

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:

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

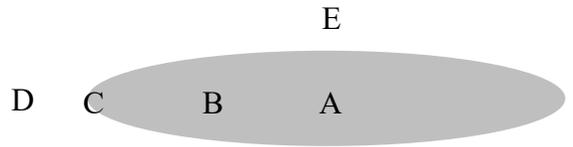
$$c = \lambda f \quad c = 3 \times 10^8 \text{ m/sec} \quad E = hf \quad P = knT$$

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

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

- Which of the following classifications might be our galaxy?
A) E0 B) E7 C) Irr D) Sd E) SBb
- How do we detect hot bubbles, regions that have been brought to high temperatures within our galaxy by violent events like supernovae?
A) From the vibrations of the molecules in the hot regions
B) By measuring their temperature with thermometers aboard spacecraft
C) By measuring the 21 cm line emitted as electrons flip over in atoms
D) By the expansion of regions around these regions caused by the exploding gasses
E) By the X-rays they emit
- Which of the following planets does not have rings around it?
A) Jupiter B) Saturn C) Neptune D) Uranus E) All of these have rings
- The center of the Earth is believed to be made of
A) Solid rock B) Liquid rock C) Liquid metal D) Solid metal E) None of these
- Which stage is the Sun in?
A) Main sequence
B) Protostar
C) Planetary nebula
D) Red giant
E) Core helium burning

6. The best method we have to estimate the total mass of a cluster of galaxies is from
- The total number of stars
 - The amount of hot gas as measured by X-rays
 - The amount of cool hydrogen as measured by the 21 cm line
 - The mass of the black hole in the largest galaxy
 - The lensing of light from objects behind the cluster
7. What makes Venus and Mercury unique, in that they are always in the same general direction as the Sun?
- They are smaller than the Earth; the other planets are larger
 - They are closer than the Earth to the Sun, the rest are farther
 - They are orbiting in the same plane as the Sun; the rest orbit in very tilted planes
 - They are in circular orbits; the rest are in elliptical orbits
 - They are close enough to Earth to feel its gravitational force; the others are farther away
8. When the Sun dies, what sort of a star will it become?
- Neutron star
 - Black hole
 - White dwarf
 - Supernova
 - None of these
9. The nearest large galaxy to ours (not counting our own) is called
- Milky Way
 - Virgo
 - Andromeda
 - Coma
 - Laniakea
10. Who discovered the universal law of gravitation?
- Copernicus
 - Galileo
 - Tycho Brahe
 - Newton
 - Kepler
11. Which of the positions at right roughly corresponds to the position of the Sun compared to the galactic disk?



12. Besides making stars look dimmer, what other effect does dust have on the appearance of stars?
- It makes them look like they are moving away from us
 - It makes them look like they are moving towards us
 - It makes them look bluer
 - It makes them look redder
 - Nothing; it just dims them

13. A galaxy with the shape sketched at right would be classified roughly as
- E0
 - E7
 - Irr
 - Sd
 - SBb



14. Regions where new stars are being formed typically have what type of gas?
- A) Hot and high density
 - B) Hot and low density
 - C) Cool and high density
 - D) Cool and low density
 - E) No gas
15. What makes the central part of our galaxy harder to study than in many other galaxies?
- A) It is so far away it is difficult to observe
 - B) There are very few stars there
 - C) The black hole there blocks our view of most of the center
 - D) There is a lot of gas and dust between us and the center
 - E) The Sun is in the same direction, making it almost impossible to see that direction
16. Which distance method can be used to find the distance to nearby galaxies, such as Andromeda?
- A) Cepheid variable stars
 - B) Hubble's Law
 - C) Radar distancing
 - D) Parallax
 - E) Spectroscopic parallax
17. Which of the following might be an indication that a star currently in the disk is not in fact a disk star?
- A) It is a very young star
 - B) It has planets
 - C) It is an especially high-mass star
 - D) It is a red giant star
 - E) It is moving in such a way that it is just passing through the disk
18. The biggest component of Venus's atmosphere is believed to be
- A) Nitrogen
 - B) Carbon dioxide
 - C) Hydrogen
 - D) Methane
 - E) Water vapor
19. What is believed to be the cause of the spiral structure in spiral and barred spiral galaxies
- A) Winding – they started straight but have wound up due to differential rotation
 - B) Dark matter – they trace the location of the dark matter that comprises them
 - C) Density waves – the gravitational attraction of high density waves makes them self-propagating
 - D) Central source – they are caused by pulses of energy from a rotating central source
 - E) Storm fronts – they form by the same mechanism that causes hurricanes

