

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:

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

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

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

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

- Our best guess for what is causing a Blazar (also known as a BL Lacartae object) is
  - An active galaxy with a jet that points almost straight at us
  - An active galaxy with a jet that is towards us, but not straight at us
  - An active galaxy with a jet that is perpendicular to our line of sight
  - An active galaxy with no jets
  - None of the above
- How do we obtain images of our galaxy from the outside?
  - Space-based telescopes like the Hubble
  - Spacecraft like Voyager 1 and 2, which have left the Solar System
  - Reflections off of planetary nebulas
  - By studying ancient light that *did* actually leave from outside the galaxy
  - We don't; the best we can do is map it with the 21 cm line and compare to other galaxies we *can* view from the outside
- Which of the following, like Earth, is composed primarily of rock and metal?
  - Jupiter
  - Venus
  - Neptune
  - Uranus
  - Saturn
- Which of the following planets has the most moons?
  - Neptune
  - Earth
  - Venus
  - Mars
  - Mercury

5. Most of the asteroids can be found
  - A) Inside the orbit of Mercury
  - B) Between Venus's and Earth's orbit
  - C) Between Mars's and Jupiter's orbit
  - D) Among the gas giants' orbits
  - E) Beyond Neptune's orbit
  
6. Which of the following elements were probably formed during the big bang?
  - A) Hydrogen but not helium
  - B) Hydrogen and helium, but not carbon nor oxygen
  - C) Hydrogen, helium, and carbon, but not oxygen
  - D) Hydrogen, helium, and oxygen, but not carbon
  - E) Hydrogen, helium, carbon, and oxygen
  
7. Star X and star Y are both Cepheid variable stars. Star X has a period of pulsation of 7 days, while star Y has a period of 14 days. From this we can conclude that
  - A) Star X is brighter than star Y
  - B) Star Y is brighter than star X
  - C) Star X is more luminous than star Y
  - D) Star Y is more luminous than star X
  - E) The stars must have the same luminosity, since they are both Cepheid variable stars
  
8. Prominences are caused by hot plasma expelled from the Sun. This plasma tends to follow what path as it leaves the Sun?
  - A) It flows in a straight line, since there are effectively no forces on it
  - B) It flows in curves governed caused by the Sun's gravity
  - C) It flows in curves caused because they follow magnetic field lines
  - D) It flows in curves caused by always moving perpendicular to magnetic field lines
  - E) It flows on curves governed by the underlying convection inside the Sun
  
9. What method can be used to approximately measure the mass of a galaxy cluster?
  - A) Gravitational lensing of objects behind it
  - B) Measuring the period of time it takes galaxies to orbit the cluster
  - C) Measuring the quantity of hot gas via the X-rays produced
  - D) Estimate the number of stars in a galaxy, and multiply by the number of galaxies
  - E) Measure the number of galaxy collisions going on in the cluster
  
10. The name of the galaxy we live in is
  - A) Milky Way
  - B) Virgo
  - C) Laniakea
  - D) Andromeda
  - E) Coma
  
11. Most of the mass in our galaxy, and most galaxies, is made of
  - A) Stars
  - B) Gas
  - C) Dark Energy
  - D) Dark Matter
  - E) Black holes
  
