by electron degeneracy pressure.

Answer: A

3) A teaspoonful of white dwarf material on Earth would weigh

A) the same as a teaspoonful of Earth-like material.

B) about the same as Mt. Everest.

C) about the same as Earth.

D) a few tons.

E) a few million tons.

Answer: D

4) Which of the following is closest in mass to a white dwarf?

A) the Moon

B) Earth

C) Jupiter

D) Neptune

E) the Sun

Answer: E

5) Why is there an upper limit to the mass of a white dwarf?

A) White dwarfs come only from stars smaller than 1.4 solar masses.

B) The more massive the white dwarf, the greater the degeneracy pressure and the faster the speeds of its electrons. Near 1.4 solar masses, the speeds of the electrons approach the speed of light, so more mass cannot be added without breaking the degeneracy pressure.

C) The more massive the white dwarf, the higher its temperature and hence the greater its degeneracy pressure. At about 1.4 solar masses, the temperature becomes so high that all matter effectively melts, even individual subatomic particles.

D) The upper limit to the masses of white dwarfs was determined through observations of white dwarfs, but no one knows why the limit exists.

E) Above this mass, the electrons would be pushed together so closely they would turn into neutrons and the star would become a neutron star.

Answer: B

6) What is the ultimate fate of an isolated white dwarf?

A) It will cool down and become a cold black dwarf.

B) As gravity overwhelms the electron degeneracy pressure, it will explode as a nova.

C) As gravity overwhelms the electron degeneracy pressure, it will explode as a supernova.

D) As gravity overwhelms the electron degeneracy pressure, it will become a neutron star.

E) The electron degeneracy pressure will eventually overwhelm gravity and the white dwarf will slowly evaporate.

Answer: A

7) Suppose a white dwarf is gaining mass because of accretion in a binary system. What happens if the mass someday reaches the 1.4-solar-mass limit?

A) The white dwarf undergoes a catastrophic collapse, leading to a type of supernova that is somewhat different from that which occurs in a massive star but is comparable in energy.

B) The white dwarf, which is made mostly of carbon, suddenly becomes much hotter in temperature and therefore is able to begin fusing the carbon. This turns the white dwarf back into a star supported against gravity by ordinary pressure.

C) The white dwarf immediately collapses into a black hole, disappearing from view.

D) A white dwarf can never gain enough mass to reach the limit because a strong stellar wind prevents the material from reaching it in the first place.

Answer: A

8) Which of the following statements about novae is *not* true?

A) A star system that undergoes a nova may have another nova sometime in the future.

B) A nova involves fusion taking place on the surface of a white dwarf.

C) Our Sun will probably undergo at least one nova when it becomes a white dwarf about 5 billion years from now.

D) When a star system undergoes a nova, it brightens considerably, but not as much as a star system undergoing a supernova.

E) The word nova means "new star" and originally referred to stars that suddenly appeared in the sky, then disappeared again after a few weeks or months.

Answer: C

9) What kind of pressure supports a white dwarf?

A) neutron degeneracy pressure

B) electron degeneracy pressure

C) thermal pressure

D) radiation pressure

E) all of the above

Answer: B

10) What is the upper limit to the mass of a white dwarf?

A) There is no upper limit.

B) There is an upper limit, but we do not yet know what it is.

C) 2 solar masses

D) 1.4 solar masses

E) 1 solar mass

Answer: D

11) How does a 1.2-solar-mass white dwarf compare to a 1.0-solar-mass white dwarf?

A) It has a larger radius.

B) It has a smaller radius.

C) It has a higher surface temperature.

D) It has a lower surface temperature.

E) It is supported by neutron, rather than electron, degeneracy pressure.

Answer: B

12) Which of the following is closest in size (radius) to a white dwarf?

A) Earth

B) a small city

C) a football stadium

D) a basketball

E) the Sun

Answer: A

13) What kind of star is most likely to become a white-dwarf supernova?

A) an O star

B) a star like our Sun

C) a binary M star

D) a white dwarf star with a red giant binary companion

E) a pulsar

Answer: D

14) Observationally, how can we tell the difference between a *white-dwarf supernova* and a *massive-star supernova*?

A) A massive-star supernova is brighter than a white-dwarf supernova.

B) A massive-star supernova happens only once, while a white-dwarf supernova can repeat periodically.

C) The spectrum of a massive-star supernova shows prominent hydrogen lines, while the spectrum of a white-dwarf supernova does not.

D) The light of a white-dwarf supernova fades steadily, while the light of a massive-star supernova brightens for many weeks.

E) We cannot yet tell the difference between a massive-star supernova and a white-dwarf supernova.

