

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:

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

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

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

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

- The evidence for dark matter in galaxies like our own mostly comes from
 - Measuring how much light is blocked out by the dark matter
 - Measuring the mass of the dark matter from gravitational lensing
 - Measuring the mass from its effects on rotation curves for the galaxy
 - X-rays from gravitationally trapped hot gas within our halo
 - Measuring the speed of stars orbiting the very center of our galaxy
- Often, the power of an active galaxy comes mostly from right in the center, but _____ waves are often found coming from giant lobes that stick entirely out of the galaxy
 - Visible
 - Ultraviolet
 - X-ray
 - Radio
 - Gamma
- What is the name of the galaxy we live in?
 - Milky Way
 - Virgo
 - Local Group
 - Andromeda
 - Coma
- Within the disk of the galaxy, what sort of clusters of stars can typically be found?
 - Open clusters (only)
 - Globular clusters (only)
 - Spiral clusters (only)
 - Open and globular clusters, but not spiral clusters
 - Open and spiral clusters, but not globular clusters
- If a rocket were moving somewhat faster than escape velocity from the Sun, what shape would its orbit take?
 - Circle
 - Ellipse
 - Parabola
 - Straight Line
 - Hyperbola

6. Dark matter is probably mostly comprised of
 - A) Planets not orbiting stars
 - B) White Dwarfs
 - C) Neutron stars
 - D) Black Holes
 - E) None of the above
7. Who came up with three laws of motion, invented calculus, invented a new type of telescope, and studied light?
 - A) Galileo
 - B) Newton
 - C) Kepler
 - D) Tycho Brahe
 - E) Copernicus
8. Which of the following is generally *not* considered necessary for a planet to generate a magnetic field?
 - A) Rotation
 - B) Magnetic minerals, like magnetite
 - C) An electrically conducting layer
 - D) A fluid (liquid or gas) layer
 - E) Actually, all of these are required to generate a magnetic field
9. A galaxy that appears to be a perfect sphere would be categorized as
 - A) E0
 - B) E7
 - C) S0
 - D) SBd
 - E) Irr
10. Which of the following approximately corresponds to the amount of time it takes for the Moon to go through a full cycle of its phases?
 - A) One day
 - B) One week
 - C) Two weeks
 - D) One month
 - E) One year
11. Which of the following methods would decrease the gravitational force of the Earth on the Moon by a factor of four?
 - A) Increase their separation by a factor of two (only)
 - B) Increase their separation by a factor of four (only)
 - C) Decrease their masses by a factor of two each (only)
 - D) A and C would both work, but not B
 - E) B and C would both work, but not A
12. Why is the banding pattern on Jupiter more evident than on Saturn, and far more evident than on Uranus or Neptune?
 - A) Jupiter has a larger fraction of the relatively rare compounds that form those clouds
 - B) Icy layers on Neptune and Uranus (and to some extent on Saturn) block our view of these clouds
 - C) Jupiter spins much faster than any of these planets, causing it to naturally have a more band-like structure
 - D) Jupiter is simply better illuminated, since it is closer to the Sun
 - E) Jupiter is warmer, and hence the clouds that cause these bands are closer to the outside, since they form at temperatures close to the surface temperature
13. The most common element in most stars is

