ASTRONOMY 101, SECTION 004
Spring, 2018
Third Hour Examination

Print Your Name: ____ SID ___________________

Please legibly write your name and student ID on this answer sheet and print your name on your test.

Now you are ready to begin the test. For each question, select the one ***best*** answer and write it on your answer sheet. Ensure that the number of your answer corresponds to the number of the question.

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Feel free to mark your test, including eliminating answers, doing calculations or estimates, and especially making drawings. You must hand in your test and answer sheet before leaving the test site.

The 85 questions are multiple choice. Mark the correct answer A - D.

A proctor will be available to answer questions. You are on your honor as a lady or gentleman not to cheat on this test.

1. What is the Sun's current energy source?
   A) primordial heat left over from the release of gravitational energy when the Sun first formed
   B) radioactivity (nuclear fission of uranium and related heavy nuclei to less massive nuclei)
   C) thermonuclear fusion in the core (hydrogen to helium/helium to carbon and oxygen)
   D) heat released by gravitational contraction (like Jupiter, Neptune, or Saturn)

2. Nuclear fusion is
   A) the combining of electrons with nuclei to produce atoms and release energy.
   B) the chemical combining of hydrogen atoms to produce hydrogen molecules (H_2), and energy.
   C) the process of fusing together light nuclei (e.g. hydrogen) to produce heavier nuclei (e.g. helium) and energy.
   D) the splitting of heavier nuclei to produce lighter nuclei and energy.

3. Thermonuclear fusion reactions (nuclear fusion driven by large temperatures) in the core of the Sun convert our hydrogen nuclei into one helium nucleus. The helium nucleus has
   A) less mass than the four hydrogen nuclei, the lost mass becomes energy (energy conservation) in an amount given by $E = mc^2$.
   B) the same mass as the four hydrogen nuclei, because the mass of any product has to equal the mass of the sum of its parts by the law of conservation of matter.
   C) an undetermined amount of mass that depends on the temperature at which the reaction occurs.
   D) more mass than the four hydrogen nuclei, because energy is produced in the reaction, and this energy adds the extra mass.

4. Hydrogen "burning" by fusion reactions occurs only in the deep interior of the Sun (and other stars), because this is the only place in the Sun where
   A) there is sufficient hydrogen.
   B) the density is sufficiently low for the high temperature atoms to build up enough energy to collide and undergo fusion.
   C) the temperature is low enough and the density is high enough to allow hydrogen atoms to collide with each other often enough for fusion to occur.
   D) the requisite conditions of both high temperature and high density occur.

5. The Sun has two distinct regions of energy transportation. In the inner region, known as the radiation zone, why is energy transported by radiation?

A) The temperature and pressure are so large that convection rolls cannot develop.
B) The opacity of this region is low enough to allow photons to scatter and drift outwards.
C) The photons are generated with such large energies due to the hot core that they can radiate large distances before being completely absorbed.
D) All of the above

6. In the outer layer of the Sun, energy is transported by convection. In this part of the Sun, temperatures have cooled enough such that electron have recombined to form atoms. This region is almost completely opaque to photons, unlike the radiation zone. How do we know that convection is actually occurring in this region?

A) The Internal-Surface Sun (ISS) probe has measured the motion of large convection cells deep inside the Sun.
B) The atomic spectra indicates convective motion.
C) By measuring the Doppler shift of the surface of the Sun, we see that some areas are blue shifted and some areas are red shifted indicating large internal convective motion.
D) The 11 year modulation of Sunspots across the surface indicated convective motion.

7. The Sun has existed for a very long time without much change in its size, appearance, or behavior. This means that it must be in hydrostatic equilibrium. Under these conditions, which two parameters must be in exact balance within the Sun?

A) numbers of hydrogen and helium nuclei
B) hydrogen gas pressure and helium gas pressure
C) inward force of gravity and outward gas pressure
D) magnetic field and force of gravity

8. Why are neutrinos so important in validating the solar model?

A) All of the bellow.
B) They are a critical byproduct of the proton-proton chain.
C) Without neutrinos, energy would not be conserved in the proton-proton chain.
D) Because they interact so weakly with matter, they provide a probe to the deep interior of the Sun.

