

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 Sun is currently a main sequence star. What stage comes next for the Sun?
 - Double shell burning
 - Core helium burning
 - Red giant
 - Planetary nebula
 - Protostar
- In order for an object to make a good standard candle, it must have a pretty consistent
 - Distance
 - Temperature
 - Luminosity
 - Mass
 - Brightness
- What advantage do white dwarf supernovae have over other standard candle techniques, such as spectroscopic parallax, cluster fitting, and Cepheid variable stars?
 - They have much more consistent luminosities than these other objects
 - They are much more common than these other objects
 - They are typically much closer, so we can measure them more accurately
 - They are extremely bright, so we can see them very far away
 - Their spectra are easier to measure, which is necessary for this technique
- We live in one galaxy in our galaxy group. What is the name of the other large galaxy in our galaxy group?
 - Virgo
 - Coma
 - Andromeda
 - Scorpio
 - Milky Way

5. Stars are often found grouped in clusters, rather than being spread uniformly. What causes them to cluster?
 - A) Gravity has pulled them together over time
 - B) Since stars tend to be moving the same direction, they tend to end up at the same place
 - C) Large stars often fragment after they are born into several smaller stars
 - D) They are afraid of the dark
 - E) Molecular clouds tend to give birth to many stars which end up near each other

6. The most common types of stars are
 - A) Protostars
 - B) Main sequence
 - C) White dwarf
 - D) Giant
 - E) Supergiant

7. One of the best ways to measure the mass of a cluster of galaxies is
 - A) Measure the bending of light from some object behind it
 - B) Estimate the mass of one galaxy and multiply by the number of galaxies
 - C) Estimate the rotation rate of the cluster
 - D) Measure the rotation rate of the individual galaxies of the cluster
 - E) Measure the amount of light absorbed by all the gas in the cluster

8. During which stage of the Sun's lifetime is it or will it have the highest average density?
 - A) Main sequence
 - B) Red giant
 - C) White dwarf
 - D) Core helium burning
 - E) Protostar

9. The 21 cm line comes from what sort of source?
 - A) Hot hydrogen clouds when the ionized electrons collide
 - B) Atomic hydrogen clouds when the electrons flip their spins inside atoms
 - C) Cool molecular clouds when the molecules vibrate
 - D) Atoms that are near extremely hot stars
 - E) Dust

10. The real reason that planets seem to sometimes move backwards (show retrograde motion) compared to the stars is because
 - A) The Earth is sometimes passing the planets, making it look like they are moving backwards
 - B) The speed of the planets increases and decreases as they orbit the Sun
 - C) The planets follow epicycles that cause the apparent backwards motion
 - D) Gravitational effects from other planets sometimes affect the orbits of the planets
 - E) The rotation of the Earth about its axis causes the apparent motion

11. I am standing on a moon. I can see a giant planet with rings around it. Nearby, fissures in the moon are spewing ice out into space. Where am I?
A) Titan B) Io C) Europa D) Enceladus E) Ganymede
12. Which of the following objects would have the most stars in them?
A) Stellar system
B) Galaxy cluster
C) Galaxy group
D) Galaxy
E) Stellar cluster
13. Why is it that some of the large moons of Jupiter have very little ice on them?
A) The Sun warmed them so much the ice couldn't form
B) They are captured asteroids, which do not contain ices
C) Early Jupiter was so hot it probably evaporated the water away
D) The high levels of radiation from Jupiter destroyed the ice
E) Tidal heating melted and evaporated the ice
14. Which two pieces of information would allow me to deduce the luminosity of a star?
A) Temperature and mass
B) Distance and mass
C) Temperature and distance
D) Distance and brightness
E) Brightness and temperature
15. Which of the following, besides Earth, is believed to have active volcanoes on the surface?
A) Mercury (only)
B) Mars (only)
C) Venus (only)
D) Mercury and Mars
E) Mercury and Venus
16. Most radio galaxies produce large amounts of radio power in what region?
A) The nucleus of the galaxy
B) The bulge
C) The disk
D) Globular clusters
E) Huge regions that actually stick outside the galaxy
17. Which of the following objects would have the highest proportion of ice?
A) Mars B) Pluto C) Moon D) Asteroid Ceres E) Mercury