20. If we look at the largest scales, what fraction of the universe is filled with superclusters, as opposed to empty space
- A) Very little
 - B) About one-fourth
 - C) About half
 - D) About three-fourths
 - E) Almost all of it
21. What is the typical source of power that is powering ionization (emission) nebulae?
- A) Collisions between molecular clouds
 - B) Ultraviolet light from hot stars nearby
 - C) Radioactive decay of dark matter
 - D) Explosions from nearby supernovae
 - E) Gravitational waves from nearby black holes
22. Two charges repel each other due to electric forces. From this we conclude that the two charges must
- A) Both be positive (only)
 - B) Both be negative (only)
 - C) Both be positive OR both be negative
 - D) One must be positive and one must be negative
 - E) None of the above are correct
23. Which of the following are we confident we understand about the origins of things in the universe?
- A) Where all the matter comes from
 - B) What the nature of the dark matter is
 - C) What the nature of the dark energy is
 - D) What the universe was like at its origin at the Planck scale
 - E) None of these
24. What happened to Earth's primary atmosphere, which was probably made mostly of hydrogen?
- A) It combined with oxygen to produce our oceans
 - B) It was blown away by the early solar wind
 - C) It underwent chemical reactions which made it into rocks
 - D) It was converted by early plants into other chemical compounds
 - E) Nothing; it just ended up mixed with all the other gasses in our atmosphere

25. Because the Earth pulls on the Moon, the Moon moves in an orbit around the Earth. Why doesn't the Earth similarly move?
- A) The Moon's mass is so tiny that it has no effect on the Earth
 - B) Because the orbit is in orbit around the Sun, it can't orbit the Moon
 - C) The Moon only is in orbit because it is moving. Since the Earth isn't moving, it can't orbit
 - D) It is impossible to measure the motion of the Earth; only relative motion can be detected
 - E) The Earth does move in response, but the motion is smaller because its mass is larger
26. How can we typically measure how fast a galaxy is rotating?
- A) We take pictures several years apart and estimate how much the picture has rotated
 - B) We measure the Doppler shift of the 21 cm line from different parts of the galaxy
 - C) We measure the amount the spiral is wound up, and estimate the velocity from the picture
 - D) We estimate the total mass by counting up the stars, and then use Newton's Laws to deduce the speed
 - E) We measure the temperature of the gas, which is an indirect measure of the rotation rate
27. Which shape are the largest galaxies in the Universe?
- A) Elliptical
 - B) Spiral
 - C) Barred spiral
 - D) Irregular
 - E) None of these
28. Which of the following allowed ancient astronomers to deduce the shape of the Earth?
- A) Solar eclipses
 - B) Lunar eclipses
 - C) The phases of the Moon over the course of the month
 - D) The angle between the Sun and the Moon at first quarter
 - E) None of these; ancients didn't know the shape of the Earth
29. Based on the study of rotation curves of galaxies, what comprises most of the mass of typical galaxies?
- A) Stars
 - B) Gas
 - C) Dust
 - D) Dark energy
 - E) Dark Matter
30. Which of the following is a likely consequence of two galaxies colliding?
- A) Individual stars merge due to collisions (only)
 - B) Gas colliding with the galaxies can heat up (only)
 - C) The galaxies may merge (only)
 - D) Both gas clouds collide and galaxies merge, but individual stars do not merge
 - E) Galaxies and individual stars merge, and the gas clouds can get hot
31. The Milky Way is the name of our
- A) Stellar system
 - B) Stellar cluster
 - C) Galaxy
 - D) Galaxy Group
 - E) Galaxy Supercluster

32. Based on our current measurements, what shape does the Universe have due to the matter in it on the largest scale?
- A) Definitely closed
 - B) Definitely open
 - C) Flat, or very close to flat
 - D) We currently have no idea which of these possibilities might be correct; it could be any of them
 - E) The question is meaningless, since only physical objects have “shape” and this question is asking about the shape of space
33. The Universe is currently expanding. According to our current understanding, if we go into the past, was it always expanding at the same rate?
- A) Yes
 - B) No; it has been speeding up the whole time
 - C) No; it has been slowing down the whole time
 - D) No; it was slowing down early on but now it’s speeding up
 - E) No; it was speeding up early on but now it’s slowing down
34. Which of the following has the largest number of moons?
- A) Earth
 - B) Mercury
 - C) Uranus
 - D) Mars
 - E) Venus
35. Which factor contributes most to determining how long a star will live?
- A) Mass: low mass lives the longest
 - B) Mass: high mass lives the longest
 - C) Composition: the more hydrogen the longer it lives
 - D) Composition: the less hydrogen, the longer it lives
 - E) Rotation: high rotation stars live a long time
36. Which of the following is not believed to be one of the components of our galaxy?
- A) An active galactic nucleus (AGN)
 - B) A disk of stars
 - C) A dark matter halo
 - D) A bulge near the center
 - E) A giant black hole right in the center
37. Which of the following is believed could not be explained in terms of inflation, a period of rapid growth in the early universe
- A) Why matter is approximately 25% helium and 75% hydrogen
 - B) Why the universe is approximately the same temperature in all directions
 - C) The origin of tiny fluctuations that ultimately led to all the structure in the Universe
 - D) Why the Universe is so close to being perfectly flat
 - E) All of these are explained by inflation