9. Approximately every 11 years the Sun’s magnetic north and south poles switch positions. This is due to

A) the Sun rotating around the equator as well as the poles.
B) differential rotation of the gaseous Sun.
C) dramatic collisions in the early formation of our solar system.
D) convection transporting heating from the interior.

10. Sunspots are

A) cooler regions of the Sun's high corona.
B) the shadows of cool, dark curtains of matter, hanging above the solar surface.
C) cooler, darker regions on the Sun's surface.
D) hotter, deeper regions in the Sun's atmosphere.

11. Stellar parallax is the

A) elliptical motion of a star in a binary system, as the two stars orbit around each other.
B) difference between the apparent magnitude and the absolute magnitude of a star.
C) assumed change in the distance to a star when it dims, as it passes through an interstellar cloud.
D) apparent shift in the position of a nearby star because of the Earth's motion about the Sun.

12. Stellar parallax is used to determine which of the following properties of a nearby star?

A) its spectral type and surface temperature
B) its rotation period
C) its apparent magnitude
D) its distance from the Sun

13. Suppose that, at night, the brightness of a light bulb is measured from a certain distance and then the light bulb is moved to a distance twice as far away. Using the "inverse square law," how bright will the light appear compared to the earlier measurement?

A) 1/16 as bright B) twice as bright C) 1/8 as bright D) 1/4 as bright

14. Suppose that two identical stars (having the same total light output or luminosity) are located such that star A is at a distance of 5 pc from Earth and star B is at a distance of 25 pc from Earth. How will star B appear, compared to star A as measured from Earth?

A) 1/2.2 as bright B) 1/25 as bright C) 1/20 as bright D) 1/5 as bright

15. How do astronomers measure the radius of almost all stars?

A) They are easily able to resolve the star as a sphere and thus measure the radius.
B) If the luminosity and surface temperature are known, the radius can be determined.
C) If the mass is known, then the radius can be determined
D) Stars don't have a radius because they are made of gas.

16. How do we use spectroscopic parallax to measure distance?

A) If the surface temperature is known, one can use the H-R diagram to calculate the luminosity, then from the inverse square law, calculate the distance.
B) The hotter the star, the farther away from us it is.
C) The intensity of a stars hydrogen absorption line allows use to locate it in the Milky Way
D) If the radius of the star is known, one can use the H-R diagram to calculate the distance.

17. Measurements of the brightness of a distant star through the three appropriate filters indicate that the star is brightest in U (ultraviolet), less bright in B (blue), and faintest in V ("visual," or green). What conclusion can be drawn from this information, assuming no absorption of light between the star and Earth?

A) This information is insufficient to allow a conclusion to be drawn about star surface temperature.
B) The star has an intermediate temperature, close to the Sun.
C) The star has a very low surface temperature.
D) The star has a very high surface temperature.

18. If a binary star system cannot be resolved visually, what is another viable way of measuring the system's orbital dynamics?

A) By measuring the absolute luminosity of the system.
B) By measuring the periodic Doppler shift of the system's absorption lines.
C) By measure the distance to both stars.
D) By calculating the radius of the larger star using an inverse square law.

19. The chemical makeup of a star's surface is usually determined by

A) spectroscopy of the light emitted by the star.
B) examining the chemicals present in a meteorite.
C) theoretical methods, considering evolution of the star.
D) taking a sample of the star's surface with a probe.

20. The spectrum of an ordinary main sequence star (like our Sun) is a

A) continuum of colors crossed by dark absorption lines, caused by absorption of cooler atoms and molecules at the surface.
B) smooth continuum of color, peaking at a specific wavelength whose position is dependent on the surface temperature.
C) series of emission lines, mostly from hydrogen, the major constituent of stellar surfaces, that occasionally overlap to produce sections of continuous color.
D) continuum of colors crossed by bright emission lines of hot atoms and molecules on the surface.