A) Helium B) Carbon C) Iron D) Hydrogen E) Oxygen

14. What interesting property is believed to happen to the hydrogen atoms in Jupiter's and Saturn's interior, due to the enormous pressure?
- A) They undergo nuclear fusion, becoming helium
 - B) They undergo chemical reactions, making complex hydrogen rings
 - C) They compress so tightly that Jupiter and Saturn each have very high average density
 - D) They form a liquid metallic layer where the magnetic fields are probably generated
 - E) They create enormous heat, which is the source of these planet's internal heat
15. Ionization nebulae emit light when free electrons are captured by atoms and fall from high levels to low levels. What typically knocked the electrons out of the atoms in the first place?
- A) Collisions with fast-moving clouds
 - B) X-rays from X-ray binaries
 - C) Strong magnetic fields
 - D) Ultraviolet light from hot, young, high-mass stars
 - E) Supernovae and similar violent events
16. Which observations allowed early astronomers to realize that the Earth is a sphere, not a flat disk (or some other shape)?
- A) The shape of the Earth's shadow on the Moon during lunar eclipses
 - B) The apparent shape of the Sun during solar eclipses
 - C) The apparent shape of the phases of the Moon
 - D) The fact that only certain stars are visible on any given night
 - E) The motion of the stars over the course of a night
17. In the Doppler method, how do we detect the presence of extrasolar planets?
- A) The light from the planet is alternately red shifted and blue shifted by its motion around the star
 - B) The light from the star is alternately red shifted and blue shifted by the gravitational influence of the planet
 - C) The planet is observed to move slightly to one side and back as it orbits its star
 - D) The star is observed to move slightly to one side and back under the influence of the planet
 - E) Light from a distant star is gravitationally lensed by the planet
18. What is the largest contributor to the mass of our galaxy?
- A) Dark matter B) Dark Energy C) Neutrinos D) Neutrinos E) Stars
19. Which gas is believed to be responsible for Venus's high temperature?
- A) Water B) Methane C) Carbon monoxide D) Carbon dioxide E) Ammonia
20. The Hertzsprung-Russell diagram is a plot of what two things?
- A) Temperature and mass

- B) Temperature and composition
 - C) Luminosity and mass
 - D) Luminosity and composition
 - E) Temperature and luminosity
21. Which represents the best guess about how the spiral structures occur in spiral galaxies?
- A) Ribbons of gravity are curved by rotation to make the spiral structure
 - B) The spiral structure is actually an illusion caused by gravitational lensing
 - C) Dark matter spewed out from the rotating bulge attracted stars in a spiral pattern, much like the patterns from a rotating garden sprinkler
 - D) They were initially straight lines, but as the galaxy rotated, they got bent into their current shape
 - E) They are self-propagating waves of high density, where new bright stars form
22. As viewed from Earth, essentially all galaxies are moving away from us. If we moved to a very distant galaxy, what would we see?
- A) All galaxies moving towards us
 - B) All galaxies moving away from us
 - C) Galaxies would seem to be streaming past us
 - D) Galaxies on one side would be moving towards us, on the other they would be moving away
 - E) None of the above
23. The most massive galaxies of all tend to be
- A) Spiral
 - B) Barred spiral
 - C) Elliptical
 - D) Spherical
 - E) Irregular
24. Which of the following is not a form of stellar corpse, or dead star?
- A) White dwarf
 - B) Neutron star
 - C) Brown dwarf
 - D) Black hole
 - E) All of the above represent dead stars
25. Saturn's rings are made primarily of
- A) Rock
 - B) Metal
 - C) Hydrogen gas
 - D) Helium gas
 - E) Water ice
26. Which form of electromagnetic waves have the highest energy per photon?
- A) Visible
 - B) Gamma rays
 - C) X-rays
 - D) Ultraviolet
 - E) Infrared
27. What surprising fact was discovered about the expansion of the universe using very distant white dwarf supernovae?
- A) The expansion of the universe is speeding up
 - B) The expansion of the universe is occurring at a constant rate

