

Name _____

Do not forget to write your name on your answer sheet and above as well, and fill in your student ID bubbles and test form bubble **A** on your answer sheet. You have 120 minutes. For each question, mark the best answer. The formulas you may want are:

$$F = \frac{GMm}{d^2} \quad F = ma \quad P^2 = a^3 \quad (M + m) P^2 = a^3$$

$$c = \lambda f \quad c = 3 \times 10^8 \text{ m/sec} \quad E = hf \quad P = knT$$

$$\frac{v_{\text{rad}}}{c} = \frac{\lambda_{\text{shift}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}} \quad \lambda_{\text{Peak}} T = 2900 \text{ K} \cdot \mu\text{m} \quad \frac{L}{L_{\odot}} = \left(\frac{T}{T_{\odot}} \right)^4 \left(\frac{R}{R_{\odot}} \right)^2$$

$$d = \frac{3.26 \text{ ly}}{p} \quad L = 4\pi d^2 B \quad v = H_0 d \quad H_0 = 21 \text{ km/s/Mly}$$

- Which of the following is probably a common feature of all active galactic nuclei?
 - Most of the power comes out in the form of visible light
 - The power is always measured to come from a tiny region near the center
 - They are all powered by a black hole at the center that is swallowing gas
 - They all vary their power very quickly
 - They occur in galaxies with very active star formation
- The distance measurement technique that allowed us to see that the expansion of the universe is, in fact, accelerating, is
 - Radar distancing
 - Parallax
 - Main sequence fitting (cluster fitting)
 - White dwarf supernovae
 - Hubble's law
- The position of our Sun in our galaxy is
 - Very near the center
 - In the disk, about half way out
 - In the disk, very near the edge
 - Way above the disk
 - Way below the disk

4. In what way is the white dwarf supernova method of distance measurement dependent on other methods, such as radar distancing and/or Cepheid variable stars?
 - A) The whole system is like a ladder; you have to use short distance methods to calibrate long-distance methods
 - B) The white supernova method can be used only if you already know the distance to the object, and these other methods can be used to determine the distance
 - C) The white dwarf supernova method requires you know the speed of light, which was determined by radar distancing (Cepheid variables are irrelevant)
 - D) White dwarf supernovae are binary stars, and the partner has to be a Cepheid variable star
 - E) None of the above; the white dwarf supernova method would work even if no other methods were available

5. Which of the following is approximately the diameter of the disk of our galaxy?
 - A) 100 AU
 - B) 100,000 AU
 - C) 100 ly
 - D) 100,000 ly
 - E) 1,000,000,000 ly

6. Where can you find main sequence stars on the Hertzsprung-Russel diagram?
 - A) Lower right (only)
 - B) Upper left (only)
 - C) Near the middle (only)
 - D) All of the above
 - E) None of the above

7. Mercury orbits the Sun every 88 days. Which of the following might be the orbital period for Venus?
 - A) 59 days
 - B) 225 days
 - C) 1.9 years
 - D) 12 years
 - E) 29 years

8. In addition to a white dwarf, what is required to make a white dwarf supernova?
 - A) A second white dwarf or neutron star to collide with it
 - B) A giant companion star to feed gas into it
 - C) A large supply of hydrogen in the white dwarf star
 - D) A slow rate of continuous fusion in the white dwarf star
 - E) A collection of iron at the core that is ready to collapse

9. Which of the following is not a property possessed by open clusters?
 - A) They can include some very young stars
 - B) They typically have fewer stars than globular clusters
 - C) They probably have the oldest stars in the galaxy
 - D) They often lose stars; indeed, our Sun probably once belonged to one
 - E) All of these are, in fact, properties of open clusters