21. Measurements indicate that a certain star has a very high intrinsic brightness (100,000 times as bright as our Sun) and yet is relatively cool (3500 K). How can this be?

A) There must be an error in observation, since no star can have this form.
B) The star must be quite small.
C) The star must belong to the main sequence.
D) The star must be very large – a "red giant."

22. A white dwarf is

A) an object intermediate between planets and stars, that will never become a star.
B) a star at the end of its life, with a size close to that of the Earth.
C) any main sequence star with a surface temperature between about 9000 K and 15,000 K.
D) a star at the beginning of its life, with a size two to ten times that of the Sun.

23. What proportion of stars in the night sky are in multiple-star systems?

A) about 5%, or 1/20 B) less than 1% C) nearly 100% D) about 50%, or 1/2

24. Where are cold dim stars located on the H-R diagram?

A) top left
B) bottom left
C) top right
D) bottom right

25. Which important stellar parameter can be determined by the study of binary star systems?

A) the age of the stars
B) total stellar mass of the pair
C) surface temperatures of the stars
D) the distance of the stars from Earth

26. The relationship between mass and luminosity of stars on the main sequence is that

A) the luminosity of stars rises to a peak at around a mass of 1 solar mass and decreases as mass increases beyond this limit.
B) the greater the stellar mass, the greater the luminosity.
C) luminosity is independent of the stellar mass.
D) the greater the stellar mass, the less the luminosity.

27. What places a limit on the lifetime of a star?

A) loss of the mass, and therefore of nuclear fuel, of the star into space by stellar winds
B) amount of available nuclear fuel it contains – that is, its <u>mass</u>
C) collisions between stars in a galaxy are sufficiently frequent that all stars will eventually be destroyed in this way.
D) buildup of spin as it evolves and contracts means that the star will eventually spin apart

28. The space between stars is now known to contain

A) large quantities of dust that absorb light but no gas, either atomic or molecular.
B) gas, made up of atoms and molecules, and dust particles.
C) a perfect vacuum.
D) variable amounts of gas but no dust, because dust forms only in planetary systems near stars.

29. How do astronomers study hot interstellar gas (H-II regions)?
- A) The gas is heated by young hot stars causing the regions to radiate in the visible.
- B) The gas emits a 21-cm photon from the electron spin flip.
- C) The gas contains molecules and as the molecules rotate they emit infrared radiation.
- D) The gas forms dark spots that are devoid of all wavelengths of light.

30. How do astronomers study cold neutral interstellar gas (H-I regions)?
- A) The gas is heated by young hot stars causing the regions to radiate in the visible.
- B) The gas emits a 21-cm photon from the electron spin flip.
- C) The gas contains molecules and as the molecules rotate they emit infrared radiation
- D) The gas forms dark spots that are devoid of all wavelengths of light.

31. How do astronomers study dense molecular colds (i.e. Orion Nebula)?
- A) The gas is heated by young hot stars causing the regions to radiate in the visible.
- B) The gas emits a 21-cm photon from the electron spin flip.
- C) The gas contains molecules and as the molecules rotate they emit infrared radiation
- D) The gas forms dark spots that are devoid of all wavelengths of light.

32. The distinct blue color of the <u>reflection</u> nebulosity around stars in young clusters, such as the Pleiades (Subaru), is caused by
- A) light emitted by very hot gas which has been heated by collisions in the interstellar gas.
- B) preferential scattering of blue starlight by small dust grains in the interstellar material.
- C) atoms of gas emitting light by fluorescence, having been excited by ultraviolet radiation from hot stars.
- D) halos caused by refraction of starlight in ice crystals in the nebula, similar to halos seen occasionally in the Earth's atmosphere.

