Astronomy and Cosmology - spring 2003 - final exam

Take this exam on Friday 6 June 2003, and turn it in by 5 pm.

This is a closed-book exam. Put away your notes and books. You do not need a calculator.

There are about 90 multiple choice questions on this exam. At a minute apiece, this should take you about an hour and a half. The questions are generally easier than the ones on your quizzes. So breathe deeply, relax, and take your time. I hope you will find as you take this exam that you have learned a lot this quarter!

1. Please enter your first and last name.

2. Do you promise to work this exam without looking at any books, notes, or other resources, talking to anyone, or getting any other kind of help?
   A) Yes B) No

3. Do you feel prepared for this exam?

4. Which of the online quizzes did you take this quarter?
   1 (Intro), **2** (Sky), **3** (Moon), **4** (Gravity), **5** (Light), **18** (Sun), **28** (Cosmology)

5. How did you do on the quizzes? Did you use your text to learn while taking quizzes? (This was encouraged.)

6. How much homework did you complete? How did that affect your work on the quizzes?

7. What did you do your minilecture(s) on? Who were your minilecture teammates?

8. What did you do your research project on? Who were your research teammates?

9. Describe the most vivid moments of learning you recall in this program

10. Please share any words of wisdom you have for next year's astronomy students.

11. Start time:_____ end time: _____

12. According to the scientific method, a hypothesis that is proposed to explain a particular physical phenomenon is considered to be wrong if
    A) leading scientists in the world believe that it is wrong.
    B) it is in conflict with the results of just one reliable and repeatable observation.
    C) it appears to defy logic and logical reasoning.
    D) it disagrees with the accepted theory at the time of the proposal.

13. The Moon's angular diameter in our sky is measured to be half a degree. From this, we can find the
    A) bulk density of the Moon (the average number of kilograms per cubic meter of Moon material).
    B) distance to the Moon even if we have no other information about the Moon.
    C) diameter of the Moon in kilometers even if we have no other information about the Moon.
    D) diameter of the Moon in kilometers if we know the Moon's distance.

14. An astronomer finds an object at a distance of 5.6 pc from Earth. Based on the distance, which of the following is this object most likely to be?
    A) an asteroid in our solar system
    B) a star in our galaxy
    C) an artificial satellite orbiting the Earth
    D) a distant galaxy

15. If a supernova was first seen in the year of Christ's birth (the Star of Bethlehem?) and its distance from Earth is measured to be 2 kpc, approximately when did the supernova actually explode?
    A) 2 B.C. B) 6520 B.C. C) 2000 B.C. D) 6520 A.D.

16. The nightly motion of objects across our the sky is caused by the
    A) revolution of Earth around the Sun.
    B) rotation of the whole celestial sphere of stars around the fixed Earth.
    C) rotation of the Earth on its axis.
    D) motion of the solar system around the galaxy.

17. To navigators in the northern hemisphere, their latitude in degrees is equal to
    A) 15 times the number of hours since the sun set.
    B) the angle between their meridian and the north celestial pole.
    C) the angle between the north celestial pole and their zenith.
    D) the angle between the north celestial pole and their northern horizon.

18. It is warmer in summer than winter because
    A) the Sun is higher in the sky and the days are shorter.
    B) the Sun is lower in the sky and sunlight passes through more atmosphere, thereby warming it more during summer.
    C) Earth is closer to the Sun in summer.
    D) the Sun is higher in the sky and the days are longer.

19. On the day of the vernal equinox (approximately March 21 each year), which of the following conditions holds?
    A) The Sun rises at its most northerly point on the horizon on this day.
    B) Both day and night are almost exactly 12 hours long at all locations on the Earth.
    C) Daylight is longest on this day.
    D) The Sun passes through an observer's zenith only on this day each year.

