

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:

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

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

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

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

- Approximately how fast would a galaxy 420 Mly away be moving?
A) 20 km/s B) 0.05 km/s C) 8,820 km/s D) 0.000113 km/s E) None of the above
- Compared to the background stars, which objects appear to move, as viewed from Earth?
A) The planets (only)
B) The planets and the Sun, but not the Moon
C) The planets and the Moon, but not the Sun
D) The Sun and the Moon, but not the planets
E) The Sun, the Moon, and the planets
- When we look at the background universe, we see radiation at a temperature of about 2.725 K. When is the last time that this radiation interacted with something?
A) The beginning of time, or Planck time
B) The beginning of inflation
C) The end of inflation
D) Recombination, when atoms first formed
E) During the era of nucleosynthesis

4. Radio galaxies often produce a lot of their power in giant lobes of gas that aren't in the galaxy at all. Why do we associate such power with the galaxy, and specifically, the galactic nucleus?
 - A) The gas is being attracted to the galaxy's nucleus, which is why it is producing radio waves
 - B) The gas is being heated by X-rays from the galactic nucleus
 - C) The gas is directly being stimulated by magnetic fields that come from the nucleus
 - D) The radio waves come directly from the galactic nucleus, but gravitational lensing just makes it *look like* it is coming from outside the galaxy
 - E) The gas is believed to have been flung out of the galactic nucleus
5. Which of the following is the highest frequency electromagnetic radiation?
 - A) Gamma rays
 - B) Infrared
 - C) Ultraviolet
 - D) Microwaves
 - E) X-rays
6. Our Sun is located where in the disk?
 - A) Right near the center
 - B) Right near the edge
 - C) About half way out from the center to the edge
 - D) Our position in the disk is almost completely unknown
 - E) Actually, we aren't in the disk at all
7. We know that the background universe is virtually identical temperature in all directions, with just slight variations. Which hypothesis is supposed to explain how this could have come about?
 - A) Inflation
 - B) Grand Unified Theories, or GUT's
 - C) Proton/Neutron freezeout
 - D) Primordial nucleosynthesis
 - E) The electroweak scale
8. The largest component of the composition of the universe, as far as we can tell, is
 - A) Dark matter
 - B) Dark energy
 - C) Stars
 - D) Gas
 - E) Dust
9. The number 13.8 billion years is the approximate age of the
 - A) Universe
 - B) Sun
 - C) Earth
 - D) Milky Way
 - E) Moon
10. Assuming we don't do anything about it, which of the following is the most immediate (likely to happen first) threat to civilization?
 - A) Runaway global warming caused by the gradual increase in the Sun's luminosity
 - B) Melting of Earth when the Sun becomes a red giant star
 - C) Collision with a large asteroid
 - D) Collision of our galaxy with another major galaxy
 - E) The decay of protons and neutrons

11. X-rays can be produced from close binaries where one star is a giant star and the other is a
- A) Neutron star (only)
 - B) White dwarf (only)
 - C) Black hole (only)
 - D) Neutron star or white dwarf
 - E) Neutron star or black hole

12. In the diagram, at what points would the Moon cause the Earth to have high tide?

- A) Point 1 (only)
- B) Point 2 (only)
- C) Point 3 (only)
- D) Points 1 and 2, but not point 3
- E) Points 1, 2, and 3



13. Which of the following represents a dead star that is no longer undergoing fusion?

- A) Neutron star (only)
- B) White dwarf (only)
- C) Red giant (only)
- D) Neutron star and white dwarf, but not a red giant
- E) Neutron star, white dwarf, and red giant

14. Was the rate of expansion of the Universe slower or faster than it is now?

- A) It was always slower
- B) It was always faster
- C) It was faster early on, but later it was slower
- D) It was slower early on, but later it was faster
- E) It was approximately constant up to now

15. What sorts of regions are stars and planetary systems born in?

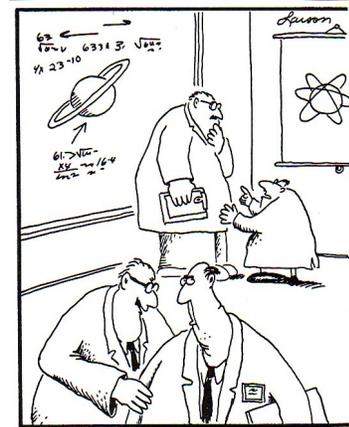
- A) Molecular clouds: regions of cool gas containing molecules
- B) Atomic hydrogen clouds: regions of warm gas containing atoms, but not molecules
- C) Hot bubbles: regions of high temperature where the gas is ionized, with electrons stripped from their atoms
- D) Reflection nebulae: regions where light from nearby stars is reflected
- E) Planetary nebulae

