**Astronomy Our Star**

14.1 Multiple-Choice Questions

1) In the late 1800s, Kelvin and Helmholtz suggested that the Sun stayed hot thanks to *gravitational contraction*. What was the major drawback of this idea?

A) It predicted that the Sun could last only about 25 million years, which is far less than the age of Earth.

B) It predicted that the Sun would shrink noticeably as we watched it, and the Sun appears to be stable in size.

C) It is physically impossible to generate heat simply by making a star shrink in size.

D) It predicted that Earth would also shrink, which would make it impossible to have stable geology on our planet.

E) It was proposed before Einstein's theory of general relativity and was therefore incorrect.

Answer: A

2) When is/was gravitational contraction an important energy-generation mechanism for the Sun?

A) only during solar minimum

B) only during solar maximum

C) when the Sun was being formed from a collapsing cloud of gas

D) right after the Sun began fusing hydrogen in its core

E) when the Sun transports radiation through the convection zone

Answer: C

3) What do we mean when we say that the Sun is in *gravitational equilibrium*?

A) The hydrogen gas in the Sun is balanced so that it never rises upward or falls downward.

B) The Sun maintains a steady temperature.

C) This is another way of stating that the Sun generates energy by nuclear fusion.

D) There is a balance within the Sun between the outward push of pressure and the inward pull of gravity.

E) The Sun always has the same amount of mass, creating the same gravitational force.

Answer: D

4) What two forces are balanced in what we call *gravitational equilibrium*?

A) the electromagnetic force and gravity

B) outward pressure and the strong force

C) outward pressure and gravity

D) the strong force and gravity

E) the strong force and kinetic energy

Answer: C

5) What is the Sun made of?

A) 100 percent hydrogen and helium

B) 50 percent hydrogen, 25 percent helium, 25 percent other elements

C) 70 percent helium, 28 percent hydrogen, 2 percent other elements

D) 70 percent hydrogen, 28 percent helium, 2 percent other elements

E) 98 percent hydrogen, 2 percent helium and other elements

Answer: D

6) The phase of matter in the Sun is

A) gas.

B) plasma.

C) liquid.

D) solid.

E) a mixture of all of the above

Answer: B

7) What are the appropriate units for the Sun's *luminosity*?

A) watts

B) joules

C) meters

D) Newtons

E) kilograms

Answer: A

8) What is the average temperature of the *surface* of the Sun?

A) 1 million K

B) 100,000 K

C) 10,000 K

D) 6,000 K

E) 1,000 K

Answer: D

9) Which is closest to the temperature of the *core* of the Sun?

A) 10,000 K

B) 100,000 K

C) 1 million K

D) 10 million K

E) 100 million K

Answer: D

10) From the center outward, which of the following lists the "layers" of the Sun in the correct order?

A) core, radiation zone, convection zone, corona, chromosphere, photosphere

B) core, corona, radiation zone, convection zone, photosphere, chromosphere

C) core, radiation zone, convection zone, photosphere, chromosphere, corona

D) core, convection zone, radiation zone, corona, chromosphere, photosphere

E) core, convection zone, radiation zone, photosphere, chromosphere, corona

Answer: C

11) Which layer of the Sun do we normally see?

A) photosphere

B) corona

C) chromosphere

D) convection zone

E) radiation zone

Answer: A

12) The core of the Sun is

A) at the same temperature and density as the surface.

B) at the same temperature but denser than the surface.

C) hotter and denser than the surface.

D) constantly rising to the surface through convection.

E) composed of iron.

Answer: C

13) Based on its surface temperature of 5,800 K, what color are most of the photons that leave the Sun's surface?

A) blue

B) red

C) yellow

D) orange

E) green

Answer: E

14) Why do sunspots appear dark in pictures of the Sun?

A) They are too cold to emit any visible light.

B) They actually are fairly bright but appear dark against the even brighter background of the surrounding Sun.

C) They are holes in the solar surface through which we can see to deeper, darker layers of the Sun.

D) They are tiny black holes, absorbing all light that hits them.

E) They emit light in other wavelengths that we can't see.

Answer: B

15) Sunspots are cooler than the surrounding solar surface because

A) they are regions where convection carries cooler material downward.

B) strong magnetic fields slow convection and prevent hot plasma from entering the region.

C) magnetic fields trap ionized gases that absorb light.

D) there is less fusion occurring there.

E) magnetic fields lift material from the surface of the Sun, cooling off the material faster.

Answer: B

16) How does the Sun generate energy today?

A) nuclear fission

B) nuclear fusion

C) chemical reactions

D) gravitational contraction

E) gradually expanding in size

Answer: B

17) How do human-built nuclear power plants on Earth generate energy?