20. The star grouping Leo (the lion) extends for about 30° along and close to the celestial equator. At low to mid-latitudes, roughly how long does it take Leo to rise above the horizon?
    A) 5 hours B) 30 seconds C) 30 minutes D) 2 hours

21. At what approximate time does a full moon rise?
    A) midnight B) sunrise C) noon D) sunset
22. Which of the following will never be seen from Earth as a crescent?
    A) Mercury B) Venus C) Mars D) Moon

23. The Moon rises later each day because each day it has moved farther along its orbit around Earth (except for observers at polar latitudes, for whom the Moon can remain above or below the horizon for 24 hours each day). On average, how much later does it rise each day (you might attempt to verify this by observation)? (Hint: What fraction of a month does a day take up?)
    A) 4 minutes B) 20 minutes C) 2 hours D) 1 hour

24. A lunar eclipse does not occur at every full moon because
    A) a lunar eclipse cannot occur after sunset.
    B) the orbit of the Moon is not a perfect circle.
    C) the plane of the Moon's orbit is at an angle to the plane of the Earth's orbit.
    D) the path of the Sun is inclined at an angle of 5° to the ecliptic plane.

25. Assuming clear skies everywhere, a total solar eclipse is visible
    A) to people anywhere in the sunlit hemisphere of Earth.
    B) to everyone on Earth.
    C) only to people in a circular area on Earth having a diameter equal to that of the Moon.
    D) only to people in a long narrow path much smaller than a hemisphere.

26. Which of the following investigations did the Ancient Greeks NOT carry out?
    A) determination that the Earth's orbit around the Sun is an ellipse
    B) determination that the Earth is approximately spherical.
    C) measurement of the relative distances of the Moon and the Sun from the Earth
    D) measurement of the Earth's radius

27. The Earth's shadow falling on the Moon is the reason we see
    A) solar eclipses.
    B) The Earth's shadow cannot fall on the Moon.
    C) lunar eclipses.
    D) the phases of the Moon.

28. Celestial navigators need to know that each day each star reaches the same location in the sky:
    A) 4 minutes earlier
    B) 4 minutes later
    C) one hour earlier
    D) one hour later

29. The correct order of "appearance" of the following "actors" on the "stage" of scientific discovery is
    A) Ptolemy, Copernicus, Newton, Kepler, Einstein.
    B) Ptolemy, Kepler, Copernicus, Newton, Einstein.
    C) Copernicus, Newton, Kepler, Einstein, Ptolemy.
    D) Ptolemy, Copernicus, Kepler, Newton, Einstein.

30. The concept called Occam's Razor tells us that
    A) the theory that is applicable to the greatest range of phenomena is more likely to be correct.
    B) when two theories describe the same phenomena equally accurately, choose the simpler theory.
    C) the theory that describes phenomena more accurately is more likely to be correct.
    D) when two theories describe the same phenomena equally accurately, choose the theory with the greater complexity.

31. Which of the following statements correctly describes why Copernicus decided that the orbits of Mercury and Venus were smaller than the orbit of Earth?
    A) Both planets show a complete cycle of phases, like the Moon.
    B) Both planets can sometimes be seen high in our sky at midnight.
    C) Both planets occasionally pass through conjunction with the Sun, as seen from Earth.
    D) Both planets stay fairly close to the Sun in our sky.

32. The one key observation Galileo made through his telescope that convinced him that the planets revolved around the Sun was
    A) the appearance of the Milky Way as a mass of individual stars.
    B) the discovery of rings around the planet Saturn.
    C) the appearance of mountains and craters on the Moon.
    D) that the appearance of Venus followed a cycle of phases, from crescent through quarter and gibbous phases to full phase.

33. Which of the following statements is true, according to Kepler's third law?
    A) The smaller the orbit, the longer it takes for the planet to complete one revolution.
    B) The smaller the radius of a planet, the more rapidly it rotates on its axis.
    C) The larger the orbit, the longer it takes for the planet to complete one revolution.
    D) The time to complete one revolution of its orbit depends on the size or radius of the planet.

34. Radio waves travel through space at what speed?
    A) much faster than the speed of light
    B) faster than the speed of light, since their wavelength is longer
    C) slower than the speed of light
    D) at the speed of light, 3×10^8 m/s

35. Spring tides occur
    A) once per month, at full moon.
    B) twice a month, at full and new moon.
    C) most often during springtime.
    D) once a year, in springtime.