16. Which of the following units of time has to do with the cycles of where the Sun is in the sky at different times?

- A) The day (only)
- B) The day and the year, but not the month
- C) The day and the month, but not the year
- D) The day, the month, and the year, but not the week
- E) The day, the month, the year, and the week

17. Hubble's Law says the universe is expanding. Does everything expand?

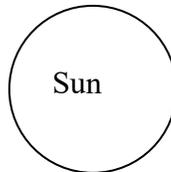
- A) No, atoms don't expand, but larger things like the Solar System do
- B) No, the Solar System isn't expanding, but larger things like stellar clusters do
- C) No, stellar clusters don't, but larger things like galaxies do
- D) No, galaxies and other structures do not, the expansion is just on larger scales
- E) Yes, it applies on all scales, but is too small to notice on most scales



"There goes Williams again...trying to win support for his Little Bang theory!"

18. If the Sun, the Moon, and the Earth were configured as sketched below, what sort of eclipse might occur?

- A) Total solar
- B) Annular solar
- C) Partial solar
- D) Lunar
- E) None of the above



19. If you plot the velocity of stars or hydrogen clouds orbiting in a typical spiral galaxy, what would the velocity typically do at large distances?

- A) It would increase, roughly proportional the distance
- B) It would increase, roughly proportional to the square root of distance
- C) It would stay roughly the same
- D) It would decrease, roughly proportional to the square root of distance
- E) It would decrease, roughly proportional the distance

20. If you have two types of electromagnetic radiation, the one that goes fastest will be the one that

- A) Has the shortest wavelength
- B) Has the longest wavelength
- C) Has the lowest frequency
- D) Has the highest frequency
- E) Actually, they will all have the same speed

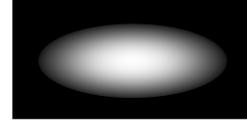
21. When we talk about the universe, what do we mean by the horizon; i.e., how come we can't see forever?

- A) The gas and dust are too thick to see farther
- B) The stars are too dim to see any more
- C) The universe has only a finite age
- D) Light becomes tired and can't travel farther than this distance
- E) Our atmosphere blocks light farther than the horizon, so the next generation of space telescopes will see beyond the horizon

22. Which of the following is not part of where we live?
- A) Galaxy
 - B) Stellar cluster
 - C) Galaxy group or galaxy cluster
 - D) Galaxy supercluster
 - E) Actually, we are a part of all of these
23. When I say the Sun is a G2 star, I am telling you the Sun's
- A) Mass
 - B) Radius
 - C) Temperature
 - D) Luminosity
 - E) Composition
24. Which of the following partly accounts for the fact that there seem to be so many different types of active galactic nuclei?
- A) The central object might be a black hole, neutron star or white dwarf, so this creates many possibilities
 - B) The gas flowing into it can be hydrogen, helium, or heavier elements
 - C) The same AGN might look like very different objects if viewed from different angles
 - D) Some central objects suck in gas, others expel it, and still others do both at the same time allowing for multiple possibilities
 - E) The same object can have very different appearances based on how far away it is
25. Which event is the last thing that is likely to occur in the distant future?
- A) Galaxies separate from each other
 - B) The last stars are born
 - C) All matter decays
 - D) The Sun dies
 - E) Black holes decay by Hawking evaporation
26. What allows binary stars to have a fundamentally different evolution than isolated stars?
- A) The gravity of each star distorts the shape of the other, causing its burning to be lopsided during the main sequence
 - B) Since the two stars had to share gas to be formed, they tend to be low mass stars
 - C) The light from each star heats the other, causing evolution to be much faster
 - D) Planets cannot form in a binary system, and planets have a big effect on stellar evolution
 - E) When one of the stars goes into a giant stage, it can transfer gas to the other star
27. How do we approximately estimate the mass of the black hole at the center of our galaxy?
- A) By the amount it bends light rays via gravitational lensing in its vicinity
 - B) By seeing how close stars come to it before they are ripped apart by tidal forces
 - C) By direct measurement of the Schwarzschild radius (event horizon)
 - D) By measuring how much the black hole moves as it is tugged on by other objects
 - E) By studying the orbits of other stars about the black hole
28. Does our galaxy probably ever collide with or eat other galaxies?