Answer: C

15) After a massive-star supernova, what is left behind?

A) always a white dwarf

B) always a neutron star

C) always a black hole

D) either a white dwarf or a neutron star

E) either a neutron star or a black hole

Answer: E

16) A teaspoonful of neutron star material on Earth would weigh

A) about the same as a teaspoonful of Earth-like material.

B) a few tons.

C) more than Mt. Everest.

D) more than the Moon.

E) more than Earth.

Answer: C

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

A) Earth

B) a city

C) a football stadium

D) a basketball

E) the Sun

Answer: B

18) Which of the following best describes what would happen if a 1.5-solar-mass neutron star, with a diameter of a few kilometers, were suddenly (for unexplained reasons) to appear in your hometown?

A) The entire mass of Earth would end up as a thin layer, about 1 cm thick, over the surface of the neutron star.

B) It would rapidly sink to the center of Earth.

C) The combined mass of Earth and the neutron star would cause the neutron star to collapse into a black hole.

D) It would crash through Earth, creating a large crater, and exit Earth on the other side.

E) It would crash into Earth, throwing vast amounts of dust into the atmosphere which in turn would cool Earth. Such a scenario is probably what caused the extinction of the dinosaurs.

Answer: A

19) From an observational standpoint, what is a *pulsar*?

A) a star that slowly changes its brightness, getting dimmer and then brighter with a period of anywhere from a few hours to a few weeks

B) an object that emits flashes of light several times per second or more, with near perfect regularity

C) an object that emits random "pulses" of light that sometimes occur only a fraction of a second apart and other times stop for several days at a time

D) a star that changes color rapidly, from blue to red and back again

E) a star that rapidly changes size as it moves off the main sequence

Answer: B

20) From a theoretical standpoint, what is a pulsar?

A) a star that alternately expands and contracts in size

B) a rapidly rotating neutron star

C) a neutron star or black hole that happens to be in a binary system

D) a binary system that happens to be aligned so that one star periodically eclipses the other

E) a star that is burning iron in its core

Answer: B

21) What causes the radio pulses of a pulsar?

A) The star vibrates.

B) As the star spins, beams of radio radiation sweep through space. If one of the beams crosses Earth, we observe a pulse.

C) The star undergoes periodic explosions of nuclear fusion that generate radio emission.

D) The star's orbiting companion periodically eclipses the radio waves emitted by the main pulsar.

E) A black hole near the star absorbs energy and re-emits it as radio waves.

Answer: B

22) How do we know that pulsars are neutron stars?

A) We have observed massive-star supernovae produce pulsars.

B) Pulsars and neutron stars look exactly the same.

C) No massive object, other than a neutron star, could spin as fast as we observe pulsars spin.

D) Pulsars have the same upper mass limit as neutron stars do.

E) none of the above

Answer: C

23) What is the ultimate fate of an isolated pulsar?

A) It will spin ever faster, becoming a millisecond pulsar.

B) As gravity overwhelms the neutron degeneracy pressure, it will explode as a supernova.

C) As gravity overwhelms the neutron degeneracy pressure, it will become a white dwarf.

D) It will slow down, the magnetic field will weaken, and it will become invisible.

E) The neutron degeneracy pressure will eventually overwhelm gravity and the pulsar will slowly evaporate.

Answer: D

24) What is the basic definition of a *black hole*?

A) any compact mass that emits no light

B) a dead star that has faded from view

C) any object from which the escape velocity exceeds the speed of light

D) any object made from dark matter

E) a dead galactic nucleus that can only be viewed in infrared

Answer: C

25) How does the gravity of an object affect light?

A) Light doesn't have mass; therefore, it is not affected by gravity.

B) Light coming from a compact massive object, such as a neutron star, will be redshifted.

C) Light coming from a compact massive object, such as a neutron star, will be blueshifted.

D) 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.

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.

Answer: B

26) How does a black hole form from a massive star?

A) During a supernova, if a star is massive enough for its gravity to overcome neutron degeneracy of the core, the core will be compressed until it becomes a black hole.

B) Any star that is more massive than 8 solar masses will undergo a supernova explosion and leave behind a black-hole remnant.

C) If enough mass is accreted by a white-dwarf star so that it exceeds the 1.4-solar-mass limit, it will undergo a supernova explosion and leave behind a black-hole remnant.

D) If enough mass is accreted by a neutron star, it will undergo a supernova explosion and leave behind a black-hole remnant.

E) A black hole forms when two massive main-sequence stars collide.

Answer: A

27) 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 him or her cross the event horizon. However, he or she will fade from view as the light he or she emits (or reflects) 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 nearer to the black hole.