A) chemical reactions

B) nuclear fusion

C) nuclear fission

D) converting kinetic energy into electricity

E) converting gravitational potential energy into electricity

Answer: C

18) Hydrogen fusion in the Sun requires a temperature (in Kelvin) of

A) thousands of degrees.

B) millions of degrees.

C) billions of degrees.

D) trillions of degrees.

E) any temperature, as long as gravity is strong enough.

Answer: B

19) At the center of the Sun, fusion converts hydrogen into

A) hydrogen compounds.

B) plasma.

C) radiation and elements like carbon and nitrogen.

D) radioactive elements like uranium and plutonium.

E) helium, energy, and neutrinos.

Answer: E

20) How much mass does the Sun lose through nuclear fusion per second?

A) 4 tons

B) 4 million tons

C) 600 tons

D) 600 million tons

E) Nothing: mass is conserved.

Answer: B

21) Suppose you put two protons near each other. Because of the electromagnetic force, the two protons will

A) collide.

B) remain stationary.

C) attract each other.

D) repel each other.

E) join together to form a nucleus.

Answer: D

22) Which is the strongest of the fundamental forces in the universe?

A) strong force

B) weak force

C) electromagnetic force

D) gravitational force

E) none of the above

Answer: A

23) The first step in the proton-proton chain produces an antielectron, or *positron*. What happens to the positron?

A) It slowly works its way to the Sun's surface, where it escapes into space.

B) It rapidly escapes from the Sun, traveling into space at nearly the speed of light.

C) It is rapidly converted to energy when it meets an ordinary electron, resulting in matter-antimatter annihilation.

D) It quickly meets an ordinary electron, forming an electron-positron pair that remains stable.

E) It joins with a nearby neutron to form a proton.

Answer: C

24) The overall fusion reaction by which the Sun currently produces energy is

A) 3 H ⇒ 1 Li + energy.

B) 3 He ⇒ 1 C + energy.

C) 4 H ⇒ 4 He + energy.

D) 6 H ⇒ 1 He + energy.

E) 4 H ⇒ 1 He + energy.

Answer: E

25) Why must the Sun's rate of fusion gradually rise over billions of years?

A) The Sun becomes less efficient and must increase the rate of fusion to produce the same amount of energy.

B) Fusion reactions decrease the overall number of particles in the core, causing the core to shrink, converting gravitational potential energy into thermal energy, and increasing the rate of fusion.

C) The radiation produced by fusion reactions that is trapped in the core gradually raises the temperature, increasing the rate of fusion.

D) The Sun gets heavier as it gets older, and the stronger inward pull of gravity increases the fusion rate.

E) The rate of fusion is not rising; it is actually decreasing over time.

Answer: B

26) Suppose that, for some unknown reason, the core of the Sun suddenly became hotter. Which of the following best describes what would happen?

A) Higher temperature would cause the rate of nuclear fusion to rise, which would increase the internal pressure, causing the core to expand and turn the Sun into a giant star.

B) Higher temperature would cause the rate of nuclear fusion to rise, which would increase the internal pressure, causing the core to expand and cool until the fusion rate returned to normal.

C) Higher temperature would cause the rate of fusion to fall, decreasing the internal pressure and causing the core to collapse until the rate of fusion returned to normal.

D) The higher temperature would not affect the fusion rate but would cause the core to expand and cool until the temperature returned to normal, with the core at a new, slightly larger size.

Answer: B

27) How do we know what goes on under the surface of the Sun?

A) We have X-ray images from satellites of the interior of the Sun.

B) Astronomers create mathematical models that use the laws of physics, the Sun's observed composition and mass, and computers to predict internal conditions.

C) We have sent probes below the surface of the Sun.

D) By measuring Doppler shifts, we observe vibrations of the Sun's surface that are created deep within the Sun.

E) both B and D

Answer: E

28) Studies of sunquakes, or *helioseismology*, have revealed that

A) the Sun vibrates only on the surface.

B) "sunquakes" are caused by similar processes that create earthquakes on Earth.

C) the Sun generates energy by nuclear fusion.

D) our mathematical models of the solar interior are fairly accurate.

E) neutrinos from the solar core reach the solar surface easily.

Answer: D

29) Which statement best describes the *solar neutrino problem*?

A) Theoretical models predict that neutrinos should be produced in the Sun, but no neutrinos have ever been observed to be coming from the Sun.

B) Solar neutrinos have been detected, but in fewer numbers than predicted by theoretical models.

C) No one understands how it can be possible for neutrinos to be produced in the Sun.

D) Our current understanding of fusion in the Sun suggests that all neutrinos should be destroyed before they arrive at Earth, yet neutrinos are being detected.

E) The term *solar neutrino problem* refers to the fact that neutrinos are extremely difficult to detect.

Answer: B

30) Why are neutrinos so difficult to detect?