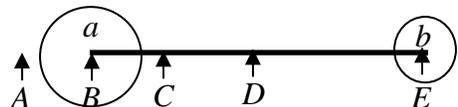
10. Naively, to find the age of the Universe, you would simply take the distance to a distant galaxy, and divide by its velocity away from us to get the time. What is naïve about this assumption?
- A) It assumes the universe is expanding at a constant rate, while in fact in the past it always expanded slower than it does now
 - B) It assumes the universe is expanding at a constant rate, while in fact in the past it always expanded faster than it does now
 - C) It assumes the universe is expanding at a constant rate, while in fact in the past there were times when it went slower and other times it went faster than now
 - D) It assumes the velocity of those galaxies is real, when it's really just an illusion caused by the expansion of space
 - E) Nothing; this is in fact the correct explanation of how we find the age of the universe
11. What is the name of the other large galaxy in our galaxy group or cluster (not our galaxy)?
- A) Hubble
 - B) Virgo
 - C) Milky Way
 - D) Andromeda
 - E) Coma
12. If used Hubble's law to try to figure out how fast Barnard's star is moving, a star 6.0 ly away, what should we expect about its motion?
- A) It should be moving away from us at about 0.12 m/s
 - B) It should be moving towards us at about 0.12 m/s
 - C) Because it is so distant, we can't use Hubble's law, but it should definitely be moving away from us
 - D) Because it is so distant, we can't use Hubble's law, and can't conclude anything about its motion
 - E) Because it is so close, we can't use Hubble's law, and can't conclude anything about its motion
13. Two stars have equal brightness. Star A is spectral type A5. Star B is spectral type B5. Which additional information would allow you to conclude something about the two stars?
- A) If they are both supergiants, then star A is farther away than star B
 - B) If they are both supergiants, then star B is farther away than star A
 - C) If they are both main sequence, then star A is farther away than star B
 - D) If they are both main sequence, then star B is farther away than star A
 - E) None of the above
14. Which part of our galaxy currently has the most production of new stars?
- A) Disk
 - B) Nucleus
 - C) Halo
 - D) Bulge
 - E) Globular clusters
15. On the largest scale, how are galaxies, clusters, and superclusters arranged?

- A) Mostly huge voids, with the galaxies clustered on narrow structures between them
 - B) Arranged along narrow strings scattered throughout the universe
 - C) About half empty and half full
 - D) Mostly uniform, but with occasional small voids scattered throughout
 - E) Almost completely uniform
16. What type of gas produces the 21 cm line caused by the flipping of the spin of the electron?
- A) Hot bubbles of hydrogen gas, so hot the hydrogen is ionized
 - B) Atomic hydrogen clouds, where hydrogen consists of individual atoms
 - C) Molecular clouds, where hydrogen forms molecules
 - D) Ionization nebulae, where nearby stars have superheated the hydrogen
 - E) Complicated molecules like carbon monoxide (CO)
17. Which of the following is a criterion that all standard candles must share?
- A) They must all have a relationship between their period and luminosity
 - B) They must have a consistent luminosity which you can determine without knowing the distance
 - C) They must be common, such that many of them occur in a galaxy at the same time
 - D) They must be bright enough to see across a substantial fraction of the universe
 - E) They must follow Hubble's law
18. How do we know that the black hole at the center of our galaxy has a mass of about 4 million solar masses?
- A) We measure the Doppler shift of gas just before it plunges in
 - B) We measure the 21 cm line of clouds at the edge of our galaxy
 - C) We plot the position of stars over time and use Kepler's laws
 - D) We can see when gas disappears, which tells us the radius of the event horizon
 - E) We don't, it's just a vague guess
19. Which of the following planets has at least five moons?
- A) Jupiter (only)
 - B) Saturn (only)
 - C) Uranus (only)
 - D) Jupiter, Saturn, and Uranus
 - E) None of the above
20. Which of the following is not found in the Solar System?
- A) Planets B) Asteroids C) Ionization nebula D) Oort cloud E) Kuiper belt
21. If a star were in the neighborhood of the Sun, what clue would indicate that it is nonetheless probably a halo star?

