

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:

$$\sin\left(\frac{\theta}{2}\right) = \frac{\ell}{2d} \quad F = \frac{GMm}{d^2} \quad P^2 = a^3 \quad (M + m) P^2 = a^3$$

$$c = \lambda f \quad c = 3 \times 10^8 \text{ m/sec} \quad \frac{v_r}{c} = \frac{\lambda_1 - \lambda_0}{\lambda_0} \quad E = hf$$

$$T \lambda_{\text{peak}} = 2900 \text{ K} \cdot \mu\text{m} \quad P = knT$$

$$d = \frac{3.26 \text{ ly}}{p} \quad \frac{L}{L_{\odot}} = \left(\frac{T}{T_{\odot}}\right)^4 \left(\frac{R}{R_{\odot}}\right)^2 \quad L = 4\pi d^2 B$$

$$v = Hd$$

$$H = 22 \text{ km/s/Mly}$$

- Long ago, there were lots of relatively small galaxies. How come now there are lots of relatively large galaxies?
 - It's like mice vs. elephants: Little ones are born quickly, and big ones have a longer gestation period
 - It's like children: They start small but gradually grow over time
 - It's like corporate America: Mergers between little ones formed big ones
 - It's like wide screen TV's: The universe had to figure out how to build little ones before it could start building bigger ones
 - It's like looking at a forest: The nearby ones LOOK bigger, just because they are closer
- What is the basic difference between a plasma, like the stars are made from, and an ordinary gas, like our atmosphere?
 - Our atmosphere is all gas; plasmas are a mixture of gas and liquid
 - Plasmas are made primarily of hydrogen, while atmospheres are made of nitrogen and oxygen
 - Plasmas are very low density; atmospheres tend to be much higher density
 - Plasmas have nuclear processes occurring in them; atmospheres have only chemical processes
 - Plasmas have ionized (charged) particles in them; gasses consist of neutral atoms

3. Suppose we took a box full of hydrogen molecules, and replaced them with the same number of oxygen molecules (Oxygen molecules are 16 times heavier than hydrogen molecules). Under what condition would the pressure in the box remain the same? Assume we have an ideal gas in both cases.
 - A) If the temperature were also increased by a factor of 16
 - B) If the temperature were also decreased by a factor of 16
 - C) If the temperature were also increased by a factor of 4
 - D) If the temperature were also decreased by a factor of 4
 - E) If the temperature was also the same

4. Two photons are produced. Photon A has a longer wavelength than photon B. Which one has a higher frequency?
 - A) Photon A
 - B) Photon B
 - C) They have the same frequency
 - D) It is impossible to know unless you know the *color* of the photons as well
 - E) It is impossible to know unless you know the *energy* of the photons as well

5. A galaxy is measured to be moving away from us at about 4400 km/s. Based on this, we can conclude that it's distance is about
 - A) 97,000 Mly
 - B) 200 Mly
 - C) .005 Mly
 - D) 0.00001 Mly
 - E) None of these are (approximately) correct

6. After a star explodes in a supernova (type I or type II), what usually becomes of the gas that is blown away from the star?
 - A) It becomes a large cloud called a supernova remnant
 - B) It becomes a disk called a protoplanetary disk
 - C) It becomes a roughly spherical shell called a planetary nebula
 - D) It recollapses to join the neutron star that is at the core of the supernova
 - E) It forms new stars called protostars

7. According to Kepler's laws, which of the following describes the orbits of the planets?
 - A) They orbit on a circle with the Earth at the center
 - B) They orbit on an ellipse with the Earth at the center
 - C) They orbit on an ellipse with the Earth at one focus
 - D) They orbit on an ellipse with the Sun at the center
 - E) They orbit on an ellipse with the Sun at one focus