38. Why are we confident that the dark matter is not made of rogue planets that are not orbiting a star?
- A) These objects should occasionally pass through our Solar System, and we've never seen one
 - B) These objects should cause the bending of light and magnification of distant stars behind them
 - C) These objects should be easily observable with visible-light telescopes
 - D) These objects would have to be concentrated in the disk, not the halo
 - E) We aren't confident; this is a very plausible explanation for dark matter
39. How can we possibly know what typical galaxies were like or what they were doing billions of years ago?
- A) We can extrapolate backwards their current motion and figure it out
 - B) We can look at newly formed galaxies now, and assume that ancient galaxies looked the same when they were young
 - C) We can look at very distant galaxies, billions of light-years away
 - D) We can run extensive computer simulations, showing how they formed and evolved
 - E) Since galaxies are assumed to pretty much always be the same, we can simply examine current galaxies
40. Drake's equation estimates the number of intelligent species in the galaxy. Which of the following factors do we actually know something about in this formula?
- A) The probability that life appears on a suitable planet or moon
 - B) The probability that life ultimately evolves intelligence
 - C) The probability that a star has planets
 - D) How long civilization typically lasts
 - E) Actually, we don't know any of these factors, even approximately
41. Approximately what fraction of the total stuff in the universe is in the form of dark energy?
- A) 0.01% B) 5% C) 26% D) 69% E) 99%
42. In which of the following do we commonly find new stars forming?
- A) The disk B) The halo C) Globular clusters D) The bulge E) None of these
43. Which color has the longest wavelength?
- A) Orange B) Blue C) Red D) Yellow E) Violet
44. What sort of geometry is believed to lead to Blazars, also known as BL Lacartae Objects?
- A) An active galaxy we view from the side, so we can only see the giant radio lobes
 - B) An active galaxy with no jets, but we can see right into the heart of the galaxy
 - C) An active galaxy with no jets, but we can see the heated gas around the heart of the galaxy
 - D) An active galaxy with jets that we view from an angle, not along the direction of the jets
 - E) An active galaxy where we happen to be right in line with one of the jets

45. How are we able to determine the composition of the Sun and other stars?
- A) Sampling the solar wind from the Sun and cosmic rays from other stars
 - B) Spacecraft like the Parker Solar Probe, which is flying into the Sun's corona
 - C) Comets, which are presumed to have a composition similar to the composition of the cloud from which the Sun formed
 - D) Study of spectral lines, whose positions and strength tell us what the Sun is made of
 - E) Observing the melting points of various substances in the Sun and other star's atmospheres
46. Which of the following is probably pretty close to the age of the Universe in years?
- A) 6 thousand
 - B) 13.8 million
 - C) 4.6 billion
 - D) 9.6 billion
 - E) 13.8 billion
47. When you shine white light containing all frequencies through a relatively cool gas, what sort of spectrum comes out?
- A) An unchanged spectrum, still containing all frequencies
 - B) All the waves with frequency below a special cutoff frequency, that depends on the element
 - C) All the waves with frequency above a special cutoff frequency, that depend on the element
 - D) A bright line spectrum containing only a few special frequencies, that depend on the element
 - E) A dark line spectrum missing only a few special frequencies, that depend on the element
48. On the side of the Earth facing the Moon, high tide occurs. What happens on exactly the other side of the Earth, facing away from the Moon?
- A) High tide
 - B) Low tide
 - C) Intermediate tide
 - D) Solar tide
 - E) Tide with bleach
49. The total diameter of our galactic disk is about
- A) 1 ly
 - B) 100 ly
 - C) 1,000 ly
 - D) 100,000 ly
 - E) 10 million ly
50. The source of energy for stars like the sun is
- A) Gravitational energy from the contraction of the Sun
 - B) Chemical reactions from the combustion of hydrogen with oxygen
 - C) Magnetic waves generated by the currents in the Sun
 - D) Nuclear fusion of helium into carbon and oxygen
 - E) Nuclear fusion of hydrogen into helium
51. Where is the Kuiper belt located, where short-period comets originate?
- A) Much closer than Mercury to the Sun
 - B) Scattered among the planets, pretty much equally spaced everywhere
 - C) Mostly between the orbits of Mars and Jupiter
 - D) A little farther away than the most distant planet, Neptune
 - E) Very far away from the Sun; as much as half way to the next star