36. Which is the correct sequence of electromagnetic radiation in order of increasing energy of the photons?
    A) visible light, UV radiation, X rays, gamma rays
    B) radio waves, microwaves, gamma rays, UV radiation
    C) gamma rays, radio waves, X rays, infrared rays
    D) visible light, microwave, radio waves, infrared rays.

37. As a newly formed star contracts, its temperature increases while the chemical nature of the gas does not change. What happens to the peak wavelength of its emitted radiation?
    A) It moves toward shorter wavelengths (e.g., IR to visible).
    B) It moves toward longer wavelengths (e.g., visible to IR).
    C) It remains constant, since the chemical state of the gas does not change.
    D) It does not change, since it does not depend on temperature.

38. A scientist reports the detection of an atomic particle that came toward his experiment from outer space at a speed of 4×10^5 km/s. What conclusion can we draw from this report?
    A) He has made an error in his experiment, since such a speed is considered to be impossible by all previous experiments.
    B) This "particle" must have been a photon or quantum of electromagnetic radiation of very high energy in order to have traveled this fast.
    C) This result is acceptable since atomic particles can travel this fast, whereas larger bodies are limited to 3×10^5 m s^{-1}.
    D) This is an acceptable result for a particle originating from outer space, since particle speed from such regions is unlimited.

39. The total energy emitted per unit time at all wavelengths from an object increases by what factor if its temperature is increased by a factor of 3?
    A) 27 B) 81 C) 3 D) 9

40. The important breakthrough in theoretical physics that was first suggested by Planck to explain the shape of the spectrum of a hot body was the
    A) concept that electromagnetic energy was emitted in small packets or quanta.
    B) idea that light is a form of electromagnetic energy transmitted at a constant speed and that there is a continuous spectrum of electromagnetic waves from gamma rays to radio waves.
    C) idea that light traveled at a constant speed, whatever the speed of the source.
    D) formula $F = \sigma T^4$, which can be used to calculate the energy flux emitted by the body at all wavelengths.

41. A particular photon of ultraviolet (UV) light has a wavelength of 200 nm and a photon of infrared (IR) light has a wavelength of 2000 nm. What is the energy of the UV photon compared to the IR photon?
    A) 100 times more energy than the IR photon
    B) 1/10 of the energy of the IR photon
    C) 10 times more energy than the IR photon
    D) 1/100 of the energy of the IR photon

42. The chemical makeup of a star's surface is found by
    A) measuring the chemical elements present in the stellar wind.
    B) theoretical methods, considering the evolution of the star.
    C) taking a sample of the surface with a space probe.
    D) spectroscopy of the light emitted by the star.

43. The basic makeup of an atom is
    A) small, negatively charged particles orbiting around a central positive charge.
    B) negative and positive charges mixed uniformly over the volume of the atom.
    C) small, positively charged particles orbiting around a central negative charge.
    D) miniature planets, possibly with miniature people, gravitationally bound in orbits around a miniature star.

44. An astronomer photographs the spectrum of an object and finds a spectral line at 499 nm wavelength. In the laboratory, this spectral line occurs at 500 nm. According to the Doppler effect, this object is moving
    A) away from the Earth at 499/500 the speed of light.
    B) away from the Earth at 1/500 the speed of light.
    C) toward the Earth at 499/500 the speed of light.
    D) toward the Earth at 1/500 the speed of light.

45. A spectrograph is usually used in astronomy to measure the
    A) variation of the mass of an object as it moves through space.
    B) distribution of light intensity among the various colors.
    C) vibration of Earth following an earthquake.
    D) brightness of light at one specific color.

46. Which of the following is not a defect or problem that occurs in a refracting telescope?
A) opaqueness of the glass lens to certain wavelengths of light
B) bubbles in the glass lens which scatters light
C) chromatic aberration, focusing light of different wavelengths to different foci
D) spherical aberration at the primary reflecting surface

47. A particular reflecting telescope has a primary mirror 0.4 m in diameter, 2.0 m focal length, and an eyepiece lens 1.0 cm in diameter and 0.5 cm focal length. What is the magnifying power of this telescope?
A) 400× B) 40× C) 4× D) 80×

48. The two ranges of electromagnetic radiation for which Earth's atmosphere is reasonably transparent are
A) UV and radio waves.
B) visible and far infrared radiation.
C) X rays and visible radiation.
D) visible and radio radiation.

