

Elementary Cosmology ... Fall 2013
Final Exam ... December 20, 2013 ... 10:30am-12:30pm

Name: _____ NetID: _____

**As a member of the Notre Dame community,
I will not participate in, or tolerate, academic dishonesty.**

**Please read all answers.
Please choose the correct answer.
Please check your work**

1. What do physicists mean by the concept of “locality”?
 - A) Some routes between two spatial points are impossible.
 - B) We are unwilling to wait for light to reach us from distant quasars.
 - C) * There is a limited region of space and time that can have an influence on a space-time event.
 - D) We can't see past the CMB radiation
 - E) We can't see inside stars

2. The horizon problem in cosmology deals with the fact that
 - A) nothing can escape a black hole
 - B) we can not see past the Earth's horizon
 - C) the universe appears to be very flat
 - D) * regions that are separated by distances larger than those light could travel in the entire age of the universe look very similar.
 - E) gravity can not make things slide on a horizontal surface

3. How do scientist explain the observation that the universe is made of matter and not antimatter?
 - A) * a very small violation of matter-antimatter symmetry followed by matter-antimatter annihilation leaves only matter
 - B) at no point was antimatter created in the Big Bang
 - C) antimatter is unstable and decays
 - D) antimatter annihilates
 - E) We have no idea.

4. GUT monopoles have never been found and yet they should have been created in the Big Bang. Why have they not been found?
 - A) They have all decayed
 - B) They weren't made in the Big Bang
 - C) They have been found but the discovery has been kept secret
 - D) They are too heavy
 - E) * They have been diluted by cosmic inflation so there are very few in our visible universe

5. To observe proton decay with a lifetime of 10^{31} years.
 - A) one has to wait more than 10^{31} years
 - B) * one has to look at 10^{31} protons for a few years
 - C) one has to wait $\sqrt{10^{31}}$ years
 - D) one can use an accelerator to accelerate the decay
 - E) one can use relativity to stretch out the lifetime

6. The QCD concept of “color” was first proposed
- A) to get quarks to bind together
 - B) to explain the rainbow
 - C) * to understand how the three seemingly identical fermions in a baryon could be in a symmetric wavefunction
 - D) to explain the number of quarks
 - E) to explain the three known charges of QCD
7. Why is the electron in weak decays “almost” always left handed
- A) Half the time it is right handed
 - B) Half the time it is left handed
 - C) All electrons are left handed
 - D) Neutrinos are always left handed
 - E) * The small electron mass permits observation from reference frames that reverse the momentum but not the spin of the electron.
8. A hidden symmetry can be restored
- A) * by imagining the system without the extraneous symmetry breaking
 - B) turning of the magnetic field
 - C) removing the Higgs boson
 - D) turning off gravity
 - E) removing the veil
9. An example of a spontaneously broken symmetry would be.
- A) left hand - right hand
 - B) * the direction of a magnetic field in a ferromagnet (permanent magnet)
 - C) a broken teacup
 - D) there is no preferred location in the universe
 - E) one can never determine that a reference frame is at rest
10. The age of the solar system determined from radioactive dating of Earth rocks, moon rocks and meteorites all comes out close to
- A) about 6000 years
 - B) about 500 million years
 - C) about 13.7 billion years
 - D) about 13.4 billion years
 - E) * about 4.5 billion years

11. The age of the universe estimated from Biblical texts is close to
- A) * about 6000 years
 - B) about 500 million years
 - C) about 13.7 billion years
 - D) about 13.4 billion years
 - E) about 4.5 billion years
12. In the mid nineteenth century the German physicist Herman von Helmholtz estimated that if the Sun derived its energy from burning wood it could be no older than
- A) about 500 million years
 - B) about 4.5 billion years
 - C) * about 1000 years
 - D) about 13.4 billion years
 - E) about 6000 years
13. In the mid nineteenth century the English physicist Lord Kelvin estimated that if the Sun derived its energy from gravitational contraction its age could be at most
- A) * about 500 million years
 - B) about 4.5 billion years
 - C) about 1000 years
 - D) about 13.4 billion years
 - E) about 6000 years
14. Electrical repulsion prevents protons (hydrogen nuclei) in the sun from getting close enough for nuclear forces to dominate unless the temperature is 10 billion degrees Kelvin or greater. But the core of the sun has the hydrostatic equilibrium pressure of a gas at a temperature of 10 million degrees Kelvin. How can the sun generate energy?
- A) the thermal and pressure temperatures are different
 - B) the sun doesn't make enough energy and is dying
 - C) the high energy tail of the thermal distribution of proton energies extends above the energies needed
 - D) quantum tunneling permits some of the reactions to proceed even if the protons are not close enough for the nuclear force to dominate
 - E) * both of the two immediately above (C and D)