8. What makes a blazar different from other active galaxies (AGN's) is probably
 - A) Blazars are probably inherently much more powerful than other types of AGN's
 - B) We are probably looking straight along the direction of the jet for a blazar
 - B) Blazars are producing large amounts of radio waves
 - C) Blazars are coming from much smaller black holes than other types of AGN's
 - D) Blazars are moving towards us rapidly

9. What is the name of the galaxy we live in?

- A) The Milky Way galaxy
 - B) The Great Galaxy in Andromeda
 - C) The Local Group
 - D) The Coma Cluster
 - E) The Virgo Supercluster
10. What fundamental aspect of a galaxy probably determines if it will be an elliptical or a spiral galaxy?
- A) Rotation: The fastest spinning galaxies form spirals
 - B) Rotation: The fastest spinning galaxies form ellipticals
 - C) Mass: The highest mass galaxies form spirals
 - D) Mass: The highest mass galaxies form ellipticals
 - E) Luminosity
11. Newton's three laws of motion were first proposed by
- A) Galileo
 - B) Tycho Brahe
 - C) Newton
 - D) Kepler
 - E) Copernicus
12. Why are there no blue stars in old stellar clusters?
- A) The clusters are filled with dust, which filters out all the blue light
 - B) Stars turn red in the late stages of the main sequence
 - C) Stellar mergers turn them all into red giants
 - D) The red giants are the brightest stars, and these are the only ones we see
 - E) Blue stars are high mass stars, and they don't live long
13. The one quantity that most determines a star's entire history is its
- A) Mass
 - B) Temperature
 - C) Composition
 - D) Rotation
 - E) Radius
14. The Cassini spacecraft is currently in orbit around Saturn. Assuming its engines are not firing, and that no other objects are pulling gravitationally on it, the shape of Cassini's orbit must be a
- A) Parabola
 - B) Hyperbola
 - C) Straight line
 - D) Ellipse
 - E) Frustum
15. How do the stars of the disk of our galaxy differ from those found in the bulge of our galaxy?
- A) The ones in the bulge tend to be much more massive
 - B) The ones in the bulge tend to be much less massive
 - C) The ones in the bulge tend to be younger
 - D) The ones in the bulge tend to be older
 - E) The ones in the bulge tend to be bluer
16. The reason we don't have any good pictures of our galaxy from the outside is because
- A) There is too much gas and dust to see the galaxy from out there

- B) The Voyager spacecraft, the only spacecraft that have left our galaxy, do not have sufficient power to continue functioning that far from the Sun
 - C) The galaxy is just so big that we cannot now (or any time in the near future) send spacecraft outside of it
 - D) Spacecraft are not equipped with wide angle lenses, which would be required for seeing such a large object
 - E) Actually, we do have some pictures from outside the galaxy
17. H II regions, which consist of very hot hydrogen gas, are most easily detected by
- A) The way they block light from objects behind them
 - B) The visible light that occurs when atoms capture electrons that came loose from them
 - C) The 21 cm line that comes from the spin of the electron flipping over
 - D) The molecular vibrations that occur from the many molecules in them
 - E) The stars that formed from these clouds
18. The difference between a poor cluster and a rich cluster is
- A) A poor cluster has fewer bright galaxies
 - B) A poor cluster has less gas
 - C) A poor cluster has more of a round shape
 - D) A poor cluster has less money
 - E) A poor cluster has mostly old stars
19. Which of the following elements is believed to have been primarily produced by the Big Bang?
- A) No elements were formed in the Big Bang
 - B) Hydrogen, but not helium
 - C) Helium, but not hydrogen
 - D) Hydrogen and helium, but not carbon
 - E) Hydrogen, helium, and carbon
20. Which of the following objects has never been visited by any space probe?
- A) Pluto (only)
 - B) Neptune (only)
 - C) Mercury (only)
 - D) All of the above have not been visited
 - E) All of the above have been visited
21. The gas that we produce that contributes a lot to global warming is
- A) Carbon Monoxide
 - B) Carbon Dioxide

