1) The photons from the microwave background have not interacted with matter since the universe was how old? 1) _____
A) 4,000,000,000 years old B) 4,000,000 years old C) 400,000 years old D) 4,000 years old E) 4 seconds old

2) The pregalactic blobs had masses similar to 2) _____
A) the Earth. B) the Sun. C) the Large Magellanic Cloud. D) globular clusters. E) the Milky Way.

3) A merger between two large galaxies of comparable size will most likely produce 3) _____
A) a small elliptical galaxy and a large spiral galaxy. B) a small elliptical galaxy and a small spiral galaxy. C) two small elliptical galaxies. D) a large elliptical galaxy. E) a large spiral galaxy.

4) The lensing of a distant quasar is produced by _______ of a foreground galaxy. 4) _____
A) only the mass of the black hole in the nucleus B) a pulsar's intense magnetic field C) all the normal matter and dark matter D) an individual star E) a relativistic jet

5) The Hubble time is expressed as: 5) _____

6) Which of these could be considered as "hot dark matter"? 6) _____
A) weakly interacting magnetic particles (WIMPS) B) deuterium C) dust close to H II regions D) dark energy E) neutrinos

7) In Robert Frost's classic poem, when he ends with "ice will suffice", the universe is: 7) _____

8) The stellar epoch, which we are still in today, began with 8) _____
A) about three billion years after the Big Bang, with population I stars forming. B) the end of the lepton epoch, when neutrinos were formed and escaped from matter. C) about 100 million years after the Big Bang, with the making of galaxies. D) the end of the quark epoch, when neutrons and protons fused into deuterium. E) with the liberation of the dark energy.

9) Before about 4 billion years ago the universe was 9) _____

10) A galaxy that was once a quasar is likely to 10) _____
A) now be a dwarf irregular. B) be less than 5 billion years old. C) still be a quasar. D) have burned all its fuel by now and be dark. E) have a black hole at its nucleus.

11) All of the following are clusters of galaxies EXCEPT 11) _____
A) Perseus B) Hydra C) Virgo D) Coma E) Andromeda

12) The peak of the quasar epoch was 12) _____
A) before the formation of galaxies. B) before the star formation epoch. C) when there was still enough dark matter to fuel the supermassive black holes in their bar. D) before mass had a chance to accumulate at the nucleus. E) when there was still sufficient mass to fuel the supermassive black holes at their center.

13) In pair production in the Big Bang, which statement is FALSE? 13) _____
A) Every electron should have a proton formed at the same time with it. B) Matter is frozen energy, according to Einstein's $E = mc^2$. C) The heaviest particles and their antiparticles formed first, from collisions of the highest energy gamma rays. D) In addition to familiar neutrons and protons, many other exotic particle and antiparticle pairs formed, but decayed back to radiation. E) Even neutrons have their antineutrons, although both lack any charge.
14) A billion solar mass black hole has a radius of only:  
A) 3 parsecs. B) one solar diameter. C) 20 A.U. D) 400 A.U. E) 20 parsecs.

15) An interaction between a large and a small elliptical galaxy that results in a large spiral and a small elliptical galaxy takes
A) several hundred thousand years. B) several thousand years. C) several million years. D) several billion years. E) several hundred million years.

16) At what point do the weak nuclear and electromagnetic forces split?  
A) after about $10^{-10}$ seconds, when the temperature drops below $10^{15}$ K  
B) at $10^{-43}$ seconds, when all four forces separate as the Planck Era ends  
C) at about four seconds, when at millions of degrees hydrogen forms helium  
D) never, they are still united  
E) at $10^{12}$ K, when pair production starts for neutrons and protons

17) How do astronomers define the "superforce"?  
A) a force connecting electromagnetism and the strong and the weak nuclear forces  
B) the GUT, but with no dark energy added  
C) the GUT, with all five forces combined  
D) a force connecting gravity and the electroweak force  
E) a force including only dark energy and gravity

18) The ratio of the universe’s actual density to the critical density is:  
A) $1/H$. B) $\rho_{\text{critical}}$. C) $H/\rho$. D) $\pi/\rho$. E) $\Omega_0$. 

19) A red supergiant is observed in a globular cluster in another galaxy (located 150,000 light years away). It is predicted, based on its mass and age of the star that it will supernova in about 10,000 years. Is this star still there?  
A) No, it died in a supernova 150,000 years ago. B) Yes, it will die in a supernova 160,000 years from now. C) No, it died in a supernova 10,000 years ago. D) No, it died in a supernova 140,000 years ago. E) Yes, it will die in a supernova in 10,000 years.

20) Careful observations of nearby normal and active galaxies reveal that the axis of the central black hole is well correlated with the mass of the galactic bulge. The ratio of bulge mass to black hole mass is roughly  
A) 1 to 20. B) 1 to 2000. C) 20 to 1. D) 200 to 1. E) 1 to 200.