15. What fraction of the Sun's total *mass* will be converted into energy over its entire lifetime?
- A) 10%
 - B) 0.7%
 - C) 100%
 - D) * $75\% \times 10\% \times 0.7\% = 0.0525\%$
 - E) 24%
16. The parsec, a unit of distance in cosmology is about
- A) a light year
 - B) the distance of the Earth from the sun
 - C) * 3.278 light years
 - D) the size of our galaxy
 - E) a light second
17. A 10 Watt light bulb at a distance of 10 meters will appear as bright as a 1000 Watt light bulb if the 1000 Watt bulb is at a distance of
- A) 10 meters
 - B) 31.62 meters
 - C) 1 meter
 - D) * 100 meters
 - E) 20 meters
18. In the magnitude scale used by astronomers to describe stellar brightness a star which is 5 magnitudes *larger* than a second star is how many times brighter than the second star?
- A) $10^5 = 100000$
 - B) $2^5 = 32$
 - C) $2.512^5 = 100$
 - D) * $2.512^{-5} = 0.01$
 - E) $10^{-5} = 0.00001$
19. Stars are classified by their surface temperature. From hottest to coolest they are labeled
- A) A, B, C, D, E, F, G, H
 - B) u, d, c, s, t, b
 - C) 1, 2, 3, 4, 5, 6, 7
 - D) red, orange, yellow, green, blue, indigo, violet
 - E) * O, B, A, F, G, K, M

20. The range of intrinsic stellar luminosities in the vicinity of the sun is a factor of
- A) 2
 - B) 100
 - C) 1,000,000
 - D) * 80,000,000
 - E) 1,000,000,000,000
21. Clusters of stars are helpful in estimating the age of the universe since
- A) * all the stars were formed at about the same time
 - B) all the stars are about the same distance from the Earth
 - C) all the stars have the same apparent magnitude
 - D) all of the stars have the same stellar classification
 - E) none of the above
22. Masses in stars in binary star systems can be measured by
- A) measuring their speeds via the Doppler shift of spectral lines
 - B) measuring the orbital period
 - C) measuring the star's angular separation as a function of time
 - D) * all of the above are needed
 - E) masses of stars in binaries can not be measured.
23. Physical systems can be cooled by
- A) * removing the fast components and leaving the slow ones
 - B) shining ultraviolet light on them
 - C) shining infrared light on them
 - D) Doppler blue shifting them
 - E) dropping them in a gravitational field
24. Sunsets appear red and the sky blue because
- A) the sun is red
 - B) the sun is blue
 - C) the air absorbs the red part of the spectrum
 - D) the air absorbs the blue part of the spectrum
 - E) * the air scatters the blue part of the spectrum out of the beam

25. Main sequence fitting can estimate the distance to a cluster of stars by
- A) * adjusting the distance to the cluster until most stars in the cluster lie on the main sequence
 - B) all stars lie on the main sequence
 - C) red giant stars do not lie on the main sequence
 - D) all stars in a cluster are at the same distance
 - E) all white dwarf stars are at the same distance
26. The physics responsible for the variation in luminosity of Cepheid variable stars is
- A) one can determine distances from the absolute magnitude inferred from the period
 - B) all Cepheids in the small Magellanic cloud are at the same distance
 - C) * an instability in the star causes its stellar atmosphere to expand and then cool. Once it cools it shrinks again.
 - D) all red stars have the same absolute magnitude
 - E) helium burning in the core causes the star to expand
27. White dwarf stars, while basically dead, appear to be very hot. Why?
- A) They are so close to us.
 - B) They are very red
 - C) Gas falling onto their surface heats by gravitational contraction
 - D) The core is shielded by layers of gas and dust
 - E) * The degenerate electron gas is a very good heat conductor so you are seeing the core temperature
28. In many globular clusters the main sequence of stars seems to be truncated. Why?
- A) Heavier stars are not made in clusters.
 - B) The light of brighter stars is blocked in clusters.
 - C) * All stars in the cluster are created at the same time. The brighter ones have already used up their fuel and left the main sequence.
 - D) The lack of heavy metals makes these heavy stars shine much dimmer
 - E) Dim stars have used up all of the matter in the cluster
29. The light curve, time structure of the light from a type Ia supernova is determined by
- A) the time it takes for the core to collapse
 - B) the time it takes to burn off the outer layer
 - C) the time it takes the dust to settle
 - D) the mass of the black hole formed
 - E) * the decay times of radioactive nickel and cobalt produced in the explosion