- C) Dihydrogen Monoxide (DHMO)
 - D) Sulfur Dioxide
 - E) Ozone
22. The largest and most massive planet is Jupiter. The second largest is
- A) Mars
 - B) Earth
 - C) Uranus
 - D) Saturn
 - E) Neptune
23. According to the Bohr model of the atom, what kind of light comes out of an atom when the electrons have been bumped up to high energy states?
- A) They produce a spectrum consisting of several distinct lines at definite wavelengths, with nothing in between
 - B) They produce a spectrum consisting of several broad bands of a variety of wavelengths, with dark separations between
 - C) They produce a continuous spectrum, with all wavelengths of the visible spectrum
 - D) They produce a dark line spectrum, with almost all wavelengths, but a few missing
 - E) None of the above
24. What advantage do Type I Supernovae have over other distance indicators, such as Cepheid Variable stars?
- A) They are much more common, so you are more likely to observe one
 - B) They are more likely to occur in objects that we are interested in measuring the distance to
 - C) Their spectra make it especially easy to measure their velocity
 - D) They often happen to nearby stars, which helps us get started on the cosmic distance ladder
 - E) They are much brighter than other similar indicators
25. On a scale larger than superclusters, the universe also has clear structure on the scale of
- A) Galaxies
 - B) Stellar clusters
 - C) Galaxy clusters
 - D) Galaxy superduper clusters
 - E) There is no evidence of structure on scales larger than superclusters
26. Dr. Carlson recently received a phone call from someone who said they could explain why gravity stops as soon as you leave the atmosphere because of something called buoyancy. The reason this is total nonsense is because
- A) Gravity doesn't stop as soon as you leave the atmosphere
 - B) Gravity stops long before you leave the atmosphere

- C) Buoyancy, as we discussed, acts like anti-gravity
 - D) The dark matter is so dense there is little difference between atmosphere and no atmosphere
 - E) This is the standard explanation of gravity, so he is saying nothing new
27. Whatever direction we look, we see an almost perfect thermal background at microwave wavelengths at a temperature of about 2.7 K. What is the ultimate source of this radiation?
- A) The Big Bang
 - B) Scattering of light from interstellar gas
 - C) Dust that has absorbed and then reemitted starlight at a lower temperature
 - D) An early generation of ultracold stars
 - E) Light from the upper atmosphere of Earth
28. Which of the following objects has the strongest gravity?
- A) A neutron star
 - B) A white dwarf
 - C) A black hole
 - D) A type I supernova
 - E) A type II supernova
29. What is the significance of the *horizon* when discussing the possibility of multiple universes?
- A) It merely represents the fact, in quantum mechanics, that we are incapable of seeing other parts of the wave function than the one we are in
 - B) It merely represents the fact, in quantum cosmology, that if multiple universes were spontaneously created, we can't see out of our own "bubble universe"
 - C) It merely represents the fact that we can't see farther than the speed of light times the age of the universe, and things farther than that are multiple universes
 - D) It merely represents the fact that, before the big bang, there might have been another universe, and we can't see before the big bang
 - E) It merely represents the fact that, at a microscopic scale, the universe may be filled with very many miniature universes
30. Among the bright galaxies, which type of galaxy is most common?
- A) Elliptical galaxies
 - B) Spiral galaxies
 - C) Barred spiral galaxies
 - D) Irregular galaxies
 - E) Lenticular galaxies
31. At which stage of its life is the Sun currently?
- A) Asymptotic Giant
 - B) Main Sequence
 - C) White Dwarf
 - D) Horizontal Branch
 - E) Protostar

