

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:

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

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

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

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

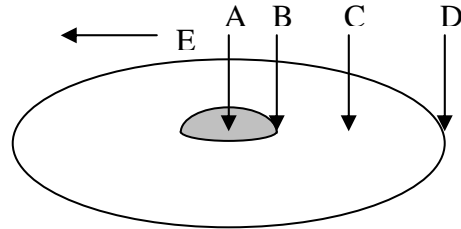
$$v = Hd \quad H = 22 \text{ km/s/Mly}$$

- When two galaxies collide, some of the things that are likely to happen are
 - Lots of stars will hit each other (only)
 - The shapes of one or both galaxies will change (only)
 - Gas and dust may get knocked out of the galaxies or into the center (only)
 - Both A and B are true
 - Both B and C are true
- Which of the following planets has the most moons?
 - Earth
 - Mercury
 - Mars
 - Venus
 - Neptune
- Which of the following has the longest wavelength?
 - Red visible light
 - Violet visible light
 - Microwaves
 - Ultraviolet light
 - X-rays
- Which of the following is false about globular clusters?
 - They consist of very old stars; some of the oldest known
 - There are several of them in the Milky Way galaxy
 - They tend to be in the halo portion of the galaxy
 - They are almost always in the same plane as the disk of the galaxy
 - Actually, all of these are properties of globular clusters

5. If you use the 21 cm line from cool hydrogen, you will get an idea of the shape of our galaxy's
A) Halo B) Globular clusters C) Nucleus D) Bulge E) Disk
6. Which planet has virtually no permanent atmosphere?
A) Mercury
B) Mars
C) Saturn
D) Venus
E) All planets have a permanent atmosphere
7. So-called giant elliptical galaxies are probably the result of
A) Collisions between many smaller galaxies
B) Burst of star formation in the early universe
C) Supermassive black holes that spawn these galaxies
D) Multiple supernovas that produced a huge region of star formation
E) Superhuge molecular clouds that produced an enormous number of stars
8. Besides Earth, which planet currently has liquid water on the surface?
A) Venus
B) Jupiter
C) Neptune
D) Mars
E) No other planet has water besides Earth
9. What is believed to be the source of heat inside Io that makes it so hot there?
A) Radioactive decay
B) Sunlight from the Sun
C) Tidal forces of Jupiter
D) Infrared radiation from Jupiter
E) Impact with particles from the radiation belt of Jupiter
10. Where in our galaxy do we find active star birth at present?
A) The halo (only)
B) The disk (only)
C) The bulge (only)
D) The disk and the bulge, but not the halo
E) The disk and the halo, but not the bulge
11. Our best guess as to the categorization of our galaxy is
A) Spiral
B) Barred spiral
C) Giant elliptical
D) Dwarf elliptical
E) Irregular
12. Besides Saturn, what other planets have rings?

- A) No other planets have rings
- B) Uranus, but not Jupiter nor Neptune
- C) Uranus and Neptune, but not Jupiter
- D) Uranus and Jupiter, but not Neptune
- E) Uranus, Neptune, and Jupiter

13. Sketched at right is a cartoon of our galaxy, with the disk and bulge shown. At which position might the Sun lie?



14. Which of the following is not considered a necessity for a planet to have a substantial magnetic field?

- A) A layer inside that conducts electricity
- B) A layer inside that is liquid
- C) Rotation (of the planet)
- D) A solid metal core
- E) Actually, all of these are considered necessary for a magnetic field

15. What event triggers the transition of a star from the red giant phase to the horizontal branch phase?

- A) Helium begins burning at the core
- B) Hydrogen starts burning at the core
- C) Carbon and Oxygen start burning at the core
- D) The hydrogen at the core runs out
- E) The helium at the core runs out

16. Which of the following can change its luminosity quickly?

- A) Radio galaxy
- B) Quasar
- C) Blazar
- D) Seyfert galaxy
- E) None of these can change their luminosity quickly

17. Which of the following pairs of object would have an enormously high average density, compared to something like an Earth rock?