30. The Hubble time is
- A) * the reciprocal of the Hubble constant $\frac{1}{H_0}$
 - B) the exposure time Hubble needed to photograph dim galaxies
 - C) the time it takes light to reach us from the galactic center
 - D) the time for a spiral galaxy to form from inter galactic gas
 - E) the year 1929 when Hubble made his discovery
31. Evidence for dark matter comes from
- A) the 25% dimmer supernovae at large red shifts
 - B) the velocity of galaxies in the Coma cluster
 - C) the velocity of stars in spiral galaxies, “rotation curves”
 - D) the separation of mass and hydrogen in colliding galaxies
 - E) * B C and D
32. Evidence for dark energy, the accelerating universe, comes from
- A) the night sky is dark
 - B) starlight is bright
 - C) the velocity of galaxies in the Coma cluster
 - D) black holes
 - E) * the 25% dimmer supernovae at large red shifts
33. Massive Compact Halo Objects (MACHOs) can be observed via
- A) * gravitational micro-lensing of background stars
 - B) regular pulsations in the radio
 - C) transient bursts of x-rays
 - D) fluctuations in the cosmic microwave background radiation
 - E) they have never been observed
34. Axions, a potential dark matter candidate, have been searched for via
- A) galaxy collisions
 - B) supernova remnants
 - C) big bang nucleosynthesis
 - D) * their scattering with photons
 - E) their violation of the symmetry between matter and antimatter

35. In cosmology reference to “large scale structure” refers to
- A) the mass of stars
 - B) the Hertzsprung-Russell diagram
 - C) * clusters and voids in galaxy distributions
 - D) the inflationary period
 - E) the first 380,000 years of the universe
36. A coordinate system NOT used in observational astronomy is
- A) galactic coordinates
 - B) * hyperbolic coordinates
 - C) ecliptic coordinates based on the plane of motion of the Earth’s orbit
 - D) right ascension and declination - equatorial coordinates
 - E) altitude-azimuth coordinates based on the horizon
37. The reason all elements are not created during the Big Bang is
- A) the neutron is not stable
 - B) there are no stable nuclei with 4 or 12 nucleons
 - C) the proton is not stable
 - D) * there are no stable nuclei with 5 or 8 nucleons
 - E) helium is not stable
38. The first peak in the angular correlation function of fluctuations in the CMB occur at
- A) the acoustic peak “l” of 4 about 90 degrees
 - B) * the acoustic peak “l” of 220 about 0.6 degrees
 - C) about 380,000 years after the Big Bang
 - D) about 330,000 years after the Big Bang
 - E) the acoustic peak “l” of 1 about 360 degrees
39. In 1931 Hubble calculated a Hubble time of about 1.8 billion years and yet at that time it was known that the geological age of the Earth was in excess of 3 billion years. What was wrong at that time.
- A) the geological age is closer to 4.5 billion years.
 - B) * Hubble had used the brighter type I Cepheids but the distance scale had been calibrated with the dimmer type II Cepheids.
 - C) the CMB had not yet been discovered
 - D) there was a 25% systematic error in the supernova luminosity
 - E) Hubble failed to account for dark matter

40. The ESA Planck CMB satellite is orbiting at the Earth Sun L2 Lagrange point. What is the L2 Lagrange point?
- A) a point midway between the Earth and the moon
 - B) a point midway between the Earth and the Sun
 - C) a point midway between the Moon and the Sun
 - D) * it is in orbit around the sun but with the same orbital period of the Earth so it never gets very far away.
 - E) the place behind the sun where alien invaders are hiding.

I hope you have enjoyed this Cosmology course.
Have a safe Christmas holiday.