21) Active galaxies are having their central engines temporarily fed by what occurrence?  
A) the merger of a binary black hole system  
B) a close interaction with a neighboring galaxy  
C) attack by a swarm of globular clusters  
D) a series of supernovae all occurring in the dense nuclear bulge  
E) a sudden surge in star formation in the nucleus

22) In the process of pair production, which of the following is a possible product pair?  
A) proton-neutron  
B) electron-positron  
C) electron-neutron  
D) proton-positron  
E) electron-proton

23) According to the data from the microwave background radiation, at what speed and in what direction is Earth moving through the universe?  
A) 70 km/s in the direction of the Big Bang  
B) 380 km/s in the direction of Leo  
C) 600 km/s North  
D) 300,000 km/s in the direction of Polaris  
E) 250 km/s in the direction of Vega

24) If $\Omega_0$ is less than one, then  
A) the universe is closed, and must recycle.  
B) the universe will expand forever.  
C) there is more matter than energy in the universe.  
D) only dark energy exists in the universe.  
E) no matter could have existed.
25) In the closed universe model, the geometry of spacetime in two dimensions resembles the surface of a 25) ______

26) In the Grand Unified Theory, the superforce was 26) ______
A) a union of all matter and energy. B) a union of the weak and electromagnetic forces. C) was only in effect at low energies. D) a union of the gravitational, strong and weak nuclear, and electromagnetic forces. E) only dark energy.

27) Before about 50,000 years after the Big Bang the universe was 27) ______

28) A supernova that occurred 30,000 years ago in a galaxy 100,000 light years away will be observed on Earth 28) ______
A) 100,000 years from now. B) 30,000 years from now. C) 70,000 years ago. D) 100,000 years ago. E) 70,000 years from now.

29) Astronomers think most galaxy interactions took place at redshifts of greater than 1 because 29) ______
A) galaxies were smaller. B) clusters were more compact. C) galaxies were bigger. D) stars were bigger. E) clusters were more diffuse.

30) Compared to the Milky Way, how many stars are contained in the most massive galaxies? 30) ______
A) millions of times. B) hundreds of times. C) tens of times. D) two-three times. E) thousands of times.

31) Before the decoupling, 31) ______
A) there was more helium than hydrogen. B) the Universe was opaque to radiation. C) protons and electrons combined to form atoms. D) deuterium produced electrons and positrons. E) the Universe was transparent to radiation.

32) The sky is dark at night 32) ______
A) because the Sun is on the other side of Earth. B) because the quasars are too far away from Earth for their light to have arrived here. C) because the stars in the Milky Way are far away. D) because there are far fewer stars on the night side of Earth. E) because all the light from all the objects in the universe hasn't arrived here yet.

33) The expansion rate of the Universe is 33) ______
A) constant. B) increasing. C) decreasing. D) different in different directions. E) independent of time.

34) Because of their mass, the threshold temperature for electrons is 34) ______
A) higher than that of protons. B) lower than that of protons. C) higher than that of neutrons. D) lower than that of hydrogen. E) higher than that of hydrogen.

35) In which of the following models will the universe stop expanding? 35) ______
A) Euclidean Universe B) Steady State Universe C) Low Density Universe D) High Density Universe E) Critical Density Universe

36) The concept that on the grandest of scales, the universe is similar in appearance everywhere is 36) ______

37) On the surface of a sphere the shortest distance between two points is 37) ______
A) an arc on a great circle. B) a curvy line. C) a straight line. D) a circle. E) a triangle.

38) The critical temperature for nucleosynthesis to begin was the 38) ______
A) formation of lithium at 50 million K. B) proton-proton cycle at 10 million K. C) deuterium bottleneck at about 900 million K. D) iron production at 10 billion K. E) triple alpha reaction at 100 million K.
39) The distance between adjacent galaxies in a typical cluster is about ____ times the size of a typical galaxy. 39) ____
A) a thousand B) ten to twenty C) five or less D) a hundred E) two or three

40) The critical evidence for cosmic acceleration in 1998 came from two teams of astronomers, both observing: 40) ____
A) type I supernovae. B) hypernovae. C) type II supernovae. D) gamma ray bursts. E) ages of globular clusters.
In the critical density universe now proposed, the ratio of dark energy to matter is about
A) 1 to 5. B) 1 to 100. C) 3 to 1. D) 10 to 1. E) 1 to 1.

The scarcity of what isotope is a critical test of the density of the present cosmos?
A) deuterium B) helium 4 C) helium 3 D) carbon 14 E) lithium 5

According to the microwave background radiation Earth is
A) moving at about 380 km/s toward Leo. B) near the location of the Big Bang. C) in no special location in the universe. D) at the center of the universe. E) in a part of the universe that is just like any other part.

Which of these seems the best present answer to the horizon and flatness problems?
A) symmetry in creation of particles and antiparticles B) the inflationary epoch C) the GUT theory D) The superforce rules creation. E) Dark Energy speeds the universe on out to infinity.

The critical temperature above which pair production can occur is called the