49. How much longer can the Sun continue to generate energy by nuclear reactions in its core?
A) about 500,000 years
B) about 50 billion years
C) about 5 billion years
D) about 5 million years

50. The contraction of a star (or other object) due to its own gravity generates heat. If this process, known as the Kelvin-Helmholtz mechanism, were to be the source of heat energy from the Sun, then the Sun's age
A) would be about 10,000 years.
B) would be about 1 billion years.
C) would be about 25 million years.
D) could easily be its present age of 4.5 billion years.

51. The average time taken for energy generated by thermonuclear fusion in the center of theSun to reach the surface layers and escape is calculated to be
A) just a few seconds, because this energy travels at the speed of light.
B) about 10 million years.
C) about 1 year.
D) 170,000 years.

52. Why is the solar corona so much hotter than the photosphere?
A) Energy is carried upward through the chromosphere by convective gas motion.
B) The corona absorbs part of the light passing through it from the photosphere.
C) The high-speed solar wind passes through it and some of it is stopped, depositing energy.
D) Energy is carried upward through the chromosphere by magnetic fields.

53. The solar wind is
    A) a violent explosive expansion of specific regions of the Sun's atmosphere at certain times.
    B) another name for the electromagnetic radiation coming from the Sun.
    C) the inflow of matter onto the Sun under gravitational attraction.
    D) a gentle outflow of solar material, mostly protons and electrons, always moving outward from the Sun.

54. How does the Sun's overall magnetic field behave?
    A) The northern and southern hemispheres have opposite magnetic polarity, and this polarity reverses every 11 years.
    B) Magnetic polarity is randomly distributed over the Sun, while the strength of the magnetic field increases and decreases with an 11-year cycle.
    C) The northern and southern hemispheres have the same magnetic polarity, and this polarity reverses every 11 years.
    D) The poles of the Sun have the opposite magnetic polarity from the equator, and this polarity reverses every 11 years.

55. What happened to the mean atmospheric temperatures in Europe in the period in history between 1645 and 1715, when virtually no sunspots were seen (now known as the Maunder minimum)?
    A) They were lower than average.
    B) They appeared to fluctuate more strongly above and below the average when compared to the period which followed, from 1715 to the present.
    C) They were higher than average.
    D) They appeared to remain unchanged, within statistical uncertainty.

56. The major feature that distinguishes a sunspot from other regions on the Sun is
    A) that it is much brighter than its surroundings.
    B) its very powerful magnetic field.
    C) faster rotation around the Sun's axis than neighboring regions.
    D) the coronal hole that exists above it.

57. Solar flares, the violent eruptive events on the Sun, occur most frequently
    A) over single, isolated, but large sunspots.
    B) in or above complex sunspot groups.
    C) within solar coronal holes, from which the solar wind originates.
    D) along the solar equator at positions aligned with Jupiter's position, caused by tidal disturbance on the Sun.

58. Two stars in our sky have the same apparent brightness. If neither of them is hidden behind gas or dust clouds, then we know that they
    A) may be at different distances, in which case the nearest one must have the greater luminosity.
    B) may be at different distances, in which case the farther one must have the greater luminosity.
    C) must have the same temperature.
    D) must be at the same distance away from us.

59. 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.

60. Which of the following statements about the mass and lifetime of a star is true?
    A) Stars of about one solar mass have the shortest lives; less massive stars evolve slowly and live a longer time, whereas more massive stars have long lives because of the large amount of fuel they contain.
    B) The more massive the star, the faster it will evolve through its life.
    C) The mass of a star has no bearing on the length of a star's life or the speed of its evolution.
    D) The less massive the star, the shorter its life, because it has less hydrogen "fuel" to burn.

61. Our Sun will end its life by becoming a
    A) black hole. B) white dwarf. C) molecular cloud. D) pulsar.

62. There is a mass limit for a star in the white dwarf phase, the Chandrasekhar limit, beyond which the star can no longer support its own weight. This mass limit, in terms of solar mass, is
    A) 1.4. B) 14. C) 30. D) 0.2.