C) A black hole is truly a hole in spacetime, through which we could leave the observable universe.

D) If the Sun magically disappeared and was replaced by a black hole of the same mass, Earth would soon be sucked into the black hole.

E) If you fell into a black hole, you would experience time to be running normally as you plunged rapidly across the event horizon.

Answer: D

28) In some cases, a supernova in a binary system may lead to the eventual formation of an *accretion disk* around the remains of the star that exploded. All of the following statements about such accretion disks are true *except*

A) X rays are emitted by the hot gas in the accretion disk.

B) the accretion disk consists of material that spills off the companion star.

C) the central object about which the accretion disk swirls may be either a neutron star or a black hole.

D) several examples of flattened accretion disks being "fed" by a large companion star can be seen clearly in photos from the Hubble Space Telescope.

E) the radiation from an accretion disk may vary rapidly in time.

Answer: D

29) When we see X rays from an accretion disk in a binary system, we can't immediately tell whether the accretion disk surrounds a neutron star or a black hole. Suppose we then observe each of the following phenomena in this system. Which one would force us to immediately *rule out* the possibility of a black hole?

A) bright X-ray emission that varies on a time scale of a few hours

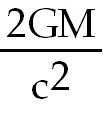
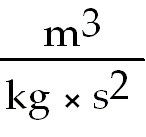
B) spectral lines from the companion star that alternately shift to shorter and longer wavelengths

C) sudden, intense X-ray bursts

D) visible and ultraviolet light from the companion star

Answer: C

30) What is the Schwarzschild radius of a 100 million-solar-mass black hole? The mass of the Sun is about 2 × 1030 kg, and the formula for the Schwarzschild radius of a black hole of mass *M* is:

Rs =  (G = 6.67 × 10-11 ; c = 3 × 108 m/s)

A) 3 km

B) 30 km

C) 3,000 km

D) 300 million km

E) 3 million km

Answer: D

31) A 10-solar-mass main-sequence star will produce which of the following remnants?

A) white dwarf

B) neutron star

C) black hole

D) none of the above

Answer: B

32) What do we mean by the *singularity* of a black hole?

A) There are no binary black holes—each one is isolated.

B) An object can become a black hole only once, and a black hole cannot evolve into anything else.

C) It is the center of the black hole, a place of infinite density where the known laws of physics cannot describe the conditions.

D) It is the edge of the black hole, where one could leave the observable universe.

E) It is the "point of no return" of the black hole; anything closer than this point will not be able to escape the gravitational force of the black hole.

Answer: C

33) How do we know what happens at the event horizon of a black hole?

A) Physicists have created miniature black holes in the lab.

B) Astronomers have sent spacecraft through the event horizon of a nearby black hole.

C) Astronomers have analyzed the light from matter within the event horizon of many black holes.

D) Astronomers have detected X rays from accretion disks around black holes.

E) We don't know for sure: we only know what to expect based on the predictions of general relativity.

Answer: E

34) Prior to the 1990s, most astronomers assumed that gamma-ray bursts came from neutron stars with accretion disks. How do we now know that this hypothesis was wrong?

A) We now know that gamma-ray bursts come not from neutron stars but from black holes.

B) Theoretical work has proven that gamma rays cannot be produced in accretion disks.

C) Observations from the Compton Gamma-Ray Observatory show that gamma-ray bursts come randomly from all directions in the sky.

D) Observations from the Compton Gamma-Ray Observatory show that gamma-ray bursts occur too frequently to be attributed to neutron stars.

E) Observations from the Compton Gamma-Ray Observatory have allowed us to trace gamma-ray bursts to pulsating variable stars in distant galaxies.

Answer: C

35) Why do astronomers consider gamma-ray bursts to be one of the greatest mysteries in astronomy?

A) because they are so rare

B) because we know they come from pulsating variable stars but don't know how they are created

C) because the current evidence suggests that they are the most powerful bursts of energy that ever occur anywhere in the universe, but we don't know how they are produced

D) because current evidence suggests that they come from our own Milky Way, but we have no idea where in the Milky Way they occur

E) because current evidence suggests that they come from massive black holes in the centers of distant galaxies, adding to the mystery of black holes themselves

Answer: C

An advanced civilization lives on a planet orbiting a close binary star system that consists of a 15*M*Sun red giant and a 10*M*Sun black hole. Assume that the two stars are quite close together, so that an accretion disk surrounds the black hole. The planet on which the civilization lives orbits the binary star at a distance of 10 AU.

36) Sometime within the next million years or so, their planet is likely to be doomed because

A) jets of material shot out of the accretion disk will shoot down their planet.

B) their planet receives most of its energy from the red giant. However, this star will soon be completely devoured in the accretion disk and thus will no longer exist.

