Astronomy 123
Test 3
March 8, 2012

Name ____

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. There are 25 multiple choice questions each worth 2 points for a total of 50 points in the multiple choice questions.

1) How hot was the Universe at time zero? 1) _____
   A) 16, 000 K
   B) 10^{32} K
   C) 5, 800 K
   D) 2.73 K
   E) We have no theory capable to addressing this phase of the evolution of the Universe.

2) The Hubble law says that: 2) _____
   A) the universe has been expanding forever; it is infinitely old.
   B) the structure in the Universe formed through the action of gravity.
   C) the universe started expanding at some time in the past; the universe has an age.
   D) the Universe will eventually collide with an other universe at some point in the future.
   E) the precise location and expansion rate of a universe cannot both be determined at the same time.

3) A reason the cosmic microwave background is important because: 3) _____
   A) it offered strong experimntal evidence in support of the Big Bang theory.
   B) it offered strong support for an inflation phase in the evolution of the Universe.
   C) it allowed us to see how the evolution of the Univerrse looked when it was only 10^{-43} seconds old.
   D) both A & B are correct.
   E) A, B & C are correct.

4) The Hubble Law is expressed as $v = H_o \times D$. We can estimate the age of the Universe as D/v, if we assume that the Universe has expanded at a constant rate. Suppose that the expansion rate of the Universe has, in fact, been slowing since its birth. Our estimate then gives, 4) _____
   A) a smaller age than the true age of the Universe
   B) the correct age of the Universe, despite our incorrect assumption
   C) a larger age than the true age of the Universe
   D) may be larger or smaller than the true age of the Universe. It depends upon whether the Universe is open or closed.
   E) None of the above are correct.

5) When particle pairs are created: 5) _____
   A) the pair is comprised of a matter particle and its anti-matter twin
   B) the particles are created from the conversion of energy into mass
   C) energy is released which is speculated to be the source of the dark matter in the Universe
   D) only A & B are correct
   E) A, B, & C are all correct

6) The data on the CMBR suggests a universe that is: 6) _____
A) completely opposite the expectations of the inflationary epoch.
B) much smaller than we thought previously, which is dominated by radiation today.
C) 27% matter and 73% dark energy.
D) flat, and static in reality.
E) closed and expected to collapse in 24 billion years.

7) Einstein's famous relation $E = mc^2$ 7) _____
A) says we cannot simultaneously measure the mass and energy of a particle with absolute precision.
B) says energy and mass are but different forms of the same physical quantity.
C) relates the mass of a galaxy to its rotation rate.
D) shows how we can solve the matter/anti–matter asymmetry problem.
E) says that nothing can travel faster than the speed of light.

8) Which of these seems the best present answer to the horizon problem? 8) _____
A) the inflationary epoch
B) Dark Energy speeds the universe on out to infinity.
C) the GUT theory
D) The superforce rules creation.
E) symmetry in creation of particles and antiparticles

9) Based on galactic rotation curves and cluster dynamics, we think dark matter: 9) _____
A) is a very minor component on the total mass of the universe.
B) does not exist.
C) is best detected by X–rays in intracluster gas clouds.
D) comprises about 90% of the entire mass of the universe.
E) exists, but has no observable effect on the visible universe.

10) Of the following, what has the cosmic microwave background told cosmologists about the Universe? 10) _____
A) The dark matter in the universe is mostly baryonic in nature.
B) Nothing; it is a product of the black hole in the center of our own Galaxy.
C) We have a *horizon problem* in that it is hard to understand why the CMBR is so isotropic.
D) There must be multiple universes to explain why the CMBR is not precisely isotropic.
E) There msut be many objects outside the observable edge of our Universe.

11) Measuring the mass (matter) in galaxies, clusters of galaxies, clusters of clusters of galaxies, and the other large structures in the Universe, shows that Ω for the mass in the Universe is: 11) _____
A) around 0.3
B) between 1.4 and 2
C) precisely 1
D) zero.
E) infinite.

12) Gravity becomes separate from the other forces at the: 12) _____
A) end of the Inflationary Epoch,.
B) end of electron production, about a minute after creation.
C) end of the Planck Era, about 10^{-43} seconds after the Big Bang.
D) decoupling Event, about a million years after the Big Bang.
E) beginning of particle production, about .0001 seconds into the universe.

13) Pair production can occur if: 13) _____
A) the energy of two photons is greater than the combined mass–energy of a particle–anti–particle pair.
B) photons are at the event horizon of a black hole.
C) the particle and antiparticle have opposite spins.
D) only virtual particles are produced.
E) one particle is struck by a sufficiently high energy photon that a pair of electrons are formed.

14) In the quark epoch, the Universe: 14) _____
A) was composed only of dark energy.
B) was composed primarily of free quarks and gluons.
C) was dominated by normal atoms.
D) was filled entirely by only radiation.
E) underwent several episodes of rapid inflation.

15) What would help scientists probe and understand the Planck Era? 15) _____
A) more detailed observations of the cosmic microwave background
B) discovery of the elusive exotic particle thought to make–up the bulk of the Dark Matter in the Universe
C) a better understanding of the nature of dark energy
D) more sophisticated gravity wave detectors
E) a theory which merges the notions of gravity and quantum mechanics.