A) because there are so rare

B) because they have no mass

C) because they move at nearly the speed of light

D) because they rarely interact with matter

E) because they are so small

Answer: D

31) Which of the following statements about neutrinos is *not* true?

A) About a thousand trillion neutrinos are passing through your body every second.

B) Neutrinos are created as a by-product of the proton-proton chain.

C) Neutrinos have no electrical charge.

D) Neutrinos have a tendency to pass through just about anything without interactions, making them very difficult to detect.

E) The mass of a neutrino is 30 percent of the mass of an electron.

Answer: E

32) What is a possible solution to the *solar neutrino problem*?

A) The Sun is generating energy other than by nuclear fusion.

B) The Sun is generating much less energy than we think it is.

C) We do not know how to detect electron neutrinos.

D) Not all fusion reactions create electron neutrinos.

E) The electron neutrinos created in the Sun change into another type of neutrino that we do not detect.

Answer: E

33) The light radiated from the Sun's surface reaches Earth in about 8 minutes, but the energy of that light was released by fusion in the solar core about

A) one year ago.

B) ten years ago.

C) a hundred years ago.

D) a thousand years ago.

E) a million years ago.

Answer: E

34) What happens to energy in the *convection zone* of the Sun?

A) Energy slowly leaks outward through the diffusion of photons that repeatedly bounce off ions and electrons.

B) Energy is produced in the convection zone by nuclear fusion.

C) Energy is transported outward by the rising of hot plasma and the sinking of cooler plasma.

D) Energy is consumed in the convection zone by the creation of electrons and positrons.

E) Energy is conserved so while the gas moves up and down, there is no net transport of energy.

Answer: C

35) Most of the energy produced in the Sun is released in the form of visible light from the photosphere. However, some energy is released from the upper layers of the solar atmosphere. Which of the following best describes where other forms of light are released?

A) The chromosphere is the source of ultraviolet light, and the corona is the source of X rays.

B) The chromosphere is the source of infrared light, and the corona is the source of ultraviolet light.

C) The chromosphere is the source of X rays, and the corona is the source of radio waves.

D) The convection zone is the source of ultraviolet light, and the upper photosphere is the source of X rays.

E) Radio waves can pass directly through the gas which allows us to see the core.

Answer: A

36) What is *granulation* in the Sun?

A) the bubbling pattern on the photosphere produced by the underlying convection

B) another name for the way sunspots look on the surface of the Sun

C) elements in the Sun other than hydrogen and helium

D) dust particles in the Sun that haven't been turned into plasma

E) lumps of denser material in the Sun

Answer: A

37) What are *coronal holes*?

A) regions on the photosphere where magnetic lines poke through, creating the cooler areas of the sunspots

B) areas of the corona where magnetic field lines project into space, allowing charged particles to escape the Sun, becoming part of the solar wind

C) holes in the corona of the Sun that allow us to see the photosphere

D) tunnels in the outer layers of the Sun through which photons can escape more quickly than through the radiation zone

E) all of the above

Answer: B

38) Which of the following statements about the sunspot cycle is *not* true?

A) The number of sunspots peaks approximately every 11 years.

B) With each subsequent peak in the number of sunspots, the magnetic polarity of the Sun is the reverse of the previous peak.

C) The rate of nuclear fusion in the Sun peaks about every 11 years.

D) The cycle is truly a cycle of magnetic activity, and variations in the number of sunspots are only one manifestation of the cycle.

E) The number of solar flares peaks about every 11 years.

Answer: C

39) What processes are involved in the sunspot cycle?

A) gravitational contraction of the Sun

B) wave motions in the solar interior

C) variations of the solar thermostat

D) the winding of magnetic field lines due to differential rotation

E) the interaction of the Earth's magnetic field with that of the Sun

Answer: D

40) What observations characterize *solar maximum*?

A) The Sun becomes much brighter.

B) The Sun emits light of longer average wavelength.

C) The Sun rotates faster at the equator.

D) We see many sunspots on the surface of the Sun.

E) all of the above

Answer: D

41) Humans have not sent a spacecraft into the interior of the Sun to confirm any models of the interior. What evidence then do we have to support our current ideas about the solar interior?

A) solar neutrinos

B) solar flares

C) sun spots

D) X-ray observations that penetrate the gas

E) We have no evidence, just informed guesses.

Answer: A

14.2 True/False Questions

1) Gravitational equilibrium means that the surface and the core of the Sun are at the same pressure.

Answer: FALSE

2) Although the Sun does not generate energy by gravitational contraction today, this energy-generation mechanism was important when the Sun was forming.

Answer: TRUE

3) The Sun generates energy primarily by nuclear fission.

Answer: FALSE

4) Nuclear power plants on Earth create energy in the same way as the Sun.