52. Which of the following was first imaged by scientists this semester?
- A) The nucleus of our galaxy
 - B) The spiral arms of our galaxy
 - C) A collision between two galaxies
 - D) A giant black hole at the center of an active galaxy
 - E) The dark matter in a galaxy
53. When helium starts to fuse in heavy stars, which of the following elements is produced?
- A) Hydrogen
 - B) Iron
 - C) Silicon
 - D) Beryllium
 - E) Carbon
54. Just before high-mass stars turn into core-collapse supernovas, what element predominates at their centers?
- A) Silicon
 - B) Helium
 - C) Oxygen
 - D) Iron
 - E) Carbon
55. Which of the following is true about volcanoes on Mars?
- A) Mars currently has active volcanoes
 - B) Mars has only extinct volcanoes, but some of them are huge, much larger than Earth's
 - C) Mars has only extinct volcanoes, about the same size as Earth's
 - D) Mars has only extinct volcanoes, but they are much smaller than Earth's
 - E) Mars shows no signs it ever had volcanoes
56. Which two objects are believed to be necessary to produce an X-ray burster?
- A) Giant star and black hole
 - B) Giant star and neutron star
 - C) Giant star and white dwarf
 - D) White dwarf and neutron star
 - E) Neutron star and black hole
57. Which of the following events happened earliest in the history of the universe
- A) The neutrons in the early universe joined with the protons to make helium
 - B) The ratio of protons to neutrons "froze out", so they stopped interconverting
 - C) Electrons joined with nuclei to form the first atoms in a process called recombination
 - D) The first stars were born
 - E) The temperature of the universe fell to approximately 2.73 K
58. According to Hubble's Law, approximately how fast will a galaxy 10 million light years from Earth be moving?
- A) 210 km/s towards us
 - B) 210 km/s away from us
 - C) 0.47 km/s towards us
 - D) 0.47 km/s away from us
 - E) Hubble's Law cannot be used to estimate this distance

59. Suppose stars X and Y were both spectral class F5. What additional information would allow us to conclude that they are approximately the same luminosity?
- A) If they are both the same distance from the Sun
 - B) If they have the same mass
 - C) If they are both main sequence stars
 - D) If they are both about the same age
 - E) None of these would be sufficient
60. Our best guess about what the future expansion of the universe is that it will
- A) Expand forever, constantly accelerating
 - B) Expand forever, but leveling off to a constant speed
 - C) Expand forever, but gradually slowing down to almost zero
 - D) Expand for a while, then it will stop and stay constant size
 - E) Expand for a while, then it will recollapse back to a point
61. In order for an object to make a good standard candle, all examples of the object should have the same _____.
- A) Brightness
 - B) Distance
 - C) Luminosity
 - D) Temperature
 - E) Velocity
62. What is the fundamental difference between a galaxy group and a galaxy cluster?
- A) A galaxy group contains mostly ellipticals; a group contains mostly spirals
 - B) A galaxy group tends to be spread out; a cluster is more concentrated
 - C) A galaxy group contains mostly old stars; a cluster contains mostly young stars
 - D) A galaxy group has a small number of bright galaxies; a cluster contains a large number
 - E) A galaxy group is near to us; a cluster is far away
63. Ganymede, the largest moon in the Solar System, orbits which planet?
- A) Jupiter
 - B) Uranus
 - C) Neptune
 - D) Pluto
 - E) Saturn
64. The coldest possible temperature in Kelvin is
- A) 300 K
 - B) 273 K
 - C) 2.73 K
 - D) 0 K
 - E) -273 K
65. Why are white dwarf supernovae such a useful distance method?
- A) These supernovae are extremely common, so it can be used to measure lots of distances
 - B) These are some of the brightest events in the universe, so you can see them at enormous distances
 - C) These events always occur in nearby objects, where we know the distance by other means
 - D) We can reproduce these events in the laboratory, which makes them easy to study
 - E) These events produce important elements that comprise much of the Earth, so we are more interested in the distances to them

66. Which of the techniques below has been most successful in discovering the most exoplanets, or planets around other stars?
- A) The transit method: Observing the dimming of the star as the planet passes in front of it
 - B) Direct observation: Seeing the planet in images next to its star
 - C) Astrometry: Seeing the change in position of the star as the planet orbits it
 - D) Gravitational waves: Seeing the gravitational waves generated by an orbiting planet
 - E) None of these: None of these methods has discovered more than a handful of planets