C) the red giant will probably undergo a supernova explosion within the next million years.

D) tidal forces from the black hole will rip the planet apart.

E) the planet's orbit gradually will decay as it is sucked in by the black hole.

Answer: C

37) One foolhardy day, a daring major (let's call him Tom) in the space force decides to become the first of his race to cross the event horizon of the black hole. To add to the drama, he decides to go in wearing only a thin space suit, which offers no shielding against radiation, no cushioning against any forces, and so on. Which of the following is most likely to kill him first (or at least cause significant damage)? (*Hint*: The key word here is *first*. Be sure to consider the distances from the black hole at which each of the noted effects is likely to become damaging.)

A) the crush of gravity at the singularity embedded within the black hole

B) the tidal forces due to the black hole

C) the strong acceleration as he descends towards the black hole

D) the X rays from the accretion disk

E) the sucking force from the black hole, which will cause his head to explode

Answer: D

38) Through a bizarre (and scientifically unexplainable) fluctuation in the spacetime continuum, a copy of a book titled *Iguoonos: How We Evolved* appears on your desk. As you begin to read, you learn that the book describes the evolution of the people living in the star system described above. In the first chapter, you learn that these people evolved from organisms that lived 5 billion years ago. Which of the following statements should you expect to find as you continue to read this book?

A) As a result of traumatic experiences of their evolutionary ancestors, they dislike television.

B) Their immediate ancestors were chimpanzees.

C) They found that the presence of two stars in their system was critical to their evolution.

D) They evolved on a different planet in a different star system and moved to their current location.

E) They evolved from primitive wormlike creatures that had 13 legs, 4 eyes, and bald heads, thus explaining why such critters are now considered a spectacular delicacy.

Answer: D

39) If you were to come back to our Solar System in 6 billion years, what might you expect to find?

A) a red giant star

B) a white dwarf

C) a rapidly spinning pulsar

D) a black hole

E) Everything will be pretty much the same as it is now.

Answer: B

40) Black holes, by definition, cannot be observed directly. What observational evidence do scientists have of their existence?

A) Theoretical models predict their existence.

B) Gravitational interaction with other objects.

C) Space is, overall, very black.

D) We have sent spacecraft to nearby black holes.

E) We have detected neutrinos from them.

Answer: B

18.2 True/False Questions

1) Brown dwarfs, white dwarfs, and neutrons stars are all kept from collapsing by degeneracy pressure.

Answer: TRUE

2) The upper limit to the mass of a white dwarf is 1.4 solar masses.

Answer: TRUE

3) More massive white dwarfs are smaller than less massive white dwarfs.

Answer: TRUE

4) There is no upper limit to the mass of a neutron star.

Answer: FALSE

5) The remnant left behind from a white-dwarf supernova is a neutron star.

Answer: FALSE

6) Our Sun will likely undergo a nova event in about 5 billion years.

Answer: FALSE

7) All pulsars are neutron stars, but not all neutron stars are pulsars.

Answer: TRUE

8) Neutron stars are the densest objects that we can observe in the universe.

Answer: TRUE

9) No visible light can escape a black hole, but things such as gamma rays, X rays, and neutrinos can.

Answer: FALSE

10) Light from white dwarfs shows a gravitational redshift.

Answer: TRUE

11) All massive-star supernovae leave behind black holes as remnants.

Answer: FALSE

12) Planets have been detected around a pulsar.

Answer: TRUE

18.3 Short Answer Questions

1) Could our Sun ever undergo a nova or a white-dwarf supernova event? Why or why not?

Answer: No, because both events occur on white dwarfs in close binary systems. Even after our Sun becomes a white dwarf, such events won't occur because our Sun is not part of a close binary.

2) Why does the size of a white dwarf decrease with increasing mass?

Answer: A massive white dwarf has a stronger gravitational force that compresses the matter within it to a greater density. The degeneracy pressure that supports a white dwarf against collapse increases as the density increases and reaches a balance (if the mass is less than the Chandrasekhar limit) such that the more massive the white dwarf, the smaller it is.

3) Briefly describe how a nova event occurs.

Answer: A white dwarf in a close binary system accretes mass from its companion star. This mass is mostly hydrogen from the companion's outer layers. When enough builds up on the white-dwarf surface, the hydrogen undergoes fusion, generating the nova.

4) Why do white-dwarf supernovae all have the same maximum luminosity?

Answer: White-dwarf supernovae occur when the mass of the white dwarf has just exceeded 1.4 *M*Sun. Since the mass is the same and the entire object–made of degenerate matter–explodes at once, the maximum luminosity is the same.