32. The Sun, Planets, Moons, the Kuiper Belt, and the Oort cloud are all parts of our Solar System, but in addition there is/are
- A) The asteroid belt
 - B) Pluto and Charon
 - C) A protoplanetary disk
 - D) A planetary nebula
 - E) Icy bodies beyond the orbit of Neptune
33. If our current theories are correct, the ultimate fate of the universe will be that it will
- A) Recollapse to a point in a time less than the current age of the universe
 - B) Recollapse to a point in a time more than the current age of the universe
 - C) Expand, at an ever slowing down rate
 - D) Expand, at an ever increasing rate
 - E) Expand, eventually at a constant rate
34. Significant atmospheres can be found in our Solar System on
- A) All planets but no moons
 - B) All planets and a few moons
 - C) All planets and many moons
 - D) Nearly all planets but no moons
 - E) Nearly all planets and a few moons
35. In radio galaxies, the radio signals often seem to come from a region that is *not* at the center of the galaxy. Why, in this case, is it still called an active galactic *nucleus*?
- A) The nucleus in such galaxies is actually so large that it protrudes from the galaxy
 - B) The radio “lobes” started as gas that was ejected from the nucleus, and you can often see the jets connecting the two
 - C) The power actually comes from the nucleus, but gravitational lensing distorts it so it seems to come from outside the galaxy
 - D) Though it doesn’t come from the nucleus of a galaxy, it does come from *nuclear* power
 - E) Various violent events have actually flung the nucleus out of the galaxy, so it is no longer at the center of the galaxy
36. According to our current understanding of cosmology, the big bang occurred about
- A) 13.7 million years ago
 - B) 4.6 billion years ago
 - C) 13.7 billion years ago
 - D) 4.6 trillion years ago
 - E) 13.7 trillion years ago

37. How luminous might a very bright quasar be?
- A) As bright as a star like the Sun
 - B) As bright as a million stars like the Sun
 - C) As bright as a billion stars like the Sun
 - D) As bright as 100 billion stars; as bright as a galaxy
 - E) A lot brighter than a galaxy
38. Suppose I look at a galaxy that is 18 million light years away. I see it as it
- A) Is now
 - B) Was about 0.6 years ago
 - C) Was about 18 million years ago
 - D) Was about 5.4×10^{15} years ago
 - E) We cannot see individual galaxies at this distance
39. What is the fundamental difference between the different classifications of spiral galaxies Sa, Sb, Sc, and Sd?
- A) The amount of gas and dust in the galaxy, with Sa having the most and Sd having the least
 - B) The brightness of the galaxy, with Sa being the brightest and Sd the dimmest
 - C) The brightness of the galaxy, with Sa being the dimmest and Sa the brightest
 - D) The size of the spiral arms compared to the bulge of the galaxy, with Sa having the most spiral arms
 - E) The size of the spiral arms compared to the bulge of the galaxy, with Sa having the least spiral arms
40. When you attempt to view a star that is on the other side of a dust cloud, what effect does the dust cloud have on the spectrum of a star, assuming we can still see it?
- A) It tends to absorb blue light, making the star look redder than it really is
 - B) It tends to absorb red light, making the star look bluer than it really is
 - C) It shifts the spectral lines to a shorter wavelength
 - D) It shifts the spectral lines to a longer wavelength
 - E) It absorbs the spectral lines, so the star looks like it has a thermal spectrum
41. Drake's equation, which does not appear in the table above, is used to
- A) Calculate the rate at which stars appear in the galaxy
 - B) Calculate the probability that a star has planets
 - C) Estimate the number of planets and moons that would be suitable for life around a given star
 - D) Estimate the probability that life would ultimately become intelligent
 - E) Estimate the number of intelligent species in our galaxy