18. Jupiter's moon Ganymede is larger in radius than Mercury, yet it is not considered a planet. Why?
- A) Although larger in radius, it is smaller in mass, so it doesn't count
 - B) It orbits a planet, not the Sun
 - C) It's mass is insufficient to pull it into a spherical shape
 - D) There are several other objects orbiting at about the same radius, so it does not gravitationally dominate its region
 - E) It contains large amounts of ice, but planets should be made of rock and metal
19. What force causes electrons to be bound in atoms?
- A) Electromagnetic B) Strong C) Gravity D) Weak E) Quantum Mechanics
20. Which of the following was not listed as a likely way that could wipe out life (at least humans) on the Earth?
- A) The impact of a giant asteroid
 - B) Catastrophic global warming over the next billion years or so
 - C) Melting of the Earth during the Sun's red giant phase
 - D) Destruction from the collision with the Andromeda galaxy
 - E) Actually, all of these were listed as possible causes of destruction of life
21. Which part of our galaxy does our Sun belong to?
- A) Halo B) Nucleus C) Bulge D) Disk E) None of the above
22. Which of the following planets is the largest?
- A) Earth B) Venus C) Mars D) Neptune E) Mercury
23. Suppose a binary star system is producing very regular pulses of X-ray energy. What types of stars are probably in this star system?
- A) Giant star and neutron star
 - B) Giant star and black hole
 - C) Giant star and white dwarf
 - D) Main sequence star and neutron star
 - E) Main sequence star and white dwarf
24. If you were placed in a galaxy a trillion years from now, it is estimated that you would see only one galaxy in the entire universe. How could this happen?
- A) All other galaxies were absorbed by the black hole at their centers
 - B) All the galaxies in the entire universe will have merged into a single galaxy
 - C) All nearby galaxies merged into one; all distant ones have moved so far away they are no longer visible
 - D) All galaxies save ours will consist of only dead stars, and hence be invisible
 - E) There will be so much dust surrounding our galaxy that it blocks views of all other galaxies
25. The galaxy M87, shown at right, is approximately what category?



A) Irr B) SBa C) Sd D) E7 E) E0

26. The Hertzsprung-Russell diagram plots which two aspects of a star?
A) Luminosity vs. mass
B) Luminosity vs. brightness
C) Mass vs. brightness
D) Luminosity vs. temperature
E) Mass vs. temperature
27. Which of the following is the approximate age of the universe in years?
A) 13.8 million B) 4.6 billion C) 13.8 billion D) 4.6 trillion E) 13.8 trillion
28. Main sequence stars like the Sun produce energy by
A) Nuclear fusion
B) Nuclear fission
C) Gravitational energy
D) Chemical reactions
E) Proton decay
29. In which of the following parts of our galaxy are new stars being born?
A) Halo B) Nucleus C) Bulge D) Disk E) None of the above
30. Which objects in the sky have retrograde motion; that is, they sometimes move from west to east compared to the stars, but occasionally move from east to west?
A) The Moon (only)
B) The Planets (only)
C) The Sun (only)
D) The Moon and planets, but not the Sun
E) The Sun and planets, but not the Moon
31. Cepheid variable stars work well for measuring distances, because we can relate their luminosity to what other measurable quantity?
A) Color B) Mass C) Period D) Distance E) Temperature
32. The exact center of our galaxy is believed to contain
A) A giant supernova
B) A huge white dwarf
C) A fast-spinning neutron star
D) An enormous main-sequence star
E) A massive black hole
33. Which of the following best describes what the universe is doing on the largest scales?

- A) Expanding, but the expansion is slowing down
 - B) Expanding, and the expansion is accelerating
 - C) Expanding, at a steady state that will roughly stay the same
 - D) Approximately staying the same size
 - E) Shrinking
34. Which of the following factors in the Drake equation, which determines the number of civilizations in the galaxy, do we actually have a decent estimate of?
- A) Mean lifetime of civilization after it forms
 - B) Probability of life appearing on a suitable planet
 - C) Average number of suitable planets or moons for a star
 - D) Probability of life evolving to form intelligent life/civilization
 - E) Actually, we have no idea of any of these factors
35. Which of the following was not an argument given for why there might be many universes?
- A) The universe may be so huge that effectively different segments of it are cut off from each other
 - B) Since universes collide, they may fragment after collisions to make multiple universes
 - C) There are proposed mechanisms where the universe could spontaneously appear out of nothingness, or out of chaos. If it happened once, it might happen many times
 - D) According to some interpretations of quantum mechanics, when certain random events occur, effectively the universe splits into two (or more) universes
 - E) Actually, all of these were contemplated as ways to make multiple universes
36. Which of the following has the fewest moons?
- A) Mars B) Jupiter C) Uranus D) Saturn E) Neptune
37. What surprise was found when astronomers started measuring how quickly galaxies rotated?
- A) The rotation speed does not decrease with distance, indicating most of the mass is not in the middle, but in a giant halo
 - B) The rotation speed decreases quickly with distance, indicating gravity gets weaker than expected at large distances
 - C) The rotation speed is completely dominated by a single black hole in the middle of our galaxy
 - D) The outer part of galaxies rotates the opposite direction of the inner parts of the galaxy
 - E) Nothing; the curves fit more or less what everyone expected
38. The largest contribution to the composition of the universe is almost certainly
- A) Dark matter B) Dark energy C) Stars D) Gas E) Neutrinos