5) What is an X-ray burster? What causes the X-ray bursts?

Answer: It is a neutron star in a close binary system; the bursts are caused by helium fusion on the surface of the neutron star.

6) What would happen if a small piece (say the size of a paper clip) of neutron star material struck Earth?

Answer: The extremely dense material could not be supported by the ordinary material on Earth and it would plunge to the center of Earth under the action of gravity. Its momentum would carry it past the center, back to the other side and it would continue to oscillate back and forth through Earth creating a small hole each time (that would rapidly fill with molten rock) until friction finally brought it to rest at the center of Earth.

7) Suppose you find an X-ray binary that exhibits X-ray bursts. Is it possible that the system's X-ray binary consists of a red giant and a black hole? Why or why not?

Answer: No, because bursts occur on a surface; a black hole has no surface.

8) Briefly describe what you would see if your friend plunged into a black hole.

Answer: As he approached the black hole, he would be stretched by tidal forces, his time would run slow, and light coming from him would be redshifted. The closer he got to the event horizon, the slower time would run. You would never see him cross the event horizon, but he would disappear from view when his light became redshifted out of the range of detection.

9) Why would Earth's orbit be unaffected were the Sun to suddenly become a black hole?

Answer: Earth's orbit (and those of the other planets) would remain unchanged since they are far enough away that Newton's law of gravity applies and the gravitational force depends only on the masses of the objects and the distance between them, not on their composition or density.

10) What is the evidence that gamma-ray bursts originate from beyond the Milky Way Galaxy?

Answer: The distribution of gamma-ray bursts is distributed uniformly on the sky, unlike the distribution of X-ray binaries, neutron stars, and other objects within the Galaxy. Further, the afterglow of some gamma-ray bursts have now been detected and detailed observations at other wavelengths show that they are located at the position (and redshift) of distant galaxies.

11) *Process of Science*: How were neutron stars discovered?

Answer: They were detected as pulsars due to their beams of radiation.

12) *Process of Science*: Can we ever really know what happens within the event horizon of a black hole?

Answer: No, because no light can escape and we can therefore never make observations and test predictions for what happens within the event horizon.

13) *Process of Science:* Describe a hypothetical observation of a white dwarf that, if made and verified by others, would dramatically challenge our physical understanding of them.

Answer: The discovery of a white dwarf with a mass greater than the Chandrasekhar limit.

18.4 Mastering Astronomy Reading Quiz

1) A white dwarf is

A) a precursor to a black hole.

B) an early stage of a neutron star.

C) what most stars become when they die.

D) a brown dwarf that has exhausted its fuel for nuclear fusion.

Answer: C

2) A typical white dwarf is

A) as large in diameter as the Sun but only about as massive as Earth.

B) as massive as the Sun but only about as large in size as Earth.

C) about the same size and mass as the Sun but much hotter.

D) as massive as the Sun but only about as large in size as Jupiter.

Answer: B

3) If you had something the size of a sugar cube that was made of white dwarf matter, it would weigh

A) as much as a truck.

B) about 5 pounds.

C) as much as the entire Earth.

D) as much as an average person.

Answer: A

4) The *maximum* mass of a white dwarf is

A) about the mass of our Sun.

B) limitless; there is no theoretical limit to the maximum mass of a white dwarf.

C) about 3 times the mass of our Sun.

D) about 1.4 times the mass of our Sun.

Answer: D

5) What is an *accretion disk*?

A) any flattened disk in space, such as the disk of the Milky Way Galaxy

B) a disk of hot gas swirling rapidly around a white dwarf, neutron star, or black hole

C) a stream of gas flowing from one star to its binary companion star

D) a disk of material found around every white dwarf in the Milky Way Galaxy

Answer: B

6) According to our modern understanding, what is a *nova*?

A) an explosion on the surface of a white dwarf in a close binary system

B) the explosion of a massive star at the end of its life

C) the sudden formation of a new star in the sky

D) a rapidly spinning neutron star

Answer: A

7) Suppose that a white dwarf is gaining mass through accretion in a binary system. What happens if the mass someday reaches the 1.4 solar mass limit?

A) The white dwarf will collapse in size, becoming a neutron star.

B) The white dwarf will undergo a nova explosion.

C) The white dwarf will explode completely as a white dwarf supernova.

D) The white dwarf will collapse to become a black hole.

Answer: C

8) A neutron star is

A) the remains of a star that died by expelling its outer layers in a planetary nebula.

B) a star made mostly of elements with high atomic mass numbers, so that they have lots of neutrons.

C) the remains of a star that died in a massive star supernova (if no black hole was created).

D) an object that will ultimately become a black hole.