- A) It would appear old – only halo stars can be old
 - B) It would have rapid rotation
 - C) It would not have planets
 - D) It would have an orbit indicating it is orbiting out of the plane of the disk
 - E) This is impossible – nearby stars can never be halo stars
22. The Universe is about ___ times older than the Solar System
- A) One
 - B) Three
 - C) Ten
 - D) Thirty
 - E) One-hundred
23. Which of the following is false about galaxy collisions?
- A) They are common; most galaxies have probably undergone collisions
 - B) When they collide, their shapes may become distorted due to gravitational interaction
 - C) The collision can cause gas to compress, causing a burst of star formation
 - D) When a large galaxy collides with a small one, the small one can be “eaten” and incorporated into the large one
 - E) When they collide, the stars in them often collide, destroying them
24. According to lecture, Laniakea is the name of our
- A) Galaxy
 - B) Stellar cluster
 - C) Galaxy cluster
 - D) Supercluster
 - E) Stellar system
25. Which of the following is generally not true about large clusters of galaxies?
- A) They tend to have giant elliptical galaxies near their center
 - B) They tend to have lots of spiral galaxies away from their centers
 - C) They contain no more than about ten or twenty bright galaxies
 - D) There is a lot of dark matter between the galaxies
 - E) They have a lot of hot gas between the galaxies
26. Our best guess for what dark matter is is
- A) White dwarfs
 - B) Neutron stars
 - C) Black holes
 - D) Planets
 - E) None of these
27. Our best guess about what will happen to the universe in the distant future is that it will
- A) Expand forever, and at an ever increasing rate
 - B) Expand forever, but at a constant rate
 - C) Expand forever, but at an ever slowing rate
 - D) Expand for a while, then stop
 - E) Expand for a while, then contract back down again
28. Which method is useful for measuring the mass of an entire cluster of galaxies?
- A) Study how fast our galaxy is attracted to the cluster of galaxies
 - B) Measure the gravitational lensing of galaxies or other objects behind the cluster

- C) Count up all the stars in the cluster
 D) Estimate the amount of gas in the cluster by studying the X-rays from the gas
 E) Study the velocity at which the entire cluster is rotating
29. Our galaxy is especially difficult to observe than many other galaxies because
 A) It is so bright, being close to us, that it overwhelms our detectors
 B) It contains far more gas and dust than a typical galaxy
 C) We are right in the plane of our galaxy, where the most gas and dust is
 D) Our galaxy is exceptionally dim
 E) Our galaxy is so large that we can't even see to the edge of it
30. Which of the following types of electromagnetic radiation has the highest energy for a single photon (particle of light)?
 A) Radio B) X-rays C) Visible D) Infrared E) Ultraviolet
31. The Moon goes around the Earth approximately once per
 A) Year B) Day C) Week D) Month E) Decade
32. There are many uncertainties involved with the probability that intelligent civilizations exist somewhere in the galaxy. Which of the following are we now pretty certain is not a small number?
 A) The average amount of time a civilization lasts
 B) The probability that life starts, assuming there is a suitable planet
 C) The probability that life evolves into intelligent life
 D) The fraction of stars that have planets
 E) Actually, we have no idea of any of these factors
33. When we say the temperature of the universe is now around 2.73 K, what do we mean?
 A) This is the typical temperature of all the gas between the stars
 B) This the average temperature, averaging the very hot stars with all the very cold space in between
 C) This is the temperature a space craft in orbit around the Earth would reach, if not for heaters and so on
 D) This is the temperature of the actual vibrations of space-time
 E) This is the temperature of the cosmic microwave background radiation left over from the big bang

34. Suppose two stars are gravitationally bound, with star *a* substantially heavier than star *b*. Around which point might the two stars actually orbit?



35. According to Copernicus and his Sun-centered models, the reason certain planets like Mars seem to go backwards in the sky compared to the stars is because
 A) Mars is following epicycles that move with respect to deferents
 B) Mars moves at varying speeds at different times

- C) Earth passes Mars, creating the apparent backwards motion
- D) Mars moves at constant speed, but sometimes goes backwards
- E) Refraction by the air on our rotating planets makes it look like it's moving backwards

36. The reason it is hotter in the summer is because

- A) The Sun is closer to the Earth
- B) The sunlight strikes more vertically down in the summer because the Sun is higher in the sky
- C) The rotation of the Earth is faster in the summer
- D) The oceans travel to supply different hemispheres with warm currents in the summer
- E) Guys take their shirts off and women wear bikinis in the summer

37. Which event would have been especially useful for ancient astronomers in trying to figure out the shape of the Earth?