- A) An asymptotic giant star and a red giant star
- B) A white dwarf and an asymptotic giant star
- C) A white dwarf and a red giant star
- D) A red giant star and a neutron star
- E) A white dwarf and a neutron star

18. Which of the following is not even approximately true about the relationship between the calendar and the heavens?

- A) The day is based on the apparent cycles of the Sun
- B) The week is based on the apparent cycles of Venus
- C) The month is based on the apparent cycles of the Moon
- D) The year is based on the apparent cycles of the Sun
- E) Actually, all of these are true

19. Which elements are believed to have been made in the very early universe, during the big bang?

- A) Hydrogen and helium, but not carbon
- B) Hydrogen, helium, and carbon
- C) Hydrogen, but not helium or carbon
- D) Helium, but not hydrogen or carbon
- E) Hydrogen and carbon, but not helium

20. Over the course of a night, how do most stars move, as viewed from Earth?

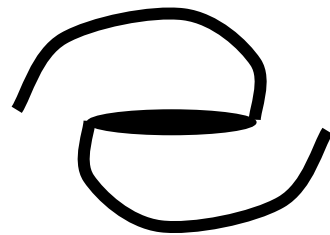
- A) They move from north to south
- B) They move from south to north
- C) They move from east to west
- D) They move from west to east
- E) The stars do not move appreciably over the course of one night

21. What is the difference between cluster fitting and spectroscopic parallax?

- A) Cluster fitting uses clusters of stars, rather than a single star
- B) Cluster fitting compares a single star to a cluster of standard spectra, rather than one spectrum
- C) Cluster fitting uses a cluster of spectral lines, rather than a single spectral line
- D) Cluster fitting measures the size of a cluster, without looking at any individual star
- E) There is no difference; they are different names for the same thing

22. What type of galaxy might be illustrated by the cartoon at right?

- A) E0
- B) E5
- C) SBb
- D) Sc
- E) Irr



23. From our galaxy, it looks like the whole universe is moving away from us, but if we lived on a distant galaxy, it would look like

- A) The whole universe is moving towards us
- B) The whole universe is moving past us in one direction
- C) The whole universe is rotating around us
- D) The whole universe is expanding in one direction and contracting in another
- E) It would look the same

24. Where are the largest number of stars in our galaxy?

- A) The disk

- B) The globular clusters
 - C) Stars in the halo that aren't in globular clusters
 - D) The nucleus
 - E) The bulge
25. According to Newton, if there are no forces on an object that is currently in motion, it will
- A) Continue moving in a straight line forever
 - B) Continue moving in a circular motion forever
 - C) Continue in a straight line, but gradually come to a stop
 - D) Continue moving in a circle, but gradually come to a stop
 - E) Immediately stop moving
26. According to Hubble's Law, a galaxy that is 88 Mly away should be moving at
- A) About 1940 km/s towards us
 - B) About 1940 km/s away from us
 - C) About 4 km/s towards us
 - D) About 4 km/s away from us
 - E) Hubble's law is not reliable in this case
27. The way we discovered that the Universe's expansion is accelerating is
- A) By comparing the velocity and distance of very distant type I supernovae
 - B) By comparing Hubble's constant measured around 1900 with current measurements
 - C) By noticing the rate at which the cosmic microwave background radiation temperature is changing
 - D) By studying how Doppler shifts of distant sources change over time
 - E) By comparing the number of stars in ancient galaxies with those of modern ones
28. Short term comets come from _____ and long term comets come from _____.
- A) The asteroid belt, the Kuiper belt
 - B) The asteroid belt, the Oort cloud
 - C) The Kuiper belt, the Oort cloud
 - D) The Oort cloud, the Kuiper belt
 - E) The Kuiper belt, the asteroid belt
29. Put the three objects in order from LARGEST to SMALLEST
- A) Galaxy clusters, galaxies, globular clusters
 - B) Galaxies, galaxy clusters, globular clusters
 - C) Globular clusters, galaxies, galaxy clusters
 - D) Globular clusters, galaxy clusters, galaxies
 - E) Galaxies, globular clusters, galaxy clusters
30. Why is our galaxy, the Milky Way, in some ways harder to study than many other galaxies?
- A) Our galaxy has more dust that blocks our view than most other galaxies