Answer: C

9) A typical neutron star is more massive than our Sun and about the size (radius) of

A) a small asteroid (10 km in diameter).

B) Earth.

C) the Moon.

D) Jupiter.

Answer: A

10) If you had something the size of a sugar cube that was made of neutron star matter, it would weigh

A) about 50 pounds.

B) as much as the entire Earth.

C) about as much as a truck.

D) about as much as a large mountain.

Answer: D

11) Pulsars are thought to be

A) accreting white dwarfs.

B) rapidly rotating neutron stars.

C) unstable high-mass stars.

D) accreting black holes.

Answer: B

12) How is an X-ray burst (in an X-ray binary system) similar to a nova?

A) Both involve explosions on the surface of stellar corpse.

B) Both typically recur every few hours to every few days.

C) Both are thought to involve fusion of hydrogen into helium.

D) Both result in the complete destruction of their host stars.

Answer: A

13) What is the basic definition of a *black hole*?

A) a dead star that has faded from view

B) any object made from dark matter

C) an object with gravity so strong that not even light can escape

D) a compact mass that emits no visible light

Answer: C

14) Based on current understanding, the *minimum* mass of a black hole that forms during a massive star supernova is roughly

A) 0.5 solar masses.

B) 1.4 solar masses.

C) 3 solar masses.

D) 10 solar masses.

Answer: C

15) What do we mean by the *event horizon* of a black hole?

A) It is the very center of the black hole.

B) It is the distance from the black hole at which stable orbits are possible.

C) It is the place where X rays are emitted from black holes.

D) It is the point beyond which neither light nor anything else can escape.

Answer: D

16) Imagine that our Sun were magically and suddenly replaced by a black hole of the same mass (1 solar mass). What would happen to Earth in its orbit?

A) Earth would almost instantly be sucked into oblivion in the black hole.

B) Earth would orbit faster, but at the same distance.

C) Earth would slowly spiral inward until it settled into an orbit about the size of Mercury's current orbit.

D) Nothing—Earth's orbit would remain the same.

Answer: D

17) What do we mean by the *singularity* of a black hole?

A) It is the center of the black hole, a place of infinite density where the known laws of physics cannot describe the conditions.

B) It is the "point of no return" of the black hole; anything closer than this point will not be able to escape the gravitational force of the black hole.

C) It is the edge of the black hole, where one could leave the observable universe.

D) The term is intended to emphasize the fact that an object can become a black hole only once, and a black hole cannot evolve into anything else.

Answer: A

18) What makes us think that the star system Cygnus X-1 contains a black hole?

A) It emits X rays characteristic of an accretion disk, but the unseen star in the system is too massive to be a neutron star.

B) No light is emitted from this star system, so it must contain a black hole.

C) The fact that we see strong X-ray emission tells us that the system must contain a black hole.

D) Cygnus X-1 is a powerful X-ray burster, so it must contain a black hole.

Answer: A

19) The *Schwarzschild radius* of a black hole depends on

A) the observationally measured radius of the black hole.

B) the way in which the black hole formed.

C) only the mass of the black hole.

D) both the mass and chemical composition of the black hole.

Answer: C

20) Scientists have detected thousands of gamma ray bursts. The evidence suggests that most or all of these bursts

A) have occurred in the central regions of the Milky Way.

B) have occurred in distant galaxies.

C) come from the same types of close binary systems that produce X-ray bursts.

D) come from the Oort cloud surrounding the Sun.

Answer: B

21) Which of the following statements about electron degeneracy pressure and neutron degeneracy pressure is true?

A) Electron degeneracy pressure is the main source of pressure in white dwarfs, while neutron degeneracy pressure is the main source of pressure in neutron stars.

B) Both electron degeneracy pressure and neutron degeneracy pressure help govern the internal structure of a main-sequence star.

C) The life of a white dwarf is an ongoing battle between electron degeneracy pressure and neutron degeneracy pressure.

D) In a black hole, the pressure coming from neutron degeneracy pressure is slightly greater than that coming from electron degeneracy pressure.

Answer: A

18.5 Mastering Astronomy Concept Quiz

1) Which of the following statements about degeneracy pressure is not true?

A) Degeneracy pressure can continue to support an object against gravitational collapse even if the object becomes extremely cold.

B) Degeneracy pressure arises from a quantum mechanical effect that we don't notice in our daily lives.

C) Black holes form when gravity overcomes neutron degeneracy pressure.

D) Degeneracy pressure can arise only from interactions among electrons.

Answer: D

2) The more massive a white dwarf, the

A) higher its temperature.

B) smaller its radius.

C) larger its radius.

D) higher its luminosity.