Answer: FALSE

5) The corona and chromosphere are hotter than the photosphere.

Answer: TRUE

6) The chromosphere is the layer of the Sun that we see as its visible surface.

Answer: FALSE

7) Energy from the core of the Sun first travels slowly through the convection zone and then much faster through the radiation zone.

Answer: FALSE

8) Sunspots are cooler than the surrounding region of the Sun's surface.

Answer: TRUE

9) The core of the Sun is at a temperature of about 20,000 K.

Answer: FALSE

10) The proton-proton chain converts four hydrogen nuclei into one helium nucleus.

Answer: TRUE

11) The Sun's rate of fusion is gradually increasing over time.

Answer: TRUE

12) The Sun is a relatively young star, near the beginning of its life.

Answer: FALSE

14.3 Short Answer Questions

1) Briefly explain how the Sun became hot enough for nuclear fusion.

Answer: The Sun formed from a cloud of gas. As it contracted, its gravitational potential energy was converted to thermal energy. The Sun continued to contract until the core became hot enough to sustain nuclear fusion.

2) Describe some of the early theories for why the Sun shines and why they are no longer accepted as viable.

Answer: The Sun was once postulated to be a cooling ember, but that would have meant the Sun would have been much hotter in its immediate past (just a few hundred years ago) and people could not have lived in such a hot environment. Another idea was that the Sun shone through chemical burning (like a conventional fire on Earth), but this was dismissed because it could not generate and sustain sufficient brightness. A more modern hypothesis was that the Sun shone through the emission of thermal energy resulting from gravitational contraction, but this could only last for about 25 million years, far less than the age of Earth, before the Sun would have contracted to a point.

3) What is the solar thermostat?

Answer: The solar thermostat is analogous to the thermostat at home: it works to maintain a constant temperature. If the solar core were to increase in temperature, the nuclear fusion rate would soar, generating excess energy that increases the pressure and pushes the core outwards. This expansion cools the core back to its normal operating temperature. Similarly if the solar core were to decrease in temperature, the nuclear fusion rate would plummet and gravity would overcome thermal pressure and contract the core. As the core contracts, it heats up and the core returns to its normal operating temperature.

4) Briefly describe why the fact that we detect neutrinos coming from the Sun supports the idea that the Sun generates energy by nuclear fusion.

Answer: Laboratory experiments and theory show that fusion produces neutrinos. Therefore, scientists *predict* that neutrinos should come from the Sun if fusion is occurring in its core. Theories predict how many and what type of neutrinos should be observed. Thus, the observations that confirm this prediction support the theory.

5) What is the solar neutrino problem?

Answer: Solar neutrinos coming from the Sun have been detected, but in fewer numbers than predicted by theoretical models. This means either that our models of the Sun are not completely correct or that we don't understand neutrinos as well as we thought we did. We can measure the luminosity that the Sun is producing and therefore determine how much fusion must be going on in its core. The rate of fusion then determines how many neutrinos should be produced by the Sun, and theories estimate how many of these should be detected here on Earth. However, we detect far fewer than expected.

6) Describe two general ways we learn about the Sun's interior.

Answer: Astronomers create mathematical models that use the laws of physics, the Sun's observed composition and mass, and computers to predict internal conditions. Therefore, we believe that our models are accurate if they can reproduce the characteristics of the Sun that we can observe. By measuring Doppler shifts of material on the Sun's surface, we observe vibrations of the surface that are created deep within the Sun. We can learn about the densities and other characteristics of the various layers within the Sun by studying how the waves propagate throughout the Sun. Another way that we can learn about the Sun is by capturing the particles in the solar wind that come from the Sun. For example, by detecting solar neutrinos we can learn more about the fusion that is going on within the Sun's core.

7) Imagine you are plunging into the Sun, starting from Earth. Briefly describe what you will see as you descend.

Answer: First you will feel the light pressure of particles from the solar wind. As you approach the Sun, you will enter the corona, an extremely hot layer of gas, but so low in density that you won't really feel how hot it is. The next layer you encounter will be the chromosphere, a very hot layer of gas just above the visible surface of the Sun. As you plunge through the "surface" of the Sun, the photosphere, the temperature will be a slightly cooler 5,800 K, compared to the outer layers, and you will see the slightly cooler regions of sunspots and the granulation on the surface caused by the convection underneath. You will then enter this convective layer, feeling regions of hot plasma rising upward to meet you and seeing cooler gas descending from the surface. After passing through this layer, you will reach the radiation zone, where photons are engaged in a random dance as they are continuously absorbed and re-emitted by the hot gas there. You will then reach the source of these photons, the core of the Sun, which is actively involved in nuclear fusion, converting hydrogen into helium and releasing multitudes of photons and neutrinos.

8) List at least two ways the sunspot cycle affects us on Earth.