33. The effect of interstellar dust on starlight is
- A) to dim and redden distant stars by preferentially scattering their blue light.
- B) to scatter the red light from stars preferentially, making them appear bluer than expected.
- C) almost nonexistent, because light does not interact with dust.
- D) to make stars appear less bright than expected by absorbing light about equally at all wavelengths.

34. New stars are formed
- A) in huge, cool dust and gas clouds.
- B) from free space, out of pure energy.
- C) within supernova remnants.
- D) by condensation of gas near black holes in the centers of galaxies.

35. Which are the two most abundant elements in the universe?
- A) hydrogen and helium
- B) nitrogen and oxygen
- C) beef jerky and oxygen
- D) hydrogen and carbon

36. At what point in its evolution will a protostar stop shrinking and stabilize into a star?
- A) when nuclear processes generate enough energy and internal pressure to resist gravitational contraction – the star will have reached the “main sequence”
- B) when contraction leads to an increase in spin rate as a result of the conservation of angular momentum and the resulting centrifugal force begins to oppose the gravitational contraction
- C) when gravitational contraction has heated up the gas to the point where radiation pressure opposes gravity for the first time
- D) when the buildup of helium in the core stops the nuclear furnace

37. Thermonuclear reactions convert hydrogen into helium in the core of a star during which phase of a star's life?
- A) the protostar phase
- B) the horizontal branch phase
- C) the time when the star moves up the red giant branch for the first time
- D) the main sequence phase

38. At what stage of its evolutionary life is the Sun?
- A) pre–main sequence—variable star
- B) main-sequence—middle age
- C) post–main sequence—red giant (cool) phase
- D) just before supernova stage (perhaps 5 years)—late evolutionary stage

39. The Orion Nebula is (this is one object worth keeping under your belt!)
- A) a large interstellar gas and dust cloud containing many young stars.
- B) a spiral galaxy in the constellation Orion.
- C) a supernova remnant (material thrown out by an exploding star).
- D) a red supergiant star surrounded by its retinue of planets.

40. Where in the universe would you look for a protostar?
- A) in globular clusters of stars
- B) near black holes
- C) in dense dust and gas clouds
- D) in the empty space between galaxies

41. All stars on the main sequence
- A) are at a late stage of evolution after the red giant stage.
- B) are changing slowly in size by gravitational contraction.
- C) generate energy by hydrogen fusion in their centers.
- D) have approximately the same age to within a few million years.

42. 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.

43. Why does the core of the Sun contain more helium and less hydrogen than the surface material of the Sun?
- A) Thermonuclear reactions have converted much of the original hydrogen in the core into helium.
- B) The hydrogen has been lifted out of the core by the Sun's magnetic field.
- C) Helium is heavier than hydrogen and has Sunk toward the center in a process of differentiation.
- D) Helium condensed more easily, so the core became helium-rich when the Sun was first forming. Vast quantities of hydrogen were added only after the core became massive enough.

44. The evolution of a star is controlled most by its
- A) initial mass.
- B) location in the galaxy.
- C) surface temperature.
- D) chemical composition.

45. Which of the following statements about the rate of stellar evolution is true?
- A) The more massive the original star, the faster the evolution.
- B) Star mass has no bearing upon stellar evolution, because all stars evolve at the same rate, controlled by nuclear fusion and core temperature.
- C) The chemical makeup of the original nebula is the major factor in deciding the rate of evolution.
- D) The more massive the original star, the slower the evolution.

46. 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

47. The majority of elements heavier than hydrogen and helium in the universe are known to have originated in

A) the original Big Bang.
B) the central cores of stars.
C) HII regions, under the action of Hα light.
D) giant molecular clouds.

48. If electrons are collectively compressed into a very small volume (e.g., within the core of a dying white dwarf star) where quantum mechanical considerations become important, what is the result?

A) The electrons fall into orbit around one another in mutual pairs, reducing the restricted volumetric space, ultimately allowing further shrinkage of the star to a black hole.
B) The electrons generate a very large pressure to oppose further compression.
C) Nuclear fusion occurs between electrons to produce energy, thereby heating the star's core.
D) Half of the electrons are transformed into antimatter (positrons) that annihilates electrons, producing a burst of energy and the explosion of the star.