16) Of the following,which force is not one of the current fundamental forces in our Universe? 16) _____
A) The gravitational force
B) The electromagnetic force
C) the strong (nuclear) force
D) the Tidal force
E) the weak (nuclear) force

17) What did the COBE and WMAP observations of the CMBR tell cosmologists about the Universe and the Big Bang theory? 17) _____
A) That dark matter dominates the Universe and the Universe is closed.
B) That the Universe could not be understood as one where the expansion rate is speeding up!
C) Nothing; COBE and WMAP raised more questions about the validity of the Big Bang than they answered.
D) The CMBR is perfectly isotropic (smooth), compounding the horizon problem.
E) There are tiny but important "ripples", temperature fluctuations in the CMBR, that are evidence of the seeds of structures that form later in the Universe's evolution.

18) Currently, most of the **MASS** of the Universe is believed to consist of: 18) _____
A) dark matter not made of protons and neutrons.
B) dark energy.
C) tachyonic matter, travelling only faster than the speed of light.
D) baryonic matter, made up of protons and neutrons.
E) tiny but very numerous black holes.

19) The first credible evidence that the expansion rate of the Universe has increased: 19) _____
A) came from observations of variable stars known as Cepheids.
B) came from more accurate determiantions of the ages of the astars in globular clusters.
C) came from observations of type I supernovae.
D) came from the discovery of the CMBR.
E) came from the discovery of large pockets of anti–matter in the Universe.

20) The determination of distances to galaxies have been commonly made using several techniques. Of the following, which is not directly used to find distances to galaxies? 20) _____
A) Cepheid variables
B) Tully–Fisher method
C) Type Ia Supernovas
D) annual trigonometric parallax
E) All of the a bove are used to find distances to far–off galaxies directly.

21) Of the following particles, which is not considered a *fundamental particle*? 21) _____
A) quark
B) electron
C) neutrino
D) proton
E) All of the a bove are considered *fundamental particles* by physicists.

22) Dark energy started to control the evolution of the Universe: 22) _____
A) right after the end of the Placnk era.
B) as soon as the Universe entered its matter dominated phase, around 50,000 years after the Big Bang.
C) at the time of recombination.
D) around 3 or 4 billion years ago.
E) just before the Universe became transparent to visible light.

23) The expansion of the Universe is speeding up, a result attributed to: 23) _____
A) the recently determined mass for the neutrinos.
B) dark energy.
C) the recently discovered negative mass property of anti–matter.
D) the faster than light nature of neutrinos.
E) repulsive electric charge on dark matter.

24) In pair production in the Big Bang, which statement is FALSE? 24) _____

A) In addition to familiar neutrons and protons, many other exotic particle and antiparticle pairs formed, but reverted to radiation. through annihilation
B) Even neutrons have their anti-neutrons, although both lack any charge.
C) Sufficiently high temperatures (energies) are required for pair production.
D) Every electron should have a proton formed at the same time with it.
E) The heaviest particles and their antiparticles formed first, from collisions of the highest energy gamma rays.

25) Which of the following is not a reason to believe that the early Universe underwent a period of rapid expansion called inflation? 25) _____

A) Inflation provides a neat solution to the flatness problem.
B) Inflation is a prediction of the Grand Unified Theories (GUTs), which are themselves becoming more established.
C) Inflation provides a neat solution to the horizon problem.
D) Inflation makes it possible to combine the four fundamental forces of nature into a single "superforce."
E) Inflation provides a nice example of a consequence of when the strong force breaks from the other forces.

SHORT ANSWER. There are 5 short answer questions. Write your answer in the space provided. The point values for each question are given in the questions. The total points in short answers is 50 points.

26) Epoch of Recombination. (10 points)

a. What is the epoch of recombination? When did the Epoch of Recombination occur? (4 points)

b. What is the significance of the Epoch of Recombination for the Cosmic Microwave Background Radiation (CMBR)? (3 points)

d. The CMBR has an average temperature of 2.73 Kelvin. We observed that the CMBR is around 0.001 Kelvin warmer in*front* of us and that it is 0.001 Kelvin in the opposite direction. What causes this difference in temperature in the CMBR? (3 points)

27) The Inflation Theory . (12 points)

a. In what phase and at around what time in the evolution of the Universe did inflation occur? (2points)

b. What caused inflation to occur? (2 points)

c. What observation of the the Universe leads to the Flatness Problem? (2 points)

d. Why is this observed property of the Universe considered a problem by astronomers? (2 points)

e. Describe how inflation solves the Flatness Problem. (4 points)

28) Big Bang Nucleosyntheis (10 points)

a. What elements were preoduced in the Big Bang? (2 points)

b. Roughly, how long after the birth of the Universe were the chemical elements produced? (2 points)

c. What is the *deuterium bottleneck?* (3 points)

d. Why weren't significant amounts of elements more massive than helium produced int he Big Bang? (3 points)

29) Cosmological Constant. (8 points)

a. The cosmological constant was first proposed by Einstein last centrury. What is the *cosmological constant*? (2 points)

b. Roughly, if the cosomological constant idea is correct, then how much of the current Universe is attributable to the *cosmological constant*? (3 points)

d. Describe the *cosmological constant* problem. (3 points)

30) Ultimate Fate of the Universe. (10 points)

a. There are three Friedman models for the Universe, closed, open, and flat. What is meant by closed, open, and flat universes? (3 points)

1.

2.

3.

b. Describe a test which has beeen performed to determine which of the Friedman models applies ot our Universe. (5 points)

c. Which type of Friedman model is thought to apply to our Universe? (2 points)

Answer Key
Testname: ASTR_123_X3_WTR2012

1) E
2) C
3) D
4) C
5) D
6) C
7) B
8) A
9) D
10) C
11) A
12) C
13) A
14) B
15) E
16) D
17) E
18) A
19) C
20) D
21) D
22) D
23) B
24) D
25) D