Answer: When the Sun is near solar maximum, it undergoes a much higher rate of violent activity in the form of solar flares. These flares are outbursts of charged particles that can affect radio communications on Earth. They also can create more auroras and can be a danger to satellites.

9) Briefly describe the phenomena of the sunspot cycle.

Answer: We observe the Sun to exhibit a sunspot cycle over a period of 22 years, tied directly to its magnetic activity. At the beginning of the period, sunspots form at higher latitudes. As magnetic activity increases, the sunspots form lower down and in greater numbers. At solar maximum, the height of magnetic activity, we observe many sunspots and solar flares. The corona is even shaped differently, streaming more from the sides of the Sun instead of forming a more spherical shape around the Sun, as when the magnetic field is weaker. As the formation of sunspots approaches the Sun's equator, the polarity of the Sun flips. Thus, the north magnetic pole becomes the south magnetic pole and vice versa. The polarity of the sunspots also changes at this time. The cycle then repeats for another 11 years with the magnetic poles of the Sun flipped. After 11 years the Sun's magnetic polarity flips again, completing the 22-year period.

10) Briefly explain why sunspots are cooler than surrounding regions of the Sun and why they look dark in photos.

Answer: They are cooler because their strong magnetic fields suppress convection and prevent hotter material from flowing into them. Because they are cooler, they emit less thermal radiation per unit area and therefore look dark in contrast to brighter surrounding regions.

11) *Process of Science*: Why is it important to understand the Sun in order to understand the Earth's radiation belts and space weather?

Answer: Solar activity causes the responses in the near-Earth space environment that produce changes in the radiation belts, so an understanding of how the Sun changes is directly relevant to space weather.

12) *Process of Science:* How do we know what is going on in the center of the Sun so well if we cannot see it or send spacecraft to it?

Answer: We can apply our knowledge of how gases behave at different temperatures and densities, which is testable in laboratory environments, to make a mathematical model of the Sun. These models make predictions about how bright and how big the Sun is, which we can then compare with observations. We also use observations of vibrations on the Sun to learn about its interior structure in much the same way we use seismic testing on Earth. Finally, we can test our knowledge of nuclear physics and the fusion process in the core using observations of solar neutrinos.

13) *Process of Science:* Explain the reasoning that led to our understanding of nuclear energy being the source of the Sun's light.

Answer: The first step was measuring the distance to the Sun which then allowed us to calculate how luminous it is and therefore how much energy is needed to power it. The energy requirements are much larger than chemical reactions (i.e., fire) so this was then ruled out. A longer lived source that could match the energy requirements is gravitational contraction. However, as geologists and paleontologists found evidence for an ancient Earth, astronomers realized that gravitational collapse could not be the dominant energy source of our Sun today. All known energy sources were eliminated and only after the recognition that mass can be converted directly into energy, was the solution of the Sun's light as nuclear energy understood.

14.4 Mastering Astronomy Reading Quiz

1) According to modern science, approximately how old is the Sun?

A) 4  billion years

B) 25 million years

C) 10,000 years

D) 400 million years

Answer: A

2) The Sun will exhaust its nuclear fuel in about

A) 5000 AD.

B) 5 million years.

C) 5 billion years.

D) 50 billion years.

Answer: C

3) Which of the following correctly describes how the process of *gravitational* *contraction* can make a star hot?

A) Gravitational contraction involves nuclear fusion, which generates a lot of heat.

B) When a star contracts in size, gravitational potential energy is converted to thermal energy.

C) Heat is generated when gravity contracts, because gravity is an inverse square law force.

D) Gravitational contraction involves the generation of heat by chemical reactions, much like the burning of coal.

Answer: B

4) What two physical processes balance each other to create the condition known as *gravitational* *equilibrium* in stars?

A) the strong force and the weak force

B) gravitational force and outward pressure

C) gravitational force and surface tension

D) the strong force and the electromagnetic force

Answer: B

5) The source of energy that keeps the Sun shining today is

A) nuclear fission.

B) gravitational contraction.

C) chemical reactions.

D) nuclear fusion.

Answer: D

6) When we say that the Sun is a ball of *plasma*, we mean that

A) the Sun is made of material that acts like a liquid acts on Earth.

B) the Sun is made of atoms and molecules.

C) the Sun consists of gas in which many or most of the atoms are ionized (missing electrons).

D) the Sun is roughly the same color as blood.

Answer: C

7) What is the Sun made of (by mass)?

A) 70% hydrogen, 28% helium, 2% other elements

B) 100% hydrogen and helium

C) 50% hydrogen, 25% helium, 25% other elements

D) 90% dark matter, 10% ordinary matter

Answer: A

8) From center outward, which of the following lists the "layers" of the Sun in the correct order?