12. The strongest evidence for dark matter in spiral galaxies comes from

- A) Studying the rotation curves of their spiral arms as a function of distance
  - B) Seeing the dark lanes of gas and dust in their disks
  - C) Measuring the rate of production of energy from their nuclei
  - D) Measuring the rate at which nearby galaxies are pulled towards them
  - E) Detection of light deflection by Massive Compact Halo Objects (MACHOs)
13. What is the name of the galaxy supercluster to which we belong?
- A) Milky Way
  - B) Virgo
  - C) Laniakea
  - D) Andromeda
  - E) Coma
14. When two galaxies collide, which of the following typically occurs?
- A) Individual stars collide (only)
  - B) The shape of the galaxies gets distorted (only)
  - C) Clouds of gas within each galaxy collide (only)
  - D) Stars collide and clouds collide, but the galaxies are not distorted
  - E) Clouds collide and galaxies are distorted, but the stars do not collide
15. Which of the following was not listed as a reason that we might wish to believe in multiple universes?
- A) The Many Worlds Interpretation of quantum mechanics
  - B) Spontaneous creation of the universe may have happened more than once
  - C) Fracturing of our universe to produce baby universes caused by massive star supernovae
  - D) A sufficiently large universe would effectively be many universes
  - E) Actually, all of these are reasons to believe in multiple universes
16. When a gas in a container is hot, its pressure increases. The cause of this pressure is
- A) Electromagnetic forces between the atoms and the container
  - B) The atoms/molecules of the gas bouncing off the walls of the container
  - C) Light produced by the gas that pushes on the container
  - D) Electrons that are flung off of the atoms and push on the walls
  - E) Heat particles that are released from the gas when it is heated
17. When we look at very distant galaxies, they seem to be typically smaller, and irregular ones are more common. Why?
- A) They had not yet had time to grow to full size and form structure
  - B) Collisions were common, which made them irregular, and mergers have made them larger
  - C) The black holes that sucked in and distorted the galaxies were more common back then
  - D) Gravitational lensing by galaxies between us and them make them look small and distorted
  - E) Dark matter had not yet been attracted to the galaxies, so they didn't have as much mass and were less ordered
18. Which of the following is among the last things that happened in the history of the Universe?

- A) The Planck era
  - B) Electroweak breaking
  - C) Proton/Neutron freezeout
  - D) First galaxies form
  - E) Recombination
19. You can tell by naked eye that the Earth is round by studying
- A) The phases of the Moon
  - B) The tides
  - C) The angular size of the Moon
  - D) Solar eclipses
  - E) Lunar eclipses
20. According to standard cosmology, what determines if the universe is finite and “closed” or infinite and “open”?
- A) The density of ordinary matter
  - B) The density of ordinary matter plus dark matter
  - C) The density of everything, including ordinary matter, dark matter, and dark energy
  - D) The number of galaxies in the Universe
  - E) The rate of rotation of galaxies in the Universe
21. Our current best estimate for the age of the Universe in years is
- A) 6000      B) 4.6 million      C) 13.8 million      D) 4.6 billion      E) 13.8 billion
22. When we measure how round an elliptical galaxy is, how do we know that it is the same from all angles?
- A) Spacecraft such as the Hubble can observe it from other angles
  - B) The orbit of stars in these galaxies show that they are the same in all directions
  - C) The spherical nature of both the stars and the hot gas surrounding them probes how round they are
  - D) Measurements of their galactic magnetic fields measure how round they are
  - E) We don't know, we can only view it from one angle
23. Our best guess for the type of galaxy we live in is a
- A) Spiral    B) Barred Spiral    C) Elliptical    D) Irregular    E) None of these
24. If a galaxy looks like a perfectly round ball, which of the following might be its classification?
- A) S0      B) SBc      C) E7      D) E0      E) Irr
25. Radar distances would be a good way to measure the distance to
- A) A nearby star