- B) Our galaxy is so large compared to other galaxies that it is impossible to view the whole thing
 - C) Our atmosphere blocks those wavelengths that come from our galaxy most effectively
 - D) Our galaxy is very dim and small, making it difficult to see
 - E) We are inside our galaxy, and this makes it hard to see the overall shape
31. The Cassini spacecraft, currently in orbit around the planet Saturn, can also study the moon
- A) Titan
 - B) Europa
 - C) Phobos
 - D) Ganymede
 - E) Miranda
32. Star A and Star B look equally bright, but star B is actually four times farther away than star A. How do their luminosities compare?
- A) Star A is 16 times more luminous than star B
 - B) Star A is 4 times more luminous than star B
 - C) Star B is 2 times more luminous than star A
 - D) Star B is 4 times more luminous than star A
 - E) Star B is 16 times more luminous than star A
33. According to our best estimates, how does the density of dark energy compare with that of dark matter and ordinary matter (stars, gas, etc.)?
- A) There is less dark energy than dark matter or ordinary matter
 - B) There is more dark energy than dark matter, but less than ordinary matter
 - C) There is more dark energy than ordinary matter, but less than dark matter
 - D) There is more dark energy than dark matter plus ordinary matter combined
 - E) There is more dark energy than dark matter or ordinary matter, but not if you combine them
34. According to Kepler, the orbits of objects such as planets around the Sun must be
- A) Circles centered on the Sun
 - B) Circles, but not centered on the Sun
 - C) Ellipses centered on the Sun
 - D) Ellipses, but not centered on the Sun
 - E) Parabolas
35. What object is suspected of lurking at Sagittarius A*, at the heart of our galaxy?
- A) A giant black hole
 - B) An enormous type O star
 - C) A tremendous neutron star
 - D) A huge white dwarf
 - E) A still, small voice
36. Some active galaxies are likely to produce more energy outside the galaxy than in it, if you measure how bright it is using
- A) Visible light
 - B) Ultraviolet
 - C) X-rays
 - D) Radio
 - E) Infrared
37. Europa is composed of

- A) All rock and metal
 - B) Mostly rock and metal with a thin layer of ice
 - C) About half ice and half rock and metal
 - D) Little rock and metal, mostly ice
 - E) All ice
38. What is the name of the other large galaxy in the same cluster as the Milky Way?
- A) Virgo B) Perseus C) Leo D) Andromeda E) Scorpio
39. Some types of active galactic nuclei produce a lot of X-rays. Where are these X-rays coming from?
- A) The gas torus, the source of the gases
 - B) The black hole at the center
 - C) The accretion disk surrounding the black hole
 - D) The thin gas above and below the accretion disk
 - E) The jets shooting out of the AGN
40. Stars like the Sun are getting their energy by what process?
- A) Nuclear burning of helium into hydrogen
 - B) Nuclear burning of hydrogen into helium
 - C) Nuclear burning of helium into carbon
 - D) Nuclear burning of carbon into helium
 - E) Nuclear burning of hydrogen into carbon
41. What is the purpose of a spectrometer? Why would someone attach it to a telescope?
- A) It increases the amount of light that the telescope gathers
 - B) It helps to focus the image of some astronomical object
 - C) It divides the light from a source up into its component wavelengths
 - D) It compensates for the blurring of the atmosphere
 - E) It rotates the telescope to compensate for the turning of the Earth
42. Gravitational lensing refers to what?
- A) The way gravitational effects can be focused or lensed by dark matter
 - B) The way that light can be bent and focused by the gravitational effects of an object in front of it
 - C) The way galaxies, through rotation and gravitational effects, naturally form a lens shape
 - D) The way light, as it leaves some object with a lot of mass like a star, tends to be focused into a tight beam by the object's gravity
 - E) The way light can pass through clouds of gravitationally bound gas and dust, which acts like a lens on the light
43. A galaxy cluster that contains lots of large elliptical galaxies, has a generally spherical shape, and has more gas between the galaxies than in the galaxies is probably a
- A) Poor Cluster
 - B) Irregular Cluster