49. What are the main general features that make clusters of stars useful to astronomers?

A) The stars are at the same distance from Earth, were formed at approximately the same time, and were made from same chemical mix.
B) The stars are all at the same distance from Earth, have the same surface temperature, and joined the cluster at various times.
C) The stars all have the same apparent magnitude, the same surface temperatures, and the same sizes.
D) The stars all have the same intrinsic brightness but differ in size and surface temperature.

50. How do the stars in a star cluster change with time?

A) The stars with the greatest heavy-element content evolve the most rapidly.
B) The highest-mass stars evolve the most quickly.
C) The lowest-mass stars evolve the most quickly.
D) All stars in it evolve at the same rate.

51. Cepheid variable stars are

A) white dwarf stars.
B) stars at an early stage in stellar evolution.
C) members of binary systems, in which one star periodically eclipses the other.
D) stars that pulsate in brightness, size, and temperature.

52. The period of variability of a Cepheid variable star, which is easily measured, is directly related to which stellar parameter, thereby providing a reliable method for the measurement of distance to stars?

A) velocity away from Earth
B) luminosity, to which the $1/R^2$ law applies
C) surface magnetic field
D) surface temperature

53. What is a Standard Candle?

A) Grandma’s favorite hand-me-down
B) A stellar object with a known brightness
C) A stellar object with a known mass.
D) A stellar object with a known temperature.

54. Why are Type 1a supernova considered a Standard Candle?

A) The white dwarfs that create them detonate because they have hit the 1.4 solar mass limit, thus have a consistent brightness when they explode.
B) The white dwarfs that create them are always at the center of galaxies.
C) The white dwarfs that create them never went through fusion is earlier stellar stages.
D) The white dwarfs that create them are always colder than the most stars.

55. A planetary nebula can rather gently form around a star at a late stage of stellar evolution and is

A) a contracting spherical cloud of gas surrounding a newly formed star, in which planets are forming.
B) the expanding nebula formed by the supernova explosion of a massive star.
C) an expanding gas shell surrounding a hot, white dwarf star.
D) a disk-shaped nebula of dust and gas from which planets will eventually form, easily photographed around relatively young stars.

56. Which of the following important components does a planetary nebula contribute to the interstellar medium?

A) nuclei of elements like carbon, nitrogen, and oxygen, which are major components of planets such as our own
B) UV light that photo-ionizes hydrogen. This hydrogen, on recombination, produces the red Balmer-α light by which we see interstellar emission nebulae (HII regions).
C) rotational motion from the original star, which serves to concentrate interstellar matter into new stars and planetary systems
D) new hydrogen nuclei, replenishing those which are lost when stars form

57. The final remnant of the evolution of a red giant star that has ejected a planetary nebula is a

A) blue supergiant. B) neutron star. C) supernova. D) white dwarf star.

58. A white dwarf is

A) an object like Jupiter which was not massive enough to become a star.
B) a low-mass star that has evolved and is at the end of its life.
C) a hot, main-sequence star.
D) a type of protostar.

59. A white dwarf star is generating energy from what source?

A) It no longer generates energy but is cooling slowly.
B) nuclear fusion of heavy elements in the central core
C) gravitational potential energy as the star slowly contracts
D) nuclear fusion of hydrogen into helium

60. A white dwarf star is supported from collapse under gravity by

A) degenerate-electron pressure in the compact interior.
B) centrifugal force due to rapid rotation.
C) pressure of the gas, heated by nuclear fusion reactions in a shell around its core.
D) pressure of the gas, heated by nuclear fusion reactions in its core.

61. What is the mass limit above which the self-gravity of stars can overcome electron degeneracy pressure – i.e. the approximate maximum mass of a white dwarf star?

A) 0.05 solar masses
B) 1.4 solar masses – the “Chandrasekhar Mass”
C) 14 solar masses
D) There is no limit, because nothing in nature can overcome this quantum mechanical limit.