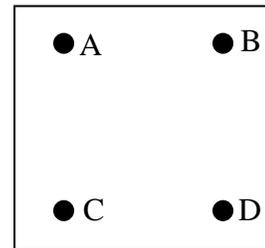
- B) A galaxy near ours
  - C) A stellar cluster
  - D) A distant supernova
  - E) None of the above
26. The Sun will end its life as a
- A) White dwarf
  - B) Neutron star
  - C) Black hole
  - D) Supernova
  - E) Quasar
27. In which parts of our galaxy is active star formation currently occurring?
- A) Bulge (only)
  - B) Halo (only)
  - C) Disk (only)
  - D) Bulge and disk, but not halo
  - E) Bulge, disk, and halo
28. Irregular galaxies are most likely irregular because
- A) They have insufficient dark matter to organize it into a regular structure
  - B) They have recently undergone collisions, messing them up
  - C) They have little rotation, and rotation is required to get them in order
  - D) We are viewing them edge on, and this makes them LOOK irregular
  - E) They are moving so fast that their order is distorted by Doppler shift
29. The central power source of an active galaxy is probably
- A) A massive star supernova
  - B) Gas falling into a giant black hole
  - C) A large collection of supergiant stars
  - D) Clouds of gas emitting powerful 21 cm lines
  - E) A really, really big 12 V battery
30. How do we typically map out the atomic hydrogen in our galaxy?
- A) Using the spectral lines from electrons going from one level to another
  - B) By studying the amount of absorption by the dust associated with hydrogen
  - C) By studying the vibration of molecules imbedded in the hydrogen
  - D) By measuring the X-ray glow from the collision of these atoms
  - E) By studying the 21 cm radio line caused by the flipping of spin of the electrons
31. There is background radiation left over from the big bang. What is the approximate temperature of this radiation?
- A) 0 K
  - B) 2.73 K
  - C) 300 K
  - D) 5,800 K
  - E) 13,000,000 K
32. Which of the following is a dead star, the end of the line for stellar evolution?
- A) White dwarf (only)
  - B) Black hole (only)

- C) Neutron star (only)
  - D) All of the above
  - E) None of the above
33. How long, approximately, does it take for the Moon to go through one cycle of phases?
- A) One day
  - B) One week
  - C) Two weeks
  - D) One month
  - E) One year
34. In which parts of our galaxy can stellar clusters be found?
- A) Disk (only)
  - B) Halo (only)
  - C) Open clusters in the halo, globular clusters in the disk
  - D) Open clusters in the disk, globular clusters in the halo
  - E) Nucleus (only)
35. According to current theory, what is the most likely fate of the Universe in the future?
- A) It will eventually reach a maximum size and then recontract
  - B) It will grow slowly to a maximum size and stay there
  - C) It will expand forever, but at an ever slowing rate
  - D) It will expand exponentially forever
  - E) It will expand super-fast, tearing everything apart in the Big Rip
36. The largest contribution to the density of the Universe comes from
- A) Dark Matter
  - B) Dark energy
  - C) Ordinary matter
  - D) Light
  - E) Neutrinos
37. Assuming we do nothing about it, which of the following natural fates would be the soonest one to threaten all of mankind?
- A) Protons and neutrons decay
  - B) The Sun expands as a red giant, melting the Earth
  - C) A giant asteroid slams into the Earth, destroying civilization
  - D) The Earth is swallowed by the black hole at the center of the galaxy
  - E) The Sun and all other stars burn out
38. Pluto's mass is about nine times greater than Charon's. How does Pluto's gravitational pull on Charon compare to Charon's pull on Pluto?
- A) The pulls are equal
  - B) Pluto's pull is three times bigger
  - C) Pluto's pull is nine times bigger
  - D) Pluto's pull is 81 times bigger
  - E) Insufficient information
39. It is estimated that the black hole at the center of our galaxy is approximately four million times more massive than the Sun. How was this estimate obtained?
- A) Using Newton's version of Kepler's laws for stars that are in close orbits around the center
  - B) Measuring the temperature of X-rays emanating from this black hole