42. How does our galaxy compare in size with other galaxies in our cluster?
- A) It is a lot smaller than most of the other galaxies
 - B) It is a lot bigger than some other galaxies, and a lot smaller than others
 - C) It is about the same size as all the other galaxies
 - D) It is one of the largest, though there is one other galaxy about the same size
 - E) It is much bigger than the other galaxies in our cluster
43. Which of the following approximately corresponds to the makeup of the universe, according to current theory?
- A) 73% dark matter, 23% dark energy, 4% gas and stars
 - B) 4% dark matter, 23% dark energy, 73% gas and stars
 - C) 73% dark matter, 23% dark energy, 4% gas and stars
 - D) 23% dark matter, 4% dark energy, 73% gas and stars
 - E) 23% dark matter, 73% dark energy, 4% gas and stars
44. How is dark energy different from dark matter, gas, stars, and everything else?
- A) It has energy instead of mass
 - B) It has repulsive gravity instead of attractive
 - C) It cannot be directly observed, i.e., we have never seen any of it, only its effects
 - D) It exists between galaxies
 - E) I have no idea; please mark this one wrong
45. Star A and star B are both main sequence stars, and they are the same distance away. Star A is an A2 star, and star B is a B7 star. Which star will look brighter?
- A) Star A
 - B) Star B
 - C) They will look the same brightness, because they are at the same distance
 - D) It is impossible to predict without knowing their temperatures
 - E) It is impossible to predict without knowing their distance
46. Which of the following planets has several very large moons, one of them larger than Mercury?
- A) Venus B) Mars C) Uranus D) Neptune E) Jupiter
47. Most of the mass of our galaxy can be found in the _____ and seems to be made mostly of _____ .
- A) Bulge, stars
 - B) Bulge, gas
 - C) Bulge, dark matter
 - D) Halo, gas
 - E) Halo, dark matter

48. What is the one requirement that a Standard Candle must have to work for measuring distances?
- A) It must be consistently the same brightness
 - B) It must be consistently at the same distance
 - C) It must be consistently the same luminosity
 - D) It must last for consistently the same duration
 - E) It must be relatively nearby
49. Which of the following is not part of our local “address”; i.e., it is not the name of one of the groupings in which Earth can be found?
- A) The Solar System
 - B) The Virgo Supercluster
 - C) The Local Group of galaxies
 - D) The Libra star cluster
 - E) Actually, we do belong to all of these
50. Suppose we wanted to know, within our lifetime, whether there are intelligent species on other planets. What would probably be the most productive way to look for them?
- A) Look for infrared signals from alien intelligent species
 - B) Look for radio signals from alien intelligent species
 - C) Send unmanned space probes to other stars
 - D) Send manned space probes to other stars
 - E) Watch Star Trek reruns, since these are actually documentaries
51. The tides on the Earth are generally caused by
- A) The rotation of the Earth
 - B) The gravitational attraction of the Sun and Moon
 - C) The rotation of the Sun and Moon
 - D) The gravitational attraction of the other planets
 - E) The rotation of the other planets
52. When is one star likely to transfer mass to its companion in a close binary system?
- A) When the more massive star dies, but not when the less massive one dies
 - B) When the less massive one dies, but not when the more massive one dies
 - C) When the more massive star is in a giant stage, but not when the less massive one is in a giant stage
 - D) When the less massive star is in a giant stage, but not when the more massive one is in a giant stage
 - E) When either star is in a giant stage