- A) New moon
- B) First quarter
- C) Full moon
- D) Solar eclipse
- E) Lunar eclipse

38. A property that is not generally true of spiral galaxies is

- A) They have a pinwheel like structure
- B) They are typically the largest type of galaxies (central dominant)
- C) They usually contain some young stars
- D) They tend to have a lot of dust in them
- E) They show signs of rotation

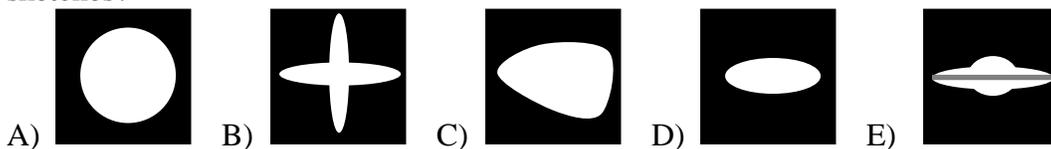
39. Our sun will end its life as a

- A) Black hole
- B) Massive star supernova
- C) Neutron star
- D) White dwarf
- E) Protostar

40. Which of the following is not a stellar corpse?

- A) White dwarf
- B) Black hole
- C) Brown dwarf
- D) Neutron star

- E) Actually, all of these are dead stars
41. Which of the following is one of the ways responsible for the discovery of hundreds of planets around other stars?
- A) The transit method, where the star's light is blocked by the planet as it passes in front
 - B) Direct observations, where high-quality images are searched for dim planets next to the stars
 - C) Robotic missions that travel to the stars to check for planets
 - D) Searches for particular wavelengths of light that are only emitted by planets, not stars
 - E) Gravitational perturbations on the Earth's orbit by those planets
42. Why would we expect the bulge of a galaxy like ours to look redder than the disk?
- A) The bulge consists mostly of old stars; the disk includes young stars
 - B) The bulge includes young stars; the disk consists mostly of old stars
 - C) There is a great deal of reddening due to dust in the bulge
 - D) The bulge is moving away from you, causing a Doppler shift
 - E) The large proportion of iron in the bulge gives it a red color, much like Mars
43. Suppose we did radar distancing to Venus, and then did it again one month later. Which of the following would indicate that Venus had moved away in the mean time?
- A) The reflected signal takes longer the second time
 - B) The reflected signal takes less time the second time
 - C) The reflected signal is weaker the second time
 - D) The reflected wave is more red-shifted the second time
 - E) The reflected wave is more blue-shifted the second time
44. What distinguishes molecular clouds from various other gas clouds in our galaxy?
- A) It is cooler than other clouds
 - B) It is hotter than other clouds
 - C) It is lower density than other clouds
 - D) It is the only regions where new stars are not forming
 - E) It has a high percentage of dust
45. If viewed edge on, our galaxy would probably most resemble which of these sketches?



46. Sort the following three objects into size from smallest to largest
- A) Solar System, Local Group, Milky Way
 - B) Solar System, Milky Way, Local Group
 - C) Local Group, Solar System, Milky Way
 - D) Local Group, Milky Way, Solar System
 - E) Milky Way, Local Group, Solar System
47. For which planets do we think the magnetic fields are primarily generated in their water layers?
- A) Earth (only)
 - B) Uranus (only)
 - C) Neptune (only)
 - D) Uranus and Neptune, but not Earth
 - E) Earth, Uranus, and Neptune
48. Which two factors cause the Moon to have much more extreme temperature variations than the Earth?
- A) Slow rotation and lack of atmosphere
 - B) Lack of atmosphere and dark color
 - C) Dark color and slow rotation
 - D) Smaller size and slow rotation
 - E) Smaller size and lack of atmosphere
49. The most distant planet from the Sun is
- A) Mercury
 - B) Venus
 - C) Uranus
 - D) Saturn
 - E) Neptune
50. How large will the Sun be in the core helium burning stage compared to other stages?
- A) Larger than main sequence, but not as large as a red giant
 - B) Larger than a red giant, but not as large as main sequence
 - C) Larger than both main sequence and red giant
 - D) Smaller than both main sequence and red giant
 - E) It depends on exactly where you are on the core helium burning stage
51. Cepheid variables are not used to study the distance to nearby stars because
- A) The method is not very precise, and radar distancing is more accurate
 - B) Cepheid variables are not visible at this distance
 - C) Nearby stars have unusual properties that messes up the period-luminosity relationship
 - D) These stars are relatively rare, and therefore nearby stars are probably not Cepheids
 - E) Timing methods for such nearby objects have never been developed