63. Which of the following properties does the neutrino NOT possess?
    A) travels very close to the speed of light
    B) highly penetrating through any matter
    C) electrical charge equal to that of the electron
    D) extremely small mass

64. 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 rapidly spinning neutron star.
    D) an accretion disk around a black hole, emitting light as matter is accumulated on the disk.

65. What is "special" about the special theory of relativity?
    A) It deals only with objects that are at rest relative to one other.
    B) It deals only with objects moving in a straight line at constant speed.
    C) It deals only with motion at speeds significantly less than the speed of light.
    D) It deals with motion at constant velocity and accelerated motion but excludes all other effects; in particular, it excludes gravity.

66. If you stay on the Earth while a friend races off in a rocket at a speed close to the speed of light then, according to special relativity, you will see a clock on the rocket appear to tick more slowly than the one on your wall. If your friend looks back at your clock then, according to the same theory, the friend will see your clock appear to tick
    A) at the same speed as the clock on the rocket.
    B) faster or slower than the clock on the rocket, depending on the direction of travel of the rocket compared to Earth.
    C) more slowly than the clock on the rocket.
    D) faster than the clock on the rocket.

67. In what way is the general theory of relativity more general (deals with more situations) than the special theory?
    A) It includes accelerated motion but not gravitation.
    B) It includes accelerated motion and gravitation.
    C) It includes only constant, unaccelerated motion.
    D) It includes only motion at the speed of light.

68. 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.

69. Why are black holes called black holes?
    A) Nothing, not even electromagnetic radiation, can escape from inside them.
    B) Only nonvisible radiation longer than about 1,000 nm wavelength (infrared and radio radiation) can escape from them.
    C) They are always surrounded by an accretion disk which absorbs all light escaping from the inside of the black hole.
    D) They emit an electromagnetic spectrum which matches that of a perfect blackbody.

70. Which effect has enabled astronomers to search for and identify black holes in the universe?
A) their magnetic fields and their influence 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 the event horizons of the black holes.
D) their gravitational influence on nearby matter, particularly companion stars.

71. What is the event horizon of a black hole?
A) the "surface" from the 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

72. The only physical properties necessary to completely describe a black hole and its interaction with the rest of the universe are
A) its mass, the chemical or atomic structure of the matter within it, and its overall size.
B) its mass, its angular momentum or spin, and its temperature.
C) its mass, its electric charge, and its angular momentum or spin.
D) the size of its event horizon, the strength of its magnetic field, and the size of its solid core.

73. In terms of black holes, what is a wormhole?
A) a direct connection from a black hole to another part of spacetime
B) a long, thin black hole known as a "string," created by unstable electric fields within the black hole
C) a hole through a solid object, such as a planet, created by the passage of a small black hole through the object
D) a "tunnel" of undistorted space through an event horizon allowing objects to enter and leave a black hole without being torn apart

74. If the Milky Way's center is now thought to contain a supermassive black hole, why is the Sun not falling into it under the black hole's extreme gravity?
A) because the inward force exerted on the Sun from the black hole is offset by the force exerted outward by the hidden "dark" matter beyond the Sun's orbit
B) because its mass is so small that even this extreme mass concentration at the galactic center will not exert a significant force upon it
C) because it has sufficient velocity that it can orbit the galactic center in a circle
D) because the mutual gravitational forces of local stars in the Orion spiral arm are sufficient to overcome the strong inward force and keep the Sun moving in its orbit

75. The possible presence of a very large amount of unseen ("dark") matter in the halo of our galaxy is deduced from
    A) the unexpected absence of luminous matter (stars, etc.) beyond a certain distance.
    B) the rotation curve of our galaxy, which indicates higher than expected orbital speeds in the outer regions of the galaxy.
    C) the rotation curve of our galaxy, which shows that orbital speeds in the outer parts of the galaxy decrease in a way that follows Kepler's law.
    D) the unexpected high amount of interstellar absorption in certain directions.