A) core, radiation zone, convection zone, corona, chromosphere, photosphere

B) core, convection zone, radiation zone, corona, chromosphere, photosphere

C) core, radiation zone, convection zone, photosphere, chromosphere, corona

D) core, corona, radiation zone, convection zone, photosphere, chromosphere

Answer: C

9) What are the appropriate units for the Sun's *luminosity*?

A) watts

B) joules

C) Newtons

D) kilograms

Answer: A

10) The Sun's surface, as we see it with our eyes, is called the

A) chromosphere.

B) photosphere.

C) corona.

D) core.

Answer: B

11) The Sun's average surface (photosphere) temperature is about

A) 1,000,000 K.

B) 5,800 K.

C) 1,000 K.

D) 37,000 K.

Answer: B

12) What is the *solar wind*?

A) the uppermost layer of the Sun, lying just above the corona

B) the strong wind that blows sunspots around on the surface of the Sun

C) the wind that causes huge arcs of gas to rise above the Sun's surface

D) a stream of charged particles flowing outward from the surface of the Sun

Answer: D

13) The fundamental nuclear reaction occurring in the core of the Sun is

A) nuclear fission.

B) radioactive decay.

C) nuclear fusion of hydrogen into helium.

D) nuclear fusion of helium to carbon.

Answer: C

14) The *proton-proton chain* is

A) the specific set of nuclear reactions through which the Sun fuses hydrogen into helium.

B) the linkage of numerous protons into long chains.

C) another name for the force that holds protons together in atomic nuclei.

D) an alternative way of generating energy that is different from the fusion of hydrogen into helium.

Answer: A

15) The overall result of the proton-proton chain is

A) 6 H becomes 1 He + energy.

B) p + p becomes 2H + energy.

C) 4 H becomes 1 He + energy.

D) Individual protons are joined into long chains of protons.

Answer: C

16) To estimate the central temperature of the Sun, scientists

A) send probes to measure the temperature.

B) use hot gas to create a small Sun in a laboratory.

C) monitor changes in Earth's atmosphere.

D) use computer models to predict interior conditions.

Answer: D

17) Why are *neutrinos* so difficult to detect?

A) They have a tendency to pass through just about any material without any interactions.

B) They are extremely rare.

C) They have no mass.

D) No one knows: this is the essence of the "solar neutrino problem."

Answer: A

18) Which statement best describes what was called the *solar neutrino problem*?

A) Early experiments designed to detect solar neutrinos found them, but in fewer numbers than had been expected.

B) It referred to the fact that neutrinos are extremely difficult to detect.

C) Our understanding of fusion in the Sun suggested that neutrinos should be destroyed before they arrive at Earth, yet neutrinos were being detected.

D) No one understood how it could be possible for neutrinos to be produced in the Sun.

Answer: A

19) The light radiated from the Sun's surface reaches Earth in about 8 minutes, but the energy of that light was released by fusion in the solar core about

A) three days ago.

B) one hundred years ago.

C) one thousand years ago.

D) a few hundred thousand years ago.

Answer: D

20) What happens to energy in the Sun's *convection zone*?

A) Energy is produced in the convection zone by thermal radiation.

B) Energy is transported outward by the rising of hot plasma and sinking of cooler plasma.

C) Energy slowly leaks outward through the radiative diffusion of photons that repeatedly bounce off ions and electrons.

D) Energy is produced in the convection zone by nuclear fusion.

Answer: B

21) What do sunspots, solar prominences, and solar flares all have in common?

A) They all have about the same temperature.

B) They are all shaped by the solar wind.

C) They are all strongly influenced by magnetic fields on the Sun.

D) They all occur only in the Sun's photosphere.

Answer: C

22) Which of the following is *not* a characteristic of the 11-year sunspot cycle?

A) The sunspot cycle is very steady, so that each 11-year cycle is nearly identical to every other 11-year cycle.

B) The likelihood of seeing solar prominences or solar flares is higher when sunspots are more common and lower when they are less common.

C) The Sun's entire magnetic field flip-flops at the end of each cycle (at solar minimum).

D) The number of sunspots on the Sun at any one time gradually rises and falls, with an average of 11 years between the times when sunspots are most numerous.

Answer: A

23) How is the sunspot cycle directly relevant to us here on Earth?

A) The sunspot cycle strongly influences Earth's weather.

B) The Sun's magnetic field, which plays a major role in the sunspot cycle, affects compass needles that we use on Earth.

C) The brightening and darkening of the Sun that occurs during the sunspot cycle affects plant photosynthesis here on Earth.

D) Coronal mass ejections and other activity associated with the sunspot cycle can disrupt radio communications and knock out sensitive electronic equipment.

E) The sunspot cycle is the cause of global warming.