52. Which of the following is not true about dust?
- A) It produces infrared light
 - B) It causes objects to look dimmer than they actually are
 - C) It causes object to look redder then they actually are
 - D) We can see through it by using blue visible or ultraviolet light
 - E) All of the above actually are true about dust
53. The largest storm in the solar system can be found on
- A) Earth
 - B) Mars
 - C) Jupiter
 - D) Neptune
 - E) Saturn
54. What fundamental difference made the inner four planets so different from the outer four planets?
- A) They were formed inside the frost line, so water and other ices couldn't condense
 - B) The were near the Sun, whose gravity attracted more metals, rather than ices
 - C) There was very little water this close to the Sun when they formed
 - D) The gravity of the large outer planets pulled the water to them; the inner planets didn't have as much gravity
 - E) The large number of moons for the outer planets contributed their ices
55. What evidence strongly indicates that our galaxy is gravitationally dominated by dark matter?
- A) The presence of gravitational lensing by MACHOS
 - B) The fact that so much of our galaxy is obscured
 - C) Experimental detection of collisions by dark matter particles
 - D) The presence of a massive black hole in the center of our galaxy
 - E) Rotation curves produced by measuring the Doppler shift of the 21 cm line
56. The Sun is currently fusing ____ into ____
- A) Hydrogen, carbon
 - B) Hydrogen, oxygen
 - C) Helium, carbon
 - D) Helium, oxygen
 - E) Hydrogen, helium
57. Assuming humanity does nothing to stop it, which natural disaster is most likely to be the first thing that could wipe out advanced life (like humans) on Earth?
- A) Killer asteroids
 - B) Proton decay
 - C) Global warming (due to the Sun)
 - D) Sun becomes a red giant
 - E) Black hole decay

58. In the early universe, pairs of protons combined with pairs of neutrons to make helium nuclei. Why didn't all the protons get incorporated into helium?
- A) The density of matter was so low that most protons couldn't find neutrons to combine with
 - B) The universe was too cold for this process, called fusion, to occur
 - C) There were, at this stage, more protons than neutrons, so there were protons left over
 - D) They all did make it into helium, but some of the helium subsequently got broken apart by photons, or particles of light
 - E) The protons repelled each other, since they have positive charge
59. The largest contribution to the density of the universe is
- A) Neutrinos
 - B) Dark matter
 - C) Gas
 - D) Stars
 - E) Dark energy
60. Which of the following planets is always in the same general direction as the Sun?
- A) Mercury (only)
 - B) Venus (only)
 - C) Mars (only)
 - D) Mercury and Venus, but not Mars
 - E) Mercury, Venus, and Mars
61. At what point did the universe go from opaque (light can get through it) to transparent?
- A) The grand unified theory (GUT) scale
 - B) The end of inflation
 - C) The Planck era
 - D) The period when the first structures/stars/galaxies formed
 - E) Recombination, when electrons combined with nuclei to make atoms
62. According to the Bohr model of the atom, how come atoms can only emit or absorb certain frequencies/wavelengths of light?
- A) The atom has a certain characteristic size, and the wavelengths have to "fit in" to that size
 - B) The electrons orbit at a specific frequency, which is the only frequency they can emit at
 - C) The electrons can only exist on certain very precise energy levels, and the light has to have exactly the right energy to shift from one level to another

- D) The atoms contain different colored electrons, and those electrons absorb or emit the light
 - E) Atoms in tight clusters work together to emit or absorb certain wavelengths
63. A sufficiently large universe effectively is many universes because of our horizon. Why is there a horizon, beyond which we can't see?
- A) Because the universe has a finite age
 - B) Because there is too much dust in the universe
 - C) Because the universe is curved, just as you can't see around the curved Earth
 - D) Because there was nothing to see at these earlier times
 - E) Because the expansion of the universe has carried things so far away that you can't see them
64. What clue helps us figure out what most stars are made from?
- A) Their overall color
 - B) X-rays caused by the fusion of elements
 - C) Stellar winds that we capture using satellites
 - D) Probes that travel to the stars and collect samples
 - E) The collection of dark absorption lines in the stars' spectra
65. Based on our observations of the universe, the shape of our universe is
- A) Definitely closed, curled up like a ball
 - B) Definitely open, curved significantly like a saddle
 - C) Flat, or nearly indistinguishable from flat, with no curvature
 - D) Closed in two dimensions, but open in the third
 - E) Open in two dimensions, but closed in the third
66. The most important cause of the tides on Earth is
- A) Gravitation from the Moon
 - B) Gravitation from the Sun
 - C) Gravitation from the planets
 - D) Rotation of the Earth
 - E) Magnetic field of the Earth