- C) The expansion of the universe is slowing down
 - D) For distant objects, the expansion of the universe has already stopped
 - E) For distant objects, the universe has already started contracting
28. Which elements are believed to have been made when the universe was a few minutes old?
- A) Hydrogen, but not helium
 - B) Hydrogen and helium, but not carbon
 - C) Hydrogen, helium, and carbon, but not oxygen
 - D) Hydrogen, helium, carbon, and oxygen
 - E) No elements were created in these first few minutes
29. If I wanted to have some idea of how galaxies looked long, long ago, my best bet would be to
- A) Find some very young galaxies, since in the past, all galaxies were young
 - B) Look at current galaxies, and extrapolate backwards to very early times
 - C) Look at galaxies very far away, since light travels at a finite speed
 - D) Look at galaxies that are heavily shrouded by dust, since the dust slows down the light
 - E) There is no way; the best you can do is pure computer modeling
30. What is the name of the galaxy group or cluster we live in?
- A) The Virgo cluster
 - B) The Coma cluster
 - C) The Local Group
 - D) The Andromeda Group
 - E) None of the above
31. Which of the following factors is NOT one of the ones we discussed for estimating the likelihood of a planet having intelligent life?
- A) The rate of star formation in the galaxy
 - B) The average number of planets and moons at the right temperature
 - C) The probability of life appearing
 - D) The probability of life evolving intelligence
 - E) The probability of a planet having an oxygen atmosphere
32. Which of the following is not a part of the Solar System?
- A) Asteroids
 - B) The Kuiper belt
 - C) The Sagittarius stream
 - D) The Oort cloud

- E) Actually, all of these are part of the Solar System
33. What two quantities are related for Cepheid variable stars?
- A) Spectral class and luminosity
 - B) Radius and luminosity
 - C) Period and luminosity
 - D) Temperature and radius
 - E) Temperature and period
34. Which of the following is NOT a categorization of galaxies?
- A) Spiral
 - B) Barred spiral
 - C) Elliptical
 - D) Spherical
 - E) Irregular
35. What force holds the nucleus together inside an atom?
- A) Electric
 - B) Magnetic
 - C) Gravity
 - D) Weak
 - E) Strong
36. Molecular clouds tend to be relatively _____ density and _____ temperature, which makes it easy for them to contract and form stars and planets
- A) high, high
 - B) low, low
 - C) high, low
 - D) low, high
 - E) shiny, obsequious
37. Which of the following probably describes at least part of the story of how large galaxies came to be?
- A) It was once much more massive, but collisions have knocked pieces off of it
 - B) It was once much more massive, but evaporation from the edges has eroded it
 - C) It has always been about the same size and mass, with little change over time
 - D) It was once much less massive, but galactic cannibalism has allowed it to grow by eating smaller galaxies
 - E) It was once much less massive, but it created dark matter that increased its mass
38. The Sun is a G2 star. The star α Centauri A is also a G2 star. What additional piece of information would allow you to conclude that they are probably about the same luminosity?
- A) They are both main sequence stars
 - B) They are both about one solar mass
 - C) They are at about the same distance from the Earth
 - D) They are about the same brightness
 - E) None of the above would allow us to conclude that they have similar luminosities
39. What advantage does the Cepheid variable method of determining distances have over cluster fitting?
- A) Cepheid variable stars are very bright, unlike the stars used in cluster fitting
 - B) Cepheid variable stars can be pinpointed accurately enough that we can use parallax to measure the distance to them
 - C) Cepheid variable stars are much more common than the stars used in cluster fitting