Answer: D

14.5 Mastering Astronomy Concept Quiz

1) In the late 1800s, Kelvin and Helmholtz suggested that the Sun stayed hot due to *gravitational contraction*. What was the major drawback to this idea?

A) It predicted that the Sun would shrink noticeably as we watched it, but the Sun appears to be stable in size.

B) It is physically impossible to generate heat simply by making a star shrink in size.

C) It predicted that the Sun could shine for about 25 million years, but geologists had already found that Earth is much older than this.

D) It predicted that Earth would also shrink in size with time, which would make it impossible to have stable geology on our planet.

Answer: C

2) When is/was gravitational contraction an important energy generation mechanism for the Sun?

A) It was important when the Sun was forming from a shrinking interstellar cloud of gas.

B) It is the primary energy generation mechanism in the Sun today.

C) It has played a role throughout the Sun's history, but it was most important right after nuclear fusion began in the Sun's core.

D) It is important during periods when the Sun is going from solar maximum to solar minimum.

Answer: A

3) What do we mean when we say that the Sun is in *gravitational equilibrium*?

A) The Sun maintains a steady temperature.

B) There is a balance within the Sun between the outward push of pressure and the inward pull of gravity.

C) The hydrogen gas in the Sun is balanced so that it never rises upward or falls downward.

D) The Sun always has the same amount of mass, creating the same gravitational force.

Answer: B

4) Which of the following is the best answer to the question, "Why does the Sun shine?"

A) As the Sun was forming, nuclear fusion reactions in the shrinking clouds of gas slowly became stronger and stronger, until the Sun reached its current luminosity.

B) As the Sun was forming, gravitational contraction increased the Sun's temperature until the core become hot enough for nuclear fusion, which ever since has generated the heat that makes the Sun shine.

C) The Sun initially began making energy through chemical reactions. These heated the interior enough to allow gravitational contraction and nuclear fusion to occur.

D) The Sun initially began generating energy through nuclear fusion as it formed, but today it generates energy primarily through the sunspot cycle.

Answer: B

5) How does the Sun's mass compare to Earth's mass?

A) The Sun's mass is about 300 times the mass of Earth.

B) The Sun's mass is about 30 times the mass of Earth.

C) The Sun's mass is about 300,000 times the mass of Earth.

D) Both have approximately the same mass.

Answer: C

6) Which of the following best describes why the Sun emits most of its energy in the form of visible light?

A) Nuclear fusion in the Sun's core produces visible light photons.

B) The visible light comes from energy level transitions as electrons in the Sun's hydrogen atoms jump between level 1 and level 2.

C) Like all objects, the Sun emits thermal radiation with a spectrum that depends on its temperature, and the Sun's surface temperature is just right for emitting mostly visible light.

D) The Sun's gas is on fire like flames from wood or coal, and these flames emit visible light.

Answer: C

7) The Sun's surface seethes and churns with a bubbling pattern. Why?

A) The Sun's surface is boiling.

B) The churning gas is being stirred up by the strong solar wind.

C) The churning is an illusion created by varying radiation, as the gas on the Sun's surface is actually quite still.

D) We are seeing hot gas rising and cool gas falling due to the convection that occurs beneath the surface.

Answer: D

8) Which of the following correctly compares the Sun's energy generation process to the energy generation process in human-built nuclear power plants?

A) The Sun generates energy by fusing small nuclei into larger ones, while our power plants generate energy by the fission (splitting) of large nuclei.

B) Both processes involve nuclear fusion, but the Sun fuses hydrogen while nuclear power plants fuse uranium.

C) The Sun generates energy through nuclear reactions while nuclear power plants generate energy through chemical reactions.

D) The Sun generates energy through fission while nuclear power plants generate energy through fusion.

Answer: A

9) Every second, the Sun converts about 600 million tons of hydrogen into 596 million tons of helium. The remaining 4 million tons of mass is

A) ejected into space in a solar wind.

B) ejected into space by solar flares.

C) converted to an amount of energy equal to 4 million tons times the speed of light squared.

D) reabsorbed as molecular hydrogen.

Answer: C

10) Which of the following best explains why nuclear fusion requires bringing nuclei extremely close together?

A) Nuclei normally repel because they are all positively charged and can be made to stick only when brought close enough for the strong force to take hold.

B) Nuclei are attracted to each other by the electromagnetic force, but this force is only strong enough to make nuclei stick when they are very close together.

C) Nuclei have to be very hot in order to fuse, and the only way to get them hot is to bring them close together.

D) Fusion can proceed only by the proton-proton chain, and therefore requires that protons come close enough together to be linked up into a chain.

Answer: A

11) If the Sun's core suddenly shrank a little bit, what would happen in the Sun?

A) The core would cool off and continue to shrink as its density increased.