39. Why is it that there are some meteorites that seem to be made almost entirely of metal?
- A) They are attracted by Earth's strong magnetic field
 - B) They were produced near the Sun, where only metals could condense
 - C) They were made from much larger bodies, that differentiated before they were broken apart
 - D) All of the rock parts of them evaporated as they fell to Earth
 - E) The metal parts fell faster than the rocky parts, separating as they fell to Earth
40. Why, fundamentally, is there a limit on how far into our universe we can see (the horizon)?
- A) Brightness falls off as distance squared, and eventually, things are just too dim to see
 - B) There is so much gas and dust in our universe that eventually we can't see through the mess
 - C) Photons get tired and run out of energy over enormous distances
 - D) The Universe has a finite age, and so light has a limit on how far it can travel since the beginning of the universe
 - E) Black holes and other massive objects curve and swallow the light over long distances
41. Which of the following is false about sunspots?
- A) They contain large quantities of dark materials like carbon
 - B) They are regions of strong magnetic fields
 - C) The surface temperature is lower than most of the Sun
 - D) They tend to occur more commonly at the same time that other solar activity (prominences, etc.) also occur
 - E) Actually, all of these are true about sunspots
42. What effects does dust have on objects that we attempt to see through clouds of dust?
- A) It dims them (only)
 - B) It makes their spectra have mostly longer wavelengths, or reddening (only)
 - C) It changes the apparent shape of objects (only)
 - D) Both A and B are true
 - E) Both A and C are true
43. If I have a gas and want to double the pressure, which of the following methods would work?
- A) Double the mass of each molecule in the gas (only)
 - B) Double the number density of the gas (only)

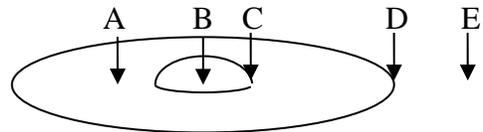
- C) Double the temperature in Kelvin (only)
- D) Doubling the mass and the number density both work
- E) Doubling the number density and the temperature both work

44. Which of the following has the longest wavelength of electromagnetic energy?
 A) X-rays B) Infrared C) Visible D) Gamma rays E) Radio

45. Which of the following is a common characteristic of Blazars, also known as BL Lacartae objects?

- A) They vary their luminosity quickly, sometimes in a day or less
- B) They are relatively dim as active galaxies go
- C) They are usually very near to our galaxy
- D) Almost all of their power comes in the form of radio waves
- E) None of the above

46. At right is a crude sketch of our galaxy. Where can the Sun be found?



47. If a galaxy is at a distance of 200 Mly, how fast one would expect it to be moving?
 A) 4,200 km/s B) 441 km/s B) 9.5 km/s C) 0.105 km/s D) 0.000024 km/s

48. What would be the best way to determine what galaxies looked like a very long time ago?

- A) Look at very distant galaxies
- B) Build a computer model of current galaxies, then run it in reverse
- C) Develop a theory of how galaxies form, and deduce it from theory
- D) Find galaxies that are just forming now
- E) Find galaxies that change very slowly, since they probably haven't changed much

49. Which of the following is believed to have occurred earliest in the universe?

- A) Inflation
- B) First structure forms
- C) Nuclei are created
- D) The electroweak scale
- E) Recombination

50. When two galaxies collide, which of the following is not likely to happen?

- A) The shape of the galaxies get distorted
- B) Individual stars in each galaxy collide
- C) Gas clouds get compressed by the collision
- D) Gas can be fed into the black hole at the center of the galaxy

E) Actually, all of these are pretty likely

51. Why do astronauts in the international space station not fall?

- A) Gravity is impossible in vacuum
- B) They are too far from the Earth to feel Earth's gravity
- C) The Earth's atmosphere screen out Earth's gravity
- D) The Earth's gravity is counteracted by the Moon's gravity
- E) Actually, they are in free fall, but so is the space station