76. The method used by Hubble to determine the distance to the Andromeda galaxy (M31), thereby establishing the concept of separate and individual galaxies throughout the universe, was the
    A) measurement of the redshift of the whole galaxy.
    B) observation of the apparent brightnesses of supernovas in M31.
    C) measurement of stellar parallax, or apparent motion of stars because of Earth's orbital motion.
    D) observation of Cepheid variable stars.

77. What method is used to determine the distances of very remote galaxies?
    A) use of their spectral redshifts and the Hubble law
    B) measurement of the angular size of the galaxy and an assumption about the actual physical size of the galaxy
    C) measurement of the apparent brightness and period of Cepheid variable stars within the galaxies
    D) comparison of their apparent and absolute magnitudes

78. What was the implication of the observation by Edwin Hubble that the Cepheid variable stars that he measured in the Andromeda Nebula appeared to be very faint compared with what was expected?
    A) The Andromeda Nebula was very far away, and was in fact a galaxy not a nebula.
    B) The observed period was affected by the intense gravitational field of the nebula as predicted by General Relativity, leading to incorrect luminosity determination.
    C) He had discovered a new class of intrinsically faint Cepheid variable stars.
    D) Dust and gas in the nebula had severely reduced the light from these stars.

79. The observational fact about a Cepheid variable star that leads to a measurement of its distance from the Earth is that its period of variation is directly related to its
    A) absolute magnitude or luminosity.
    B) apparent magnitude.
    C) speed away from us, using the relativistic effect upon pulsation period.
    D) surface temperature.

80. The Hubble distance-velocity relation states that
    A) all objects appear to have the same velocity away from the Sun, irrespective of distance from the Sun.
    B) all distant objects are moving toward the Sun, the most distant objects fastest.
    C) the further an object is from the Sun, the faster it appears to be moving away from the Sun.
    D) mutual gravitational attraction of all objects in the universe means that all objects appear to be moving toward the Sun, the closest ones traveling fastest.

81. The expansion of the universe takes place
    A) between all objects, even between the atoms in our bodies, although the expansion of a person is too small to be measured reliably.
    B) only between objects separated by a vacuum; as a result, our bodies do not expand but the Earth-Moon system does.
    C) only over distances about the size of a galaxy or larger; consequently, our galaxy expands but the solar system does not.
    D) primarily in the huge voids between clusters of galaxies: "small" objects like galaxies or the Earth do not expand.

82. How are clusters of galaxies spread throughout the universe?
    A) They are distributed more-or-less evenly (i.e., at random) throughout the universe.
    B) They are distributed over the surfaces of large voids, making the universe look like a large collection of soap bubbles.
    C) They are distributed with increasing density of galaxies toward some point which must be the original site of the Big Bang.
    D) They are distributed into long lines that cover the universe like a gigantic network of strings.

83. Most of the light from a galaxy comes from the inner parts. If this means that most of the galaxy's mass is also in the inner region, then how would we expect the galaxy's speed of rotation to behave in its outer region?
    A) The rotation speed should decrease smoothly with increasing distance from the center, following a Keplerian curve.
    B) The rotation speed should decrease sharply to zero at the outer edge of the visible galaxy.
    C) The rotation speed should increase with increasing distance from the center.
    D) The rotation speed should not change appreciably with increasing distance from the center (i.e., a "flat" rotation curve).

84. What causes cosmological redshift of photons that reach us from distant galaxies?
    A) The photons have moved from high gravitational field regions toward lower fields, thereby becoming reddened.
    B) The photons were emitted from the galaxies much earlier in time when the overall temperature of matter was much lower. Hence, the observed photons are redder, the farther away from Earth that they were produced.
    C) The photons have traveled across space that has been expanding and their wavelengths have expanded with it, becoming redder.
    D) The photons were emitted by objects that were moving rapidly away from us, and thereby have been reddened by the Doppler effect.