62. A sequence of thermonuclear fusion processes inside massive stars can continue to transform the nuclei of elements such as carbon, oxygen, etc. into heavier nuclei AND also generate excess energy, up to a limit beyond which no further energy-producing reactions can occur. The element that is produced when this limit is reached is

A) vibranium B) copper. C) uranium. D) iron.

63. What is the source of <u>most</u> of the **heavy** elements (more massive than iron) on the Earth and in our own bodies?

A) explosive nucleosynthesis during supernova explosions of massive stars
B) nuclear reactions during the formation of the Universe (the Big Bang)
C) cosmic ray interactions with hydrogen and helium nuclei in interstellar clouds
D) thermonuclear fusion reactions in the cores of massive stars

64. Type II supernovae show prominent lines of hydrogen in their spectra, whereas hydrogen lines are absent in spectra of Type Ia supernovae. Why is this? (HINT: Think about the type of star that gives rise to each of the two types of supernova.)

A) Massive stars have burned all of their hydrogen into heavier elements, whereas low-mass stars still have large hydrogen-rich envelopes.
B) Massive stars contain large amounts of hydrogen, whereas white dwarfs are mostly carbon and oxygen.
C) White dwarfs have a thick surface layer of hydrogen, whereas neutron stars contain zero hydrogen.
D) Massive stars contain large amounts of hydrogen, whereas neutron stars contain no hydrogen at all.

65. The explosion of a Type II supernova appears to leave behind

A) a rapidly expanding shell of gas and a central neutron star.
B) a rapidly rotating shell of gas, dust, and radiation, but no central object.
C) a rapidly expanding shell of gas and a compacting protostar at its center.
D) nothing, the explosion changes all the matter completely into energy, which then radiates into space at the speed of light.

66. The diameter of a typical neutron star of 1 solar mass is predicted to be approximately

A) 0.01 km.
B) that of the Sun.
C) that of an average city, about 30 km.
D) that of Earth, 12,800 km.

67. Neutron stars can rotate incredibly fast, reaching speeds of up to 20% of the speed of light, making them the fastest rotating massive objects in the universe. Why are these stars rotating so fast?

A) They are an exotic state of matter. As they ages, they slowly speed up. Astronomers are still working on an explanation.
B) They have absorbed much of the energy from the Type II supernova causing them to be spun up to incredible speeds.
C) The red giant is now compacted into a tiny neutron star, to conserve angular momentum, the neutron star must spin incredibly fast.
D) Neutrons, when compacted, create an internal dynamo that can drive this rapid rotation.

68. A pulsar is

A) an interstellar beacon manufactured by little green persons (LGPs).
B) a type of variable star, pulsating rapidly in size and brightness.
C) a neutron star, who’s periodic beams of energetic emissions can be seen from Earth.
D) an accretion disk around a black hole, emitting light as matter is accumulated on the disk.

69. Among the following locations in the universe, where would you expect to find a pulsar?

A) at the center of the galaxy
B) at the center of the Sun
C) in the Orion Nebula (stellar nursery)
D) in the Crab Nebula (supernova remnant)

70. A neutron star will be detected from Earth as a pulsar by its regular radio pulses ONLY if
- A) Earth lies in the plane of the neutron star's magnetic equator, halfway between its magnetic poles.
- B) Earth lies almost directly above the magnetic axis of the neutron star at some time during the star's rotation.
- C) Earth lies directly above the rotation axis of the rotating neutron star.
- D) Earth lies in the neutron star's "equator," the plane perpendicular to its spin axis.

71. The very strong magnetic field of a neutron star is created by
- A) a burst of neutrinos produced by the supernova explosion, because this would be the equivalent of a very large electrical current flowing for a short time.
- B) the collapse of a star, which significantly intensifies the original weak magnetic field of the star.
- C) differential rotation of the neutron star, its equator rotating faster than the poles, similar to Sunspot formation.
- D) turbulence generated in electrical plasmas during the collapse of a star, even though this star had no magnetic field originally.