- A) It has in the past, is doing so at present, and will probably continue to do so
- B) It has in the past, and still is doing so, but will probably not do so in the future
- C) It has in the past, but has already stopped
- D) It has not yet, but probably will in the future
- E) No, our galaxy is isolated enough it probably never collided and never will

29. Which classification of galaxy looks like an elongated oval of stars, one axis much longer than the other, but with no other features?



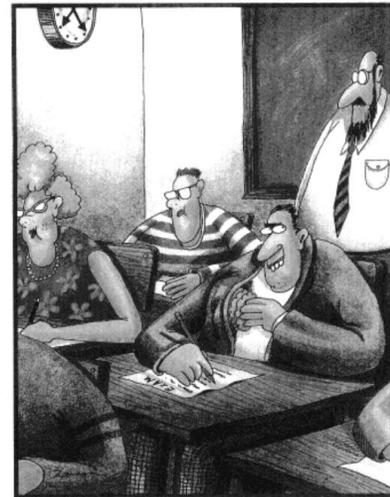
- A) E0
- B) E6
- C) Sc
- D) Irr
- E) SBa

30. Why do we tend to find metal at the center of terrestrial planets, and rock more towards the outside?

- A) Metal is attracted to the strong magnetic fields at the center of the planet
- B) Metal vaporizes at a higher temperature, so it formed first
- C) Metal is heavier, and therefore sinks to the center of planets
- D) Metal conducts electricity, and electrical currents pull it to the center
- E) Metal is stronger, and is the only material that can survive at the huge pressure at the center

31. Which distance technique is almost identical to spectroscopic parallax, except it uses a cluster of stars instead of a single star?

- A) Main sequence fitting
- B) Parallax
- C) White dwarf supernovae
- D) Hubble's Law
- E) Radar ranging / radar distancing



Midway through the exam, Allen pulls out a bigger brain.

32. Which of the following factors that contribute to Drake's equation are we pretty much completely ignorant of?

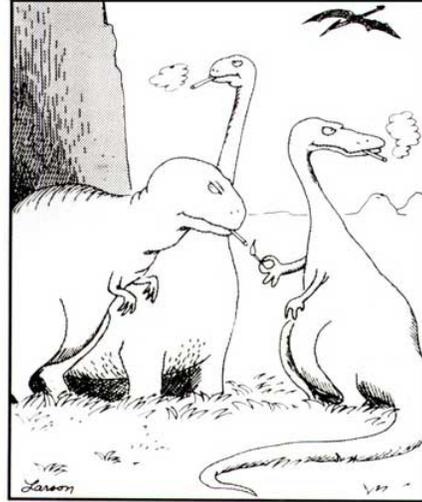
- A) The probability of life evolving intelligence, given enough time
- B) How fast stars form in the galaxy
- C) The fraction of stars with planets
- D) The number of planets or moons that fall within the habitable zone of a star
- E) Actually, we can estimate all of these pretty well

33. What technique allows us to see the hot, thin gas that forms “hot bubbles” within the disk?
- A) We look for the 21 cm line that comes from electrons flipping their spins
 - B) We see the vibrations of molecules as the atoms vibrate
 - C) We see the X-rays from colliding particles in the hot gas
 - D) We see that all asteroids in these regions are heated to high temperature
 - E) We send interstellar probes that detect the gas directly
34. What gas is responsible for the extremely high temperatures on Venus?
- A) Methane
 - B) Carbon Dioxide
 - C) Carbon Monoxide
 - D) Ozone
 - E) Sulfuric acid
35. Cepheid variable stars are great as a method for measuring distance, because there is a simple relationship between their _____ and their _____.
- A) Mass, Period
 - B) Mass, Luminosity
 - C) Mass, Temperature
 - D) Period, Luminosity
 - E) Temperature, Luminosity
36. Sometimes rings are very narrow. It is believed they are so narrow because typically
- A) Their self- gravity pulls them into a very tight region
 - B) The particles are touching each other, which keeps them together
 - C) There are a pair of shepherd moons that keep them narrow
 - D) They are actually solid, a single ring that is therefore narrow
 - E) Magnetic fields from the planet cause them to stick together
37. An irregular galaxy is probably one that
- A) Recently collided or merged with another galaxy
 - B) Has not had any cool gas fed into it in a long time
 - C) Currently has a source of gas feeding into it
 - D) Has a very active galactic nucleus
 - E) Has no active star formation and is now dying
38. The majority of the mass of a galaxy is found in its
- A) Halo
 - B) Disk
 - C) Nucleus
 - D) Bulge
 - E) None of the above