Answer: B

3) Which of the following best describes why a white dwarf cannot have a mass greater than the 1.4-solar-mass limit?

A) Electron degeneracy pressure depends on the speeds of electrons, which approach the speed of light as a white dwarf's mass approaches the 1.4-solar-mass limit.

B) White dwarfs get hotter with increasing mass, and above the 1.4-solar-mass limit they would be so hot that even their electrons would melt.

C) White dwarfs are made only from stars that have masses less than the 1.4-solar-mass limit.

D) The upper limit to a white dwarf's mass is something we have learned from observations, but no one knows why this limit exists.

Answer: A

4) The white dwarf that remains when our Sun dies will be mostly made of

A) hydrogen.

B) helium.

C) carbon.

D) neutrons.

Answer: C

5) Which statement about accretion disks is *not* true?

A) The gas in the inner parts of the disk travels faster than the gas in the outer parts of the disk.

B) The gas in the inner parts of the disk is hotter than the gas in the outer parts of the disk.

C) The primary factor determining whether a white dwarf has an accretion disk is the white dwarf's mass.

D) Accretion disks are made primarily of hydrogen and helium gas.

Answer: C

6) According to present understanding, a *nova* is caused by

A) hydrogen fusion on the surface of a white dwarf.

B) carbon fusion in the core of a white dwarf.

C) hydrogen fusion on the surface of a neutron star.

D) a white dwarf that gains enough mass to exceed the 1.4-solar-mass limit.

Answer: A

7) Which of the following is *not* true about differences between novae and supernovae?

A) Novae are much less luminous than supernovae.

B) Supernovae eject gas into space but novae do not.

C) Novae occur only in binary star systems, while supernovae can occur both among single stars and among binary star systems.

D) The same star can undergo novae explosions more than once, but can undergo only a single supernova.

Answer: B

8) Will our Sun ever undergo a white dwarf supernova explosion? Why or why not?

A) Yes, right at the end of its double-shell burning stage of life.

B) Yes, about a million years after it becomes a white dwarf.

C) No, because it is not orbited by another star.

D) No, because the Sun's core will never be hot enough to fuse carbon and other heavier elements into iron.

Answer: C

9) Which of the following *best* describes what would happen if a 1.5-solar-mass neutron star, with a diameter of a few kilometers, were suddenly (for unexplained reasons) to appear in your home town?

A) The entire Earth would end up as a thin layer, about 1 cm thick, over the surface of the neutron star.

B) It would rapidly sink to the center of Earth.

C) The combined mass of Earth and the neutron star would cause the neutron star to collapse into a black hole.

D) It would crash into Earth, throwing vast amounts of dust into the atmosphere that, in turn, would cool Earth; this is probably what caused the extinction of the dinosaurs.

Answer: A

10) Each *Voyager* spacecraft carries a "postcard" designed to be understandable to any aliens that might someday encounter it. On the "postcard," scientists pinpointed the location of Earth by triangulating it between pulsars. Why did the scientists choose pulsars rather than some other type of star?

A) Pulsars are very bright and therefore easy to find.

B) Several pulsars are located within a dozen light-years of our solar system, making them useful for finding our solar system.

C) We're pretty sure that aliens will have only radio telescopes and not optical telescopes, so they'll have a better chance of seeing pulsars than ordinary stars.

D) Pulsars are easy to identify by their almost perfectly steady periods of pulsation.

Answer: D

11) Which statement about pulsars is *not* thought to be true?

A) All pulsars are neutron stars, but not all neutron stars are pulsars.

B) Pulsars can form only in close binary systems.

C) A pulsar must have a very strong magnetic field and rotate quite rapidly.

D) Pulsars are kept from collapsing by neutron degeneracy pressure.

Answer: B

12) How does an accretion disk around a neutron star differ from an accretion disk around a white dwarf?

A) The accretion disk around a neutron star is made mostly of helium while the accretion disk around a white dwarf is made mostly of hydrogen.

B) The accretion disk around a neutron star is more likely to give birth to planets.

C) The accretion disk around a neutron star is much hotter and emits higher-energy radiation.

D) The accretion disk around a neutron star always contains much more mass.

Answer: C

13) Which statement concerning black hole masses and Schwarzschild radii is *not* true?

A) In a binary system with a black hole, the Schwarzschild radius depends on the distance from the black hole to the companion star.

B) The more massive the black hole, the larger the Schwarzschild radius.

C) Even an object as small as you could become a black hole if there were some way to compress you to a size smaller than your Schwarzschild radius.

D) For black holes produced in massive star supernovae, Schwarzschild radii are typically a few to a few tens of kilometers.