- C) Rich Cluster
 - D) Elliptical Cluster
 - E) Spiral Cluster
44. How come tides are so much bigger sometimes and smaller at others?
- A) The Moon's distance to the Earth varies
 - B) Sometimes the Sun combines with the Moon to make big tides; other times it interferes
 - C) The Sun's distance to the Earth varies
 - D) The other planets also contribute substantially to Earth's tides
 - E) Vibrations in the Earth sometimes help and other times hinder the tides
45. HII regions, or hot hydrogen clouds, glow because
- A) The spinning electrons flip over, emitting photons
 - B) Molecules vibrate, releasing energy
 - C) Free electrons recombine with their nuclei, and emit light
 - D) Light from nearby stars is reflecting off of dust
 - E) Young stars that form in these regions are producing the light seen
46. The best indication of a star's composition comes from
- A) Its temperature, indicated by the peak in its spectrum
 - B) Its spectral lines, and their intensity
 - C) The Doppler shift of the spectral lines
 - D) The solar wind from our Sun, which is presumably like other stars
 - E) The amount of dust and gas surrounding the star
47. Which one thing is critical to the use of an object as a standard candle?
- A) It must have strong spectral lines
 - B) It must be consistently the same luminosity
 - C) It must be relatively common
 - D) It must be very luminous
 - E) It must not be too close to us
48. According to the best current estimates, the parameter Ω , which describes the shape of the universe, is closest to which of the following numbers?
- A) 0.01 B) 0.28 C) 1.00 D) 1.48 E) 13.7
49. Which of the following is not considered evidence that our galaxy is rotating?
- A) The rarity of new stars in the halo
 - B) The flattened shape of the bulge
 - C) The shape of the disk
 - D) Doppler measurements of gas in our galaxy
 - E) Actually, all of these are considered such evidence
50. Which of the following effects are caused by dust in the galaxy?
- A) It adds considerable mass to the total mass of the galaxy (only)
 - B) It blocks light, making it hard to see things behind it (only)
 - C) It causes objects behind them to appear more red than they actually are (only)

- D) Both B and C are correct, but not A
E) Both A and B are correct, but not C
51. Which of the following methods has proven most productive in discovering planets around other stars?
- A) Take a picture of the star and look for the planet
 - B) Look for variations in the pulses coming from a pulsar
 - C) Look for changes in the Doppler shift caused by the star alternately moving towards and away from you
 - D) Look for a dip in the brightness of a star as the planet passes in front of it
 - E) Watch for the way the star moves from side to side in response to the gravity of the planet
52. Which of the following is true about a star's total lifetime?
- A) The larger the percentage of carbon, the longer it lives
 - B) The smaller the percentage of carbon, the longer it lives
 - C) The larger the mass, the longer it lives
 - D) The smaller the mass, the longer it lives
 - E) Neither carbon fraction nor mass has much effect on its total lifetime
53. Which of the following sea creatures best describes the distribution of galaxies in the universe on the largest scale?
- A) Like an eel – the galaxies are stretched out in long lines
 - B) Like a puffer fish – the galaxies are distributed on the surface of a large sphere
 - C) Like a brain coral – a solid mass of galaxies with small fluctuations on the surface of the Universe
 - D) Like a squid – a central concentration of galaxies with long tendrils of galaxies sticking out of it
 - E) Like a sponge – mostly empty space with thin layers of galaxies in between
54. Which of the following is not a distance measuring method discussed in class?
- A) Parallax
 - B) Radar distancing
 - C) Cepheid Variable stars
 - D) The 21 cm line
 - E) Type I supernovae
55. Which of the following is not part of where you live?
- A) The Local Group of galaxies
 - B) The Sagittarius cluster of stars
 - C) The Virgo supercluster
 - D) The Solar System