- C) Measuring the acceleration of the Earth and Sun towards the black hole
  - D) Measuring the radius of the event horizon, which shows as a black circle in high-resolution images
  - E) Measuring the gravitational red shift from hydrogen clouds near the center
40. Why is it believed that only a fraction of the planets might be suitable for life?
- A) They have to have the right temperature by being in the “Goldilocks zone”
  - B) They have to have sufficient oxygen in their atmospheres to support life
  - C) Elements like hydrogen, carbon, and nitrogen are very rare, but necessary for life
  - D) They have to be far enough from other planets not to undergo tidal disruption
  - E) They have to spin fast enough to have moving water, which is necessary for life
41. Besides Earth, which planet is believed to have currently active volcanoes?
- A) Mars, but not Venus nor Mercury
  - B) Mercury, but not Venus nor Mars
  - C) Venus, but not Mars nor Mercury
  - D) Venus and Mars, but not Mercury
  - E) Venus, Mars, and Mercury
42. According to Newton’s Laws, how much force is required to keep an object moving at constant speed in a straight line?
- A) An amount that depends only on the mass and speed
  - B) An amount that depends on the mass, the mass of the thing keeping it moving, and the separation
  - C) An amount that depends on the mass and the distance it is moving
  - D) There is no simple formula, but it must be non-zero
  - E) Zero
43. Which of the following describes our location in our galaxy?
- A) In the disk, near the center
  - B) In the disk, about half way between the center and the outer rim
  - C) In the disk, near the outer rim
  - D) In the bulge
  - E) In the halo
44. Why is the simple Hubble law formula  $v = H_0d$  actually inappropriate for extremely distant objects?
- A) Peculiar velocities ruin the simple proportional relationship
  - B) Gravitational lensing causes one to misestimate the distance, yielding errors
  - C) You get into regions where the Universe is expanding from a different point, so it stops working

- D) You are looking so far away that you are seeing the universe as it was, not as it is, when the expansion was at a different rate
- E) The light is red-shifted from the fast motion, ruining the velocity formula
45. How does spectroscopic parallax differ from main sequence fitting?
- A) Spectroscopic parallax requires you to determine spectral class; main sequence fitting does not
- B) Spectroscopic parallax applies only to giant stars; main sequence requires main sequence stars
- C) They are essentially the same, except main sequence fitting applies to clusters of stars
- D) They are essentially the same, except spectroscopic parallax applies to clusters of stars
- E) They are actually different names for the same method
46. The ecliptic describes the path that \_\_\_\_\_ takes compared to the background stars
- A) The Moon B) The Sun C) A planet D) Polaris E) None of these
47. Comets typically originate from
- A) The asteroid belt (only)
- B) The Kuiper belt (only)
- C) The Oort cloud (only)
- D) The asteroid belt and Kuiper belt
- E) The Kuiper belt and Oort cloud
48. Sirius is one of the closest stars to Earth. How far away might it be?
- A) 8.6 AU B) 8.6 ly C) 8,600 ly D) 8,600,000 ly E) 8,600,000,000 ly
49. What early event might be the explanation for why the density parameter of the universe, known as  $\Omega$ , is so close to 1?
- A) Inflation
- B) Recombination
- C) Nucleosynthesis
- D) Proton/Neutron Freezeout
- E) Grand Unification
50. Which observation gave strong experimental evidence to Galileo that planets orbited the Sun?
- A) The phases of Venus
- B) Mountains on the Moon
- C) Sunspots on the Sun
- D) The moons of Jupiter
- E) Rings around Saturn

51. Besides Saturn, what other planet has rings?
- Jupiter (only)
  - Neptune (only)
  - Uranus (only)
  - All of the above
  - None of the above
52. Why is it only during the giant stages that two stars in a binary are likely to influence each other's evolution?
- This is the stage when the star is brightest, so its energy flows more quickly
  - Only then does the star expand so much that it can transfer mass to the other star
  - Only during the giant stages is there any substantial carbon or oxygen, which is what causes the effects
  - The gravity of a star is greatest during the giant stages, because it is so large
  - Giant stars have so much area that they absorb substantial light from their smaller companions
53. Suppose star A and star B are 4 AU apart and orbit each other every 8 years. What is the combined total mass of the stars in solar masses?
- $0.25 M_{\odot}$
  - $0.50 M_{\odot}$
  - $1.00 M_{\odot}$
  - $2.00 M_{\odot}$
  - $4.00 M_{\odot}$
54. At right is a very qualitative Hertzsprung Russel diagram, with four stars marked on it. Which star would have the largest radius?
- A
  - B
  - C
  - D
  - Insufficient Info