- D) Cepheid variable stars have a luminosity that is directly related to their spectral class
 - E) Cepheid variable stars are usually much closer to us, so we can get distances more accurately to them
40. Neutral hydrogen atoms, not bound into molecules, are typically mapped out in our galaxy by
- A) The X-rays coming from colliding atoms
 - B) The 21 cm line that comes from the electron spin flipping over
 - C) The visible light produced as the electron drops from one level to another
 - D) The amount to which more distant objects are obscured by the intervening gas
 - E) The faint infrared glow of the thermal emission from this gas
41. Why don't we use Hubble's Law to get the distance to Sirius, one of the closest stars to the Sun?
- A) It is almost impossible to get the Doppler shift on an individual star
 - B) The Doppler shift for such a nearby star is too small to measure
 - C) The motion of the Earth around the Sun confuses the measurement of the velocity
 - D) Objects this close do not generally participate in the general expansion of the universe, so this method is completely unreliable
 - E) Actually, this probably is the method used to measure the distance to Sirius
42. Compared to the stars, which objects move, as viewed from Earth?
- A) The Sun, Moon, and planets
 - B) The Sun and Moon, but not the planets
 - C) The Moon and planets, but not the Sun
 - D) The Sun and planets, but not the Moon
 - E) The planets, but not the Sun or Moon
43. The main determining factor in the lifetime for a newborn star is its
- A) Mass: heavier lives longer
 - B) Mass: heavier lives shorter
 - C) Composition: more helium lives longer
 - D) Composition: more helium lives shorter
 - E) Velocity: slower moving lives shorter
44. If the universe started off very hot, you would think it would glow. What became of this light from the Big Bang?
- A) It has been absorbed by all the dust in the universe
 - B) It was absorbed by stars, which heated them up so they could undergo fusion
 - C) It is still present, as gamma rays, which are too energetic to penetrate the Earth's atmosphere
 - D) It is still present, but it has shifted to long wavelengths, and constitutes the cosmic microwave background radiation at 2.72 K.

- E) It was absorbed and eliminated during primordial nucleosynthesis
45. Why does the bulge of a galaxy typically look redder than the disk of a galaxy?
- A) Because the concentration of red helium gas is higher there
 - B) Because the bulge contains mostly older stars, which tend towards red
 - C) Because the bulge contains mostly younger stars, which tend towards red
 - D) Because there is so much dust in any bulge that it makes all the stars there look red
 - E) Because the bulge is typically moving away from us at high speed, causing red shift
46. Which types of galaxies generally still have active star formation going on?
- A) Elliptical galaxies (only)
 - B) Spiral galaxies (only)
 - C) Barred spiral galaxies (only)
 - D) Elliptical and spiral galaxies, but not barred spiral galaxies
 - E) Spiral and barred spiral galaxies, but not elliptical galaxies
47. On the largest scale, the distribution of galaxies is a bit like
- A) Like pudding, with a constant distribution throughout
 - B) Like spaghetti, with galaxies distributed in long, twisting lines
 - C) Like Swiss cheese, mostly solid with small holes throughout
 - D) Like soap bubbles, mostly empty space with thin layers of galaxies between them
 - E) Like a parfait – flat layers of galaxies with gaps between
48. Which of the following planets is the smallest?
- A) Earth B) Jupiter C) Neptune D) Saturn E) Uranus
49. We have photos of the exterior of our galaxy thanks to
- A) The Hubble Telescope
 - B) The Voyager spacecraft sent out in the 70's
 - C) The New Horizons mission to Pluto
 - D) Reflections from distant Planetary Nebulas
 - E) Actually, we have no images from outside our galaxy
50. Why is it believed there are so many varieties of active galaxies, producing different kinds of spectra and so on?
- A) Some are produced by black holes, others by neutron stars, white dwarfs, or indeed, any combination of these objects
 - B) Different kinds of gases are flowing into the central nucleus, producing differing results
 - C) Some of the central objects have a lot of gravity, some have little, producing a variety of results
 - D) The shape of the central black hole can vary widely from galaxy to galaxy

- E) Actually, there probably aren't that many types, they just look different from different angles
51. When gas moves from one star to another in a binary system, what is the nature of how the gas is usually transferred?
- A) It comes into the second star uniformly from all sides
 - B) It comes in primarily at the north and south geographic poles
 - C) It comes in straight at the equator, but falling straight into the star
 - D) It forms an accretion disk that orbits the star before falling in
 - E) It forms an ablation sphere that surrounds the star, then slowly flows in
52. At the exact center of our galaxy is believed to reside
- A) A giant star cluster
 - B) A collection of high-mass neutron stars
 - C) A conglomeration of white dwarfs
 - D) A giant black hole
 - E) A supergiant main sequence star
53. Which of the following techniques is not a standard candle technique for measuring distance?
- A) Spectroscopic parallax
 - B) Parallax
 - C) Cepheid variable stars
 - D) White dwarf supernovae
 - E) Cluster fitting
54. What two effects does dust have on objects we look at behind the dust?
- A) It makes them brighter and redder
 - B) It makes them brighter and bluer
 - C) It makes them dimmer and redder
 - D) It makes them dimmer and bluer
 - E) None of the above
55. Almost all ordinary stars have what type of spectrum?
- A) Absorption, or dark line
 - B) Emission, or bright line
 - C) Continuous
 - D) Top hat
 - E) None of the above
56. Based on our current best measurements of the shape of the universe, the universe is
- A) Flat, or nearly flat, so it is either very large or infinite
 - B) Definitely open, so this it is infinite