B) The density of the core would decrease, causing the core to cool off and expand.

C) The core would heat up, causing it to radiate so much energy that it would shrink even more.

D) The core would heat up, fusion rates would increase, and the core would re-expand.

Answer: D

12) Why does the Sun emit neutrinos?

A) Solar flares create neutrinos with magnetic fields.

B) Fusion in the Sun's core creates neutrinos.

C) Convection releases neutrinos, which random walk through the radiation zone.

D) The Sun was born with a supply of neutrinos that it gradually emits into space.

E) The Sun does *not* emit neutrinos.

Answer: B

13) If the Sun suddenly stopped emitting neutrinos, what might we infer (after checking that our neutrino detectors were still operational)?

A) Fusion reactions in the Sun ceased a few hundred thousand years ago.

B) Fission reactions in the Sun have ceased.

C) Fusion reactions in the Sun have ceased.

D) The Sun has exhausted its supply of neutrinos.

Answer: C

14) Which of the following best explains why the Sun's luminosity gradually rises over billions of years?

A) Fusion gradually decreases the number of independent particles in the core, allowing gravity to compress and heat the core, which in turn increases the fusion rate and the Sun's luminosity.

B) Nuclear reactions in the Sun become more efficient with time, so that each fusion reaction releases more energy when the Sun is old than when it is young; this in turn raises the Sun's luminosity.

C) The Sun's core gradually expands with time, and this expansion means there is more room for energy to be generated and hence increases the Sun's luminosity.

D) The planets need more and more energy to maintain any life on them as time goes on, and therefore the Sun must bet hotter.

Answer: A

15) Why do sunspots appear dark in pictures of the Sun?

A) They are too cold to emit any visible light.

B) They are holes in the solar surface through which we can see through to deeper, darker layers of the Sun.

C) They are extremely hot and emit all their radiation as X rays rather than visible light.

D) They actually are fairly bright, but appear dark against the even brighter background of the surrounding photosphere.

Answer: D

16) Which of the following best describes the current status of our understanding of the solar neutrino problem?

A) Experimental evidence indicates that the problem is solved and the expected number of solar neutrinos are indeed being produced by the Sun.

B) The problem arose only because experimental data were being misinterpreted; on re-examination, the old data showed that the expected number of neutrinos were being detected.

C) We have learned that the Sun's interior undergoes fusion at a lower rate than we had expected, and that is why we had observed fewer neutrinos than expected.

D) The solar neutrino problem remains as perplexing as ever, and indeed makes everything we think we know about stars suspect.

Answer: A

17) How can we best observe the Sun's chromosphere and corona?

A) The chromosphere is best observed with infrared telescopes and the corona is best observed with ultraviolet telescopes.

B) The chromosphere is best observed with ultraviolet telescopes and the corona is best observed with X-ray telescopes.

C) The chromosphere and corona are both best studied with visible light.

D) The chromosphere and corona are both best studied with radio telescopes.

Answer: B

18) The intricate patterns visible in an X-ray image of the Sun generally show

A) helioseismological fluctuations.

B) a bubbling pattern on the photosphere.

C) extremely hot plasma flowing along magnetic field lines.

D) structure within sunspots.

Answer: C

19) How can we measure the strength of magnetic fields on the Sun?

A) by looking for the splitting of spectral lines in the Sun's spectrum

B) by observing the sizes of sunspots: Bigger sunspots mean a stronger field

C) by observing auroras here on Earth

D) only by using sophisticated computer models, because there are no observational ways of measuring magnetic field strength

Answer: A

20) Satellites in low-Earth orbits are more likely to crash to Earth when the sunspot cycle is near *solar maximum* because

A) it is too dangerous to send the Space Shuttle to service satellites during solar maximum.

B) Earth's upper atmosphere tends to expand during solar maximum, exerting drag on satellites in low orbits.

C) of increased magnetic interference.

D) they are more likely to have their electronics "fried" by a solar flare during solar maximum.

Answer: B

21) Which of the following choices is *not* a way by which we can study the inside of the Sun?

A) We can probe the interior of the Sun by studying the vibrations in its photosphere.

B) We can make a computer model of the Sun's interior that allow us to predict the observable properties of the Sun.

C) We can send a space probe into the Sun's photosphere.

D) We can study solar neutrinos.

Answer: C

22) A computer accessory salesman attempts to convince you to purchase a "solar neutrino" shield for your new computer. (It's even "on sale"!) Why do you turn down this excellent offer?

A) There's no such thing as a solar neutrino.

B) Solar neutrinos are generated by solar winds, but we're in a solar minimum now, so the risk of damage is very low.

C) The Earth's natural magnetic field already offers excellent protection against the onslaught of solar neutrinos.

D) Neutrinos rarely, if ever, interact with your computer.

Answer: D