53. How do we know that the dark matter in our galaxy does not consist of a lot of solar mass black holes?
- A) If it did, we'd see patches of darkness in the cosmic microwave background radiation
 - B) If it did, we'd see gas flowing into it from companion stars, producing X-ray binaries
 - C) If it did, we'd see gravitational effects from passing black holes all the time
 - D) If it did, we'd see stars that they pass in front of darken or vanish, as the black hole absorbs the light from it
 - E) If it did, we'd see stars that they pass in front of brighten, as the black hole acts like a lens to magnify the light from it
54. Which distance method would be best for measuring the distance to Venus?
- A) Type I supernovae
 - B) Cepheid variable stars
 - C) Hubble's Law
 - D) Radar distancing
 - E) Spectroscopic parallax
55. Where is the Sun in our galaxy?
- A) It is almost at the exact center of the disk of our galaxy
 - B) It is near the center, but not very near the center, or the galactic disk
 - C) It is well away from the center, but not at the outer edge
 - D) Is at the outer edge, the disk ends very near us
 - E) It is not in the disk of the galaxy at all
56. Why are all of the planets of the solar system orbiting the Sun in about the same plane?
- A) They formed from a single rotating protoplanetary disk
 - B) The Sun's gravity pulls them steadily into a plane from whatever orbit they started in
 - C) The Sun's magnetic field pushes them around in this plane as the Sun rotates
 - D) Dust obscures our view outside of this plane
 - E) Asteroids destroy any objects that don't lie in this plane
57. Hubble's Law doesn't work very well for nearby objects like the Larger Magellenic Cloud because
- A) The velocity is too great to measure by this method
 - B) We are looking back in time, when Hubble's constant was different
 - C) The resulting velocity is smaller than random "peculiar velocities", and hence the result is pretty much meaningless
 - D) The velocity is so small that the Doppler shift cannot be measured
 - E) Hubble's Law only works on stars, not galaxies
58. Which of these equations is used to calculate the Doppler shift?

A) $E = hf$ B) $v = Hd$ C) $F = \frac{GMm}{d^2}$ D) $\frac{v_r}{c} = \frac{\lambda_1 - \lambda_0}{\lambda_0}$ E) $P^2 = a^3$

59. What is the difference between spectroscopic parallax and cluster fitting?
- A) Cluster fitting works with several stars allowing you to rely on better statistics and compensate for age effects
 - B) Cluster fitting measures angles; spectroscopic parallax uses the HR diagram
 - C) Spectroscopic parallax measures angles; cluster fitting uses the HR diagram
 - D) Spectroscopic parallax uses main sequence stars; cluster fitting uses giant stars
 - E) Cluster fitting uses giant stars; spectroscopic parallax uses main sequence stars
60. In which case is the volume of the universe necessarily finite?
- A) If it's closed (only)
 - B) If it's flat (only)
 - C) If it's open (only)
 - D) If it's closed or flat
 - E) If it's open or flat
61. On which of the following two objects have dunes been seen?
- A) Mars and the Moon
 - B) Titan and the Moon
 - C) Titan and Mars
 - D) Mars and Venus
 - E) Titan and Venus
62. Which of the following products of nuclear fusion in the Sun come immediately out from it at the speed of light?
- A) Energy B) Hydrogen C) Helium D) Neutrinos E) Electrons
63. What method can be used to estimate the total mass of a galaxy cluster?
- A) You can orbit a spacecraft around it and use Newton's laws
 - B) You can measure the Doppler shift of a star orbiting it and use Newton's laws
 - C) You can measure the bending of light from an object behind the cluster
 - D) You can estimate the number of stars and multiply by the number of stars
 - E) You can find the density of a galaxy and multiply by the volume of the whole cluster
64. Which cosmological parameter is supposed to determine the shape of the overall universe?

- A) The quantity Ω , which describes the density of the universe
 - B) The quantity H , which describes how fast the universe is expanding
 - C) The quantity d , which describes distances in the universe
 - D) The quantity v , which tells us the speed of the universe
 - E) The quantity q_0 , which describes how the expansion is accelerating
65. If you were to group Earth with three other planets of the Solar System, based on composition, which planets would you group it with?
- A) Jupiter, Saturn, Neptune
 - B) Mercury, Uranus, Neptune
 - C) Mercury, Venus, Mars
 - D) Venus, Jupiter, Saturn
 - E) Mars, Uranus, Neptune
66. In elliptical galaxies, where do we see spiral structure, like we have in spiral galaxies?
- A) In the bulge itself, not the disk
 - B) In the disk, but not the bulge
 - C) In both the bulge and the disk
 - D) In neither the bulge nor the disk, but in hydrogen gas clouds circling the galaxies
 - E) Elliptical galaxies do not have spiral structure