- E) The Milky Way galaxy
56. To most untrained observers, the planets look a lot like stars. How did the ancients realize that there was something different about these planets, before the invention of the telescope?
- A) They were substantially brighter than any star
 - B) They were unique colors compared to the stars
 - C) Those with good eyesight were able to tell that they were disks, not points
 - D) They move around or “wander” compared to the background stars over time
 - E) They had nearby moons that could be observed orbiting them
57. According to our current theory, how often are very bright objects like quasars, Seyfert galaxies and blazars found in or near a galaxy?
- A) Never
 - B) Rarely
 - C) Often
 - D) Usually
 - E) Always
58. Which of the following methods could be used to get the distance to a very distant galaxy?
- A) Hubble’s Law
 - B) Cluster Fitting
 - C) Spectroscopic Parallax
 - D) Cepheid Variable stars
 - E) A really, really long ruler
59. What method can be used to get an estimate of the mass of an elliptical galaxy, including any dark matter that may be in it?
- A) Measure the rotation rate of the galaxy using Doppler shift
 - B) Measure the X-rays of the gas near the galaxy, which tells you the temperature
 - C) Estimate the number of stars and multiply by the mass of each star
 - D) Study the red-shift of light coming from the heart of the galaxy
 - E) Measure the period of stars orbiting near the nucleus of the star
60. Today is the Universe’s birthday! About how many candles should go on the cake?
- A) 12 million
 - B) 137 million
 - C) 1.1 billion
 - D) 13.7 billion
 - E) 120 billion
61. Which of the following is more true of elliptical galaxies than it is of spiral galaxies?
- A) They have more spin
 - B) They contain a lot of gas and dust
 - C) They contain almost exclusively old stars
 - D) They are rarely small galaxies
 - E) They have a clearly defined disk
62. Under what two conditions will the stars in a double star system have significant interactions?
- A) When the stars are close, and one of them is a giant star
 - B) When the stars are far apart, and one of them is a giant star
 - C) When the stars are close, and one of them is a main sequence star
 - D) When the stars are far apart, and one of them is a main sequence star

E) Binary stars almost never have significant interactions

63. The AU is approximately

- A) The distance from the Earth to the Moon
- B) The distance from the Earth to the Sun
- C) The diameter of the Earth
- D) The diameter of the Sun
- E) The diameter of the Solar System

64. A planetary nebula is

- A) A huge cloud of gas from which stars form
- B) A flat rotating disk from which planets form
- C) Ejected gas from a dying low-mass star
- D) Gas ejected from a type I or type II supernova
- E) A dark region of gas containing lots of dust that blocks objects behind it

65. Where is most of the dark matter in our galaxy believed to be?

- A) Concentrated in the nucleus
- B) Spread out through the bulge
- C) Thinly distributed through the disk
- D) Arranged in a huge, roughly spherical halo
- E) Stretched in the spiral arms of the galaxy

66. What observations tell us that a galaxy cluster has more dark matter between the galaxies than in the galaxies?

- A) Rotation rates (as measured by Doppler shift) of the individual galaxies
- B) Rotation rates (as measured by Doppler shift) of the entire cluster
- C) The fact that objects behind the cluster are obscured by all the dark matter
- D) The temperature of gas between the galaxies
- E) Gravitational lensing of objects behind the cluster

The following question is worth one extra-credit point

67. Did you fill out your class evaluation form online?

- A) Yes
- B) No