39. Where are different types of stellar clusters located in a galaxy?
- A) Globular clusters are in the halo, open clusters are in the disk
 - B) Open clusters are in the halo, globular clusters are in the disk
 - C) All clusters are generally in the halo
 - D) All clusters are generally in the disk
 - E) None of the above are correct
40. Which of the following might be the approximate diameter of the disk of a spiral galaxy like ours?
- A) 100 AU
 - B) 100,000 AU
 - C) 100 ly
 - D) 100,000 ly
 - E) 1 billion ly
41. What advantage do white dwarf supernovae have as a distance method over Cepheid variable stars?
- A) They are much more common, and hence easier to use
 - B) They are better “standard candles” because their luminosity is more consistently the same
 - C) They tend to have smaller Doppler shifts, resulting in less error
 - D) They exist in distant galaxies, unlike Cepheids, which exist only in nearby galaxies
 - E) They are a lot more luminous, and hence can be seen at greater distances
42. Besides Earth, which of the terrestrial planets has moons?
- A) Mars (only)
 - B) Venus (only)
 - C) Mercury (only)
 - D) Mars and Venus
 - E) Mars and Mercury
43. Why is it that when we look through nearby dust clouds, stars look redder than they could normally?
- A) Typical silicate dust has a reddish tint to it, which gets added to the light
 - B) Dust contains iron, which when it burns up in stars becomes iron oxide, which is red
 - C) Dust has a Doppler effect on light passing through it, making objects redder
 - D) The warm dust glows in infrared, which averages with starlight to make red
 - E) Dust preferentially scatters short wavelength (blue) light, but transmits long wavelength (red) light
44. The current best measurement of the density parameter Ω is about
- A) 0.012
 - B) 0.036
 - C) 0.30
 - D) 0.70
 - E) 1.00
45. Which of the following layers of the Earth is believed to be liquid?

- A) The mantle (only)
 - B) The outer core (only)
 - C) The inner core (only)
 - D) The mantle and outer core
 - E) The inner core and outer core
46. At their centers, what would we find in most stars?
- A) Hydrogen burning to helium
 - B) Helium burning to carbon and oxygen
 - C) Carbon burning to heavier elements
 - D) Inert helium, not currently burning
 - E) Inert carbon and oxygen, not currently burning
47. Which of the following is considered evidence that the power source of some active galactic nuclei (AGN's) are very small?
- A) The amount of power coming out of them is very small
 - B) They can vary their power in very short times
 - C) Radio images always show the power coming from a single pixel
 - D) Visible light images always show the power coming from a single pixel
 - E) The high Doppler shift shows that AGN's are moving at high speeds, which is not possible for a large object
48. The dark matter is probably primarily made of
- A) White dwarfs
 - B) Neutron stars
 - C) Black holes
 - D) Brown dwarfs
 - E) None of the above
49. Which observation by Galileo directly demonstrated that there were objects that went around the Sun, not the Earth?
- A) Mountains on the Moon
 - B) Phases of Venus
 - C) Rings of Saturn
 - D) Moons of Jupiter
 - E) Sunspots on the Sun
50. A GUT or grand unified theory is a theory that
- A) Explains how the universe began
 - B) Explains how the strong, weak, and electromagnetic forces are secretly one force
 - C) Explains where dark matter originates
 - D) Explains the origin of dark energy
 - E) Explains primordial nucleosynthesis

51. Which of the elements are believed to have been made primarily in the first few minutes of the big bang, during primordial nucleosynthesis?
- A) Hydrogen (only)
 - B) Helium (only)
 - C) Carbon (only)
 - D) Hydrogen and helium, but not carbon
 - E) None of the above