Answer: A

14) Suppose you drop a clock toward a black hole. As you look at the clock from a high orbit, what will you notice?

A) Time on the clock will run faster as it approaches the black hole, and light from the clock will be increasingly blueshifted.

B) The clock will fall toward the black hole at a steady rate, so that you'll see it plunge through the event horizon within just a few minutes.

C) The clock will fall faster and faster, reaching the speed of light as it crosses the event horizon.

D) Time on the clock will run slower as it approaches the black hole, and light from the clock will be increasingly redshifted.

Answer: D

15) Which of statement below about black holes is *not* true?

A) Although we are not 100% certain that black holes exist, we have strong observational evidence in favor of their existence.

B) If you watch someone else fall into a black hole, you will never see him (or her) cross the event horizon; you'll only see him fade from view as the light he emits or reflects becomes more and more redshifted.

C) A spaceship passing near a 10-solar-mass black hole is much more likely to be destroyed than a spaceship passing at the same distance from the center of a 10-solar-mass main-sequence star.

D) If you fell into a black hole, you would experience time to be running normally as you plunged rapidly across the event horizon.

Answer: C

16) When we see X rays from an accretion disk in a binary system, we can't immediately tell whether the accretion disk surrounds a neutron star or a black hole. Suppose we then observe each of the following phenomena in this system. Which one would *rule out* the possibility of a black hole?

A) intense X-ray bursts

B) spectral lines from the companion star that alternately shift to shorter and longer wavelengths

C) visible and ultraviolet light from the companion star

D) bright X-ray emission that varies on a time scale of a few hours

Answer: A

17) Which of the following observatories is most likely to discover a black hole in a binary system?

A) the Hubble Space Telescope

B) the Chandra X-Ray Observatory

C) the SOFIA airborne infrared observatory

D) the Arecibo Radio Observatory

Answer: B

18) Which of the following statements about gamma ray bursts is *not* true?

A) Gamma ray bursts are among the most luminous events that ever occur in the universe.

B) The events responsible for gamma ray bursts apparently produce only gamma rays, and no other light that we can hope to detect.

C) Gamma ray bursts were originally discovered by satellites designed to look for signs of nuclear bomb tests on Earth.

D) Based on their distribution in the sky, we can rule out a connection between gamma ray bursts and X-ray binaries in the Milky Way Galaxy.

Answer: D

19) Imagine an advanced civilization living on a planet orbiting at a distance of 10 AU (1.5 billion kilometers) from a close binary star system that consists of a 15 *M*Sun red giant star and a 10 *M*Sun black hole. The black hole is surrounded by an accretion disk. Sometime within the next million years or so, the civilization's planet is likely to be doomed because

A) the red giant will probably supernova within the next million years.

B) jets of material shot out of the accretion disk will shoot down their planet.

C) the red giant star, which provides most of energy the civilization needs to exist, will soon be destroyed in the accretion disk.

D) tidal forces from the black hole will rip the planet apart.

Answer: A

20) Consider again the civilization described in the previous question. (They live on a planet orbiting 10 AU from a close binary star system that consists of a 15 *M*Sun red giant star and a 10 *M*Sun black hole surrounded by an accretion disk.) One foolhardy day, a daring individual in their space force (let's call him Major Tom) decides to become the first of his species to cross the event horizon of the black hole. To add to the drama, he decides to go in wearing only a thin space suit, which offers no shielding against radiation, no cushioning against any forces, and so on. Which of the following is most likely to kill him *first* (or at least to start the process of killing him first)?

A) tidal forces due to the black hole

B) X rays from the accretion disk

C) the crush of gravity at the singularity embedded within the black hole

D) the sucking force from the black hole, which will cause his head to explode

Answer: B

21) Consider again the civilization described in the previous question. (They live on a planet orbiting 10 AU from a close binary star system that consists of a 15 *M*Sun red giant star and a 10 *M*Sun black hole surrounded by an accretion disk.) Through a bizarre (and scientifically unexplainable) fluctuation in the space-time continuum, a copy of a book from that civilization arrives on your desk; it is entitled *Iguoonos: How We Evolved*. In the first chapter, you learn that these beings evolved from organisms that lived 5 billion years ago. Which of the following statements should you expect to find as you continue to read this book?

A) As a result of traumatic experiences to their evolutionary ancestors, they dislike television.

B) Their immediate ancestors were chimpanzees.

C) They believe that the presence of two stars in their system was critical to their evolution.

D) They evolved from primitive wormlike creatures that had 13 legs, 4 eyes, and bald heads, thus explaining why such critters are now considered a spectacular delicacy.

E) They evolved on a different planet in a different star system, and moved to their current location.

Answer: E