52. Which of the following do we know what it is made from?

- A) Dark matter, but not dark energy
- B) Dark energy, but not dark matter
- C) Both dark matter and dark energy
- D) Neither dark matter nor dark energy
- E) I have no idea; please mark this one wrong

53. On a modern high-quality telescope, what is the first part of the telescope that the light hits?

- A) Lens
- B) Mirror
- C) Polarizer
- D) Diffraction Grating
- E) Prism

54. Which planet has the largest known storm in the solar system?

- A) Mars
- B) Neptune
- C) Earth
- D) Saturn
- E) Jupiter

55. If the Sun, the Earth, and the Moon are aligned in a perfect line as sketched at right, what event will occur?



- A) New moon
- B) First quarter
- C) Solar eclipse
- D) Lunar eclipse
- E) None of the above

56. What is the name of the galactic supercluster we live in?

- A) Milky Way
- B) Virgo
- C) Andromeda
- D) Coma
- E) Hercules

57. Which of the following problems is it believed inflation might be a good explanation for?

- A) Flatness: Why is the universe almost perfectly flat?
- B) Dark matter: What is it made from?
- C) Matter: Why is there more matter than anti-matter?
- D) Dark energy: What is it?

- E) Toast: Why does it always fall butter side down?
58. What evidence do we have that dark matter is not made from, let's say, large numbers of stellar mass black holes?
- A) If there were that many black holes, they would have swallowed everything else in the galaxy
 - B) Stars that would make such black holes would not yet have died
 - C) Black holes can only occur in the nucleus of the galaxy, and the dark matter is in the disk
 - D) The black holes would block out the light from objects behind them, making them obvious
 - E) Black holes would cause lensing events, where they make objects behind them seem to get brighter
59. Why don't we use parallax to measure the distance to, say, the Andromeda galaxy?
- A) Parallax only works on certain very rare stars, which do not exist in Andromeda
 - B) To use parallax, you must see a single star, and there are no stars bright enough in Andromeda to see them individually
 - C) It would work, but radar distancing is more accurate, so we use that instead
 - D) Andromeda is so distant that the parallax angle would be too small to measure
 - E) Actually, we do; this is how we know the distance to Andromeda
60. The orbit of a typical star in the galactic halo tends to be _____ in the galactic plane, and _____ circular compared to a star in the disk
- A) More, less
 - B) Less, more
 - C) Less, less
 - D) More, more
 - E) same, same
61. What is the fundamental difference between the spectroscopic parallax and cluster fitting methods of determining distances?
- A) Spectroscopic parallax uses parallax, cluster fitting does not
 - B) Cluster fitting uses many stars, spectroscopic parallax uses one
 - C) Spectroscopic parallax uses main sequence stars, cluster fitting uses giants
 - D) Spectroscopic parallax requires a spectrum, cluster fitting does not
 - E) Spectroscopic parallax takes into account the rotation of the star, cluster fitting does not
62. Which of the following can be found in the disk of a galaxy like ours?
- A) Gas (only)
 - B) Dust (only)
 - C) Young stars (only)
 - D) Old stars (only)
 - E) All of the above

63. Irregular galaxies probably have their irregular shape because
- A) They have insufficient gravity to pull them into some more regular shape
 - B) Supernovae have disrupted them
 - C) They have recently undergone collisions with other galaxies
 - D) The black hole at their heart is eating them
 - E) They are rotating too slowly to develop the standard structure
64. Which of the following is the approximate value of the total Ω , the ratio of the actual density of matter to the critical density?
- A) 0.001 B) 0.05 C) 0.30 D) 0.70 E) 1.00
65. Which event is associated with the cosmic microwave background radiation. Put another way, what's the last time it interacted with anything?
- A) The Planck era, when the universe was created
 - B) Nucleosynthesis, when the first nuclei were created
 - C) The Grand Unification Theory (GUT) scale
 - D) The formation of first structure in the universe
 - E) Recombination, when electrons became trapped with nuclei to form atoms
66. Which of the following is not a correct association between the heavens and the calendar?
- A) The year is based on the apparent motion of the Sun
 - B) The month is (approximately) based on the apparent motion of the Moon
 - C) The week (approximately) is based on the apparent motion of the planets
 - D) The day is based on the apparent motion of the Sun
 - E) Actually, all of these are associations between the heavens and the calendar