85. Where are we?
    A) near the edge of an expanding universe, as shown by the Great Wall of Galaxies
    B) somewhere in an expanding universe, but not in any special part of it
    C) at the exact center of an expanding universe, as shown by the universal expansion away from us in all directions
    D) off-center in an expanding universe, as shown by the fact that the microwave background radiation is at a different temperature in one direction than in the opposite direction

86. What is the "cosmic particle horizon"?
    A) It is the maximum distance to which our own radio and television signals will have traveled through the universe since radio was invented.
    B) It is the distance from which light can travel to us over the finite age of the universe, representing a viewing distance limit for us upon Earth.
    C) It is the distance beyond which we cannot see because of absorbing matter in the universe.
    D) It is the distance at which (because we see back in time as we look out into space) galaxies are just being formed.

87. I thought that the Big Bang was hot! If the cosmic microwave background radiation is the radiation left over from the Big Bang, why then is it only 3 K?
    A) The Big Bang itself was hot, but the temperature decreased as the universe expanded, and the temperature now is 3 K.
    B) It is not from the Big Bang itself—it is from cold, intergalactic hydrogen clouds that are left over from the Big Bang.
    C) The Big Bang itself was hot, but by the time the universe became transparent the temperature had already decreased to 3 K.
    D) The Big Bang was not hot—its temperature was the same as we observe it now from the cosmic background radiation.

88. At an age of 300,000 years, the temperature of the universe had fallen to 3000 K, and electrons could then combine with protons to produce hydrogen gas instead of roaming freely through space. What major transition occurred as a consequence of this change in the universe at this time?
    A) The universe would have lost its electrical charge suddenly to become electrically neutral.
    B) The present laws of physics were applicable to the properties of the universe for the first time.
    C) The universe became transparent to light for the first time.
    D) Nuclear fusion no longer occurs below this temperature, and so, general fusion throughout the universe would have ceased.

89. The very small detected irregularities in the uniformity of the cosmic microwave background are considered to be very important in the study of the evolution of our universe because
    A) they were the seeds of supermassive black holes around which all galaxies then formed.
    B) they are thought to have led to the development of the present concentrations of matter and energy in superclusters of galaxies.
    C) they are thought to contain most of the elusive "missing matter" in the form of energy concentration in the universe.
    D) they show us how non-uniform was the Big Bang explosion.

90. The future of the overall universe, in terms of its ultimate evolution and whether it will expand forever or eventually contract again, is determined by which of its parameters?
    A) the intensity of cosmic microwave background radiation
    B) the temperature of the gas within it
    C) the present volume of the universe
    D) the average density of matter within it

91. Recent results from very bright supernovae in very distant galaxies seem to indicate that the expansion of the universe
    A) is continuing at a constant rate and has done so since just after the Big Bang.
    B) has now stopped and the universe will shortly begin to contract again toward a Big Crunch.
    C) is accelerating (speeding up).
    D) is decelerating (slowing down).

92. Where and how was most of the helium in the universe created?
    A) by nuclear reactions in the cores of stars, and was then thrown out into space by supernovae
    B) by the collision of cosmic rays with hydrogen nuclei in interstellar gas clouds
    C) by high-energy processes during the collapse of pregalactic clouds during the formation of galaxies
    D) by nuclear reactions during the Big Bang

93. The four physical forces at work in the universe are gravitation, electromagnetic, strong nuclear and weak nuclear forces. Which two of these are very short-ranged, extending over distances of only about 10^{-15} m?
    A) strong nuclear and electromagnetic forces
    B) strong and weak nuclear forces
    C) gravitation and electromagnetic forces
    D) electromagnetic and weak nuclear forces

94. How do we know that the fundamental forces become unified as the energy of particle interactions increases?
    A) because, although it is not possible to see unification in the laboratory, the theory of unification agrees with many of the observed properties of the universe
    B) because we have actually seen the start of it in high-energy particle accelerators, where the electromagnetic and weak forces become unified
    C) because experiments have actually been done with high-energy particle accelerators in which all four forces have been unified
    D) only because the theory that says that they do is a very elegant one, and it would be satisfying if it were right

95. The Planck time refers to
    A) the time of extremely rapid inflation that started 10^{-35} second after the universe began.
    B) the time at which the expanding universe became transparent to radiation.
    C) the first 10^{-43} second of time, when all four fundamental forces were united.
    D) the present age of the universe as given by Hubble's law.