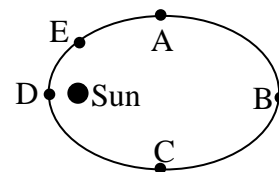
- C) Definitely closed, so that it is finite and not that much larger than what we can see
- D) Hyperboloid, so that it is closed in one direction but open in the other
- E) None of the above

57. About 10^{12} years from now, it will look as if there is only one galaxy in the entire universe. One reason for this is that galaxies in the Local Group will have merged into a single galaxy. What is the other reason?
- A) The stars in all other galaxies will be so old and dim the galaxies will be invisible
 - B) Not just the local group will have merged, but ALL galaxies throughout the whole universe will have merged
 - C) The exponential expansion of the universe will have driven all other galaxies to inconceivable distances, making them effectively invisible
 - D) There will be so much dust surrounding our galaxy that other galaxies won't be visible
 - E) The gravity of other galaxies will have grown so great that no light will be able to escape them

58. Which of the following is NOT a part of a galaxy like ours?
- A) A black hole in the center
 - B) A quasar near the center
 - C) A large disk-shaped area called the disk
 - D) A squashed sphere shape called the bulge
 - E) An enormous roughly spherical region called the halo

59. Which of the following is true of Jupiter's moon Io?
- A) It is the most volcanically active object in the Solar System
 - B) It is composed almost entirely of ice
 - C) It is larger than Earth
 - D) It is actually made from the material of Jupiter
 - E) There is evidence of liquid water on the surface

60. According to Kepler's second law, at which of the points labeled in the diagram will a planet move most quickly? Assume the planet is traveling clockwise around the Sun.



61. Which of the following is the approximate age of the universe in years?
- A) 6,000
 - B) 4.5 million
 - C) 13.8 million
 - D) 4.5 billion
 - E) 13.8 billion
62. Which planets can never be the opposite direction from the Sun, as viewed from Earth?
- A) Mercury (only)
 - B) Venus (only)
 - C) Mercury and Venus, but not Mars
 - D) Mercury, Venus, and Mars, but not the gas giants
 - E) None of the planets can be the opposite direction from the Sun

63. Which of the following structures is the largest?
- A) The Hyades star cluster
 - B) The Andromeda galaxy
 - C) The Hercules galaxy cluster
 - D) The Solar System
 - E) The Virgo supercluster
64. In which of the following regions do we see a lot of young stars being formed?
- A) The bulge (only)
 - B) The halo (only)
 - C) The disk (only)
 - D) The disk and bulge, but not the halo
 - E) The disk, bulge, and halo
65. Where are we located in our galaxy?
- A) Essentially at the exact center
 - B) In the bulge, near the center but not in the disk.
 - C) In the disk, about half way out towards the edge of the disk
 - D) In the disk, very near the edge of the disk
 - E) In the halo, well out of both the disk and the bulge
66. What are the three most important components of the makeup of the universe, in order from largest to smallest?
- A) Dark matter, dark energy, ordinary matter
 - B) Dark energy, dark matter, ordinary matter
 - C) Dark energy, ordinary matter, dark matter
 - D) Ordinary matter, dark energy, dark matter
 - E) Dark matter, ordinary matter, dark energy