The real reason dinosaurs became extinct

52. The stars in the bulge are generally _____ in color and _____ in age compared to disk stars
- A) Redder, younger
 - B) Redder, older
 - C) Bluer, younger
 - D) Bluer, older
 - E) Chartreuse, diverse
53. Why is it in many ways easier to study the overall structure of other galaxies than the Milky Way?
- A) Our galaxy is actually fairly dim, and hence hard to see
 - B) There is a great deal of dark matter in our galaxy, which blocks our view
 - C) There is a large black hole in the center of our galaxy, which absorbs much of the light
 - D) We are in the disk of our galaxy, where there is a lot of gas and dust, which makes it hard to see other things in the disk
 - E) Our galaxy has more dust than other galaxies, so we can see them more easily
54. The Andromeda (M31) galaxy is a member of the Local Group, which contains one other large galaxy called
- A) Virgo
 - B) Fornax
 - C) Coma
 - D) The Milky Way
 - E) Hydra
55. Whose first law says that objects without a force on them continue moving in a straight line at constant speed?
- A) Galileo
 - B) Newton
 - C) Tycho Brahe
 - D) Kepler
 - E) Copernicus
56. There are a lot of quasars that are very far away, but few or none near us. How is this possible?

- A) This portion of the universe has very little gas that could feed into quasars
- B) The curvature of spacetime means there is much, much more space far away than there is near us
- C) Though quasars are uniformly distributed in space, if there were any near us, it would have destroyed all life
- D) When we look very far away, we are looking back in time, and we think quasars were more common back then
- E) There are probably a lot near us, but they are blocked by the gas and dust in our disk

57. In a planetary nebula, the gas ejected from a dying star begins to glow. What is powering this glow?

- A) Nuclear fusion occurring in the nebula
- B) Ultraviolet light coming from the star's hot surface
- C) Stellar wind slamming into the interstellar medium
- D) Stellar wind slamming into previously lost stellar wind
- E) Neutrinos from the powerful fusion in the dying star

58. According to the Bohr model, why is it that only specific frequencies of light can be emitted by a particular atom?

- A) The electrons orbit at specific frequencies, and these frequencies correspond to the frequencies that are emitted
- B) The electrons are orbiting at well-defined velocities, and hence only cross each other's orbits at specific frequencies
- C) The electrons jump into the nucleus and back out at specified frequencies
- D) The light is actually emitted by the nucleus, which vibrates at the corresponding frequency
- E) The electrons can only orbit in specific orbits for each type of atom, and when the electron jumps from one orbit to another, a single photon is emitted with the corresponding energy

59. A star will increase its luminosity the most if it

- A) Doubles its radius but leaves its temperature the same
- B) Doubles its temperature but leaves its radius the same
- C) Doubles both its radius and its temperature
- D) Doubles its temperature but halves its radius
- E) Doubles its radius but halves its temperature

60. In order out from the Sun, which planet is after Saturn?

- A) Jupiter
- B) Mars
- C) Neptune
- D) Uranus
- E) Venus

61. Virgo is the name of the _____ we live in

- A) Galaxy
- B) Galaxy supercluster

- C) Galaxy cluster
- D) Stellar cluster
- E) Stellar system

62. If we realized that a nearby star had intelligent life with a civilization comparable to ours, what technique would probably work with current technology to interact with them?

- A) We could send an unmanned mission to go meet them in a few years (only)
- B) We could send a manned mission or an unmanned mission to meet them
- C) We couldn't send a spaceship, but we could send radio signals to them
- D) We couldn't send a spaceship, but we could send X-rays to them
- E) Actually, none of the above are currently possible

63. What was the primary, or first atmosphere of all the planets believed to be like?

- A) They were all made of hydrogen (and helium)
- B) The inner planets were hydrogen, the outer ones were mostly carbon dioxide
- C) The outer planets were hydrogen, the inner ones were mostly carbon dioxide
- D) They were all made of carbon dioxide (and nitrogen)
- E) They were all mostly water vapor

64. Where are most asteroid orbits located?

- A) Very near Earth
- B) Among the gas giant planets
- C) A little beyond Neptune's orbit
- D) Far outside the rest of the solar system
- E) Between Mars and Jupiter

65. The largest planet in the Solar System is

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

66. Which of the following is consistently found occurring at sunspots?

- A) Magnetic fields (only)
- B) Cooler temperatures (only)
- C) Nuclear fusion (only)
- D) Magnetic fields and cooler temperatures, but not fusion
- E) Magnetic fields, cooler temperatures, and fusion