72. Which is the correct sequence for the following end-points of stellar evolution, in order of increasing maximum mass?
- A) neutron star, black hole, white dwarf
- B) white dwarf, neutron star, black hole
- C) black hole, neutron star, white dwarf
- D) white dwarf, black hole, neutron star

73. Suppose you are in the old Space Shuttle in orbit around the Earth at a speed of 7 km/s, and at some particular time your direction of travel is straight toward the Sun. The speed of light in a vacuum is 300,000 km/s. What speed will you measure for the light from the Sun?
- A) 300,000 km/s
- B) 300,014 km/s because your speed is added to that of the light and relativistic contraction has shortened your reference meter sticks
- C) 299,993 km/s because relativistic contraction has shortened all distances, including your reference meter sticks
- D) 300,007 km/s because your speed is added to that of the light

74. How does a gravitational well 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.

75. According to general relativity, why does the Earth orbit the Sun?
- A) Space around the Sun is curved and the Earth follows 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 the Sun are continually exchanging photons of light in a way that holds the Earth in orbit.

76. Black holes are so named because
- A) they emit a perfect blackbody spectrum.
- B) no light or any other electromagnetic radiation can escape from inside them.
- C) all their electromagnetic radiation is gravitationally redshifted to the infrared, leaving no light in the optical region.
- D) they emit no visible light, their only spectral lines being in the radio and infrared.

77. A black hole can be thought of as
- A) strongly curved space.
- B) a star with a temperature of 0 K, emitting no light.
- C) the point at the center of every star, providing the star's energy by gravitational collapse.
- D) densely packed matter inside a small but finite volume.

78. If the Sun were replaced by a 1-solar-mass black hole, then the Earth would
- A) continue to orbit the black hole in precisely its present orbit.
- B) move into an elliptical orbit passing close to the black hole, with its farthest distance from the black hole equal to 1 AU.
- C) spiral quickly into the black hole.
- D) head off into interstellar space along a straight line at a tangent to its original orbit around the Sun.

79. Which effect has been most useful (and successful) in the search for and identification of black holes in the universe?
- A) the influence of their intense magnetic fields on nearby matter.
- B) the effect of their angular momentum or spin on nearby matter.
- C) the influence of their intense gravitational field on atoms which are emitting light from **inside** the event horizons of the black holes.
- D) their gravitational influence on nearby matter, particularly binary companion stars.

80. What is the event horizon of a black hole?
- A) the "surface" from inside of which nothing can escape
- B) the "surface" at which all "events" or activity appear to happen because of general relativity
- C) the infinitesimally small volume at the center of the black hole that contains all of the black hole's mass
- D) the "surface" inside which any object entering will leave with greater energy than that with which it entered

81. 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

82. The escape velocity for any object at the event horizon around a black hole is
- A) not quite but almost the speed of light.
- B) much less than the speed of light.
- C) infinite.
- D) equal to the speed of light.

83. Take two identical, nonrotating, 5-solar-mass black holes and place them side by side. Add one solar mass of pineapples to the left-hand one and one solar mass of radioactive uranium to the right-hand one (without changing their electric charge or their rotation). Afterward, how do these two black holes differ?
- A) The left-hand one will smell better.
- B) The right-hand one is radioactive, emitting alpha particles, electrons, and gamma rays.
- C) The right-hand one has a stronger gravitational field because of the denser matter inside it.
- D) They do not differ at all.

84. What appears to happen to a clock as it approaches and reaches the event horizon around a black hole, when viewed by a remote observer?

A) It speeds up because of the intensified gravitational field.
B) It appears to slow down and ultimately stop.
C) Time appears to pass at a much faster rate, the rate becoming infinitely fast at the event horizon.
D) It ticks uniformly, because nothing changes the progress of time.

85. Which of the following is not a property of a black hole?

A) Spin
B) Electric Charge
C) Mass
D) Luminosity