55. The largest galaxies tend to be
- Irregular galaxies, because they have undergone so many collisions
  - Spiral galaxies, because they have acquired so much gas from other galaxies
  - Ellipticals, because gas collisions have heated up the gas so much
  - Lenticular galaxies, because that is the shape of the clusters from which they form
  - Dark galaxies, because all the mass has been drawn into the black hole

56. Besides making stars behind them look dimmer, what is one other effect of dust?
- It blurs out their spectral lines
  - It makes them look bluer
  - It makes them look redder
  - It causes them to look smaller than they are
  - It changes the Doppler shift of their spectral lines

57. What advantage do white dwarf supernovae have over other distance methods, like Cepheid variable stars or main sequence fitting?

- A) They can be seen at much greater distances
  - B) They are more consistent in luminosity, and hence make better standard candles
  - C) They are much more common, so they can be used more often
  - D) They can be seen through dust and gas, and hence are useful for studying objects near the nucleus of our galaxy
  - E) They are subject to dark energy, so we can measure the dark energy this way
58. Active galaxies can put out a lot of power in
- A) Visible light (only)
  - B) X-rays (only)
  - C) Radio waves (only)
  - D) All of the above
  - E) None of the above
59. On the largest scale, which of the following is a good description of the structure of the Universe?
- A) Tofu: uniform, with about even density throughout
  - B) Jelly donut: Thick in the middle, but surrounded by less dense region
  - C) Swiss cheese: Mostly uniform, but with smallish round regions of empty space
  - D) Spaghetti: Tube shaped regions of matter with small gaps between them
  - E) Soap bubbles: Mostly empty space with relatively thin regions of stuff between them
60. Why do the nuclear processes in high mass stars stop when it gets to iron?
- A) Iron is incompressible, so it cannot be squeezed further
  - B) At this stage the star is losing mass so quickly that it can't get past this stage
  - C) Iron has such a large positive charge that the nuclei can't be pushed together
  - D) Iron has strong magnetic fields that oppose further fusion
  - E) Nuclear fusion of iron does not create energy, it removes it
61. Which of the following is not a type of electromagnetic wave?
- A) Ultraviolet
  - B) X-rays
  - C) Gamma rays
  - D) Neutrinos
  - E) Radio waves
62. Which of the following is larger than the planet Mercury?
- A) Io
  - B) Earth's Moon
  - C) Ganymede
  - D) Pluto
  - E) None of these
63. What is the source of power that drives Io's volcanoes?
- A) Radioactivity
  - B) Chemical reactions
  - C) Solar energy
  - D) Tidal heating
  - E) None of the above
64. Which of the following can be found in the Kuiper belt?
- A) Pluto (only)
  - B) Eris (only)

- C) Charon (only)
- D) Pluto and Charon, but not Eris
- E) Pluto, Charon, and Eris

65. When we take a picture of a planetary nebula, we see a large cloud of gas that is typically glowing. What is causing that glow?
- A) It is merely reflections of the light from the star itself, now obscured by gas and dust
  - B) Chemical reactions among the elements in the cloud
  - C) Radioactive decay of the elements in the planets that make up the planetary nebula
  - D) Collisions between the expanding gas causes the gas to glow
  - E) Ultraviolet light from the dying star at the center caused the atoms to gain energy, and when they lose it again they glow
66. Which of the following is currently taking place in the Sun?
- A) Hydrogen is being converted to helium (only)
  - B) Helium is being converted to carbon and oxygen (only)
  - C) Carbon and oxygen are converted to heavier elements (only)
  - D) All of the above
  - E) None of the above