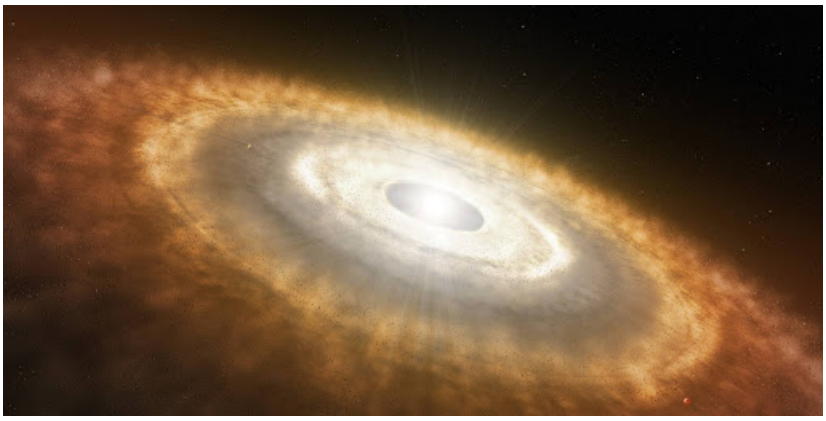
Science Olympiad
Reach for the Stars
UT Regional

February 22, 2020
Austin, Texas



School: _____

Team Number: _____

Name(s): _____

Directions:

- Each team is allowed to bring in two 8.5" × 11" sheets of paper with information on both sides as notes, and two non-programmable, non-graphing calculators.
- Do not write on this test! It is a class set. Please write all answers on the answer sheets; any marks elsewhere will not be scored.
- There is no penalty for wrong answers. Answer every question, even if you aren't sure if you're correct.
- Above all else, just believe!

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Section:	A	B	C	Total
Points:	35	28	38	101
Score:				

Section A

Choose the correct answer to the following multiple choice questions to the best of your ability. Each question is worth 1 point for a total of 35 points.

1. Which of the following best describes the Earth?
    A. A moon
    B. A planet
    C. A star
    D. A galaxy
    E. A constellation

2. Which of the following best describes the Sun?
    A. A moon
    B. A planet
    C. A star
    D. A galaxy
    E. A constellation

3. How do stars produce energy?
    A. Chemical reactions
    B. Nuclear reactions
    C. Electron degeneracy pressure
    D. Neutron degeneracy pressure
    E. None of the above

4. Which of the following lists the order of the main spectral types from hottest to coolest?
    A. OBAFGKM
    B. BOGAFMK
    C. ABFGKMO
    D. ABCDEFG

5. The spectral class of the Sun is
    A. A
    B. G
    C. M
    D. O

6. When the Sun "dies", it will become a
    A. Black hole
    B. White dwarf
    C. Supernova
    D. Red dwarf

7. On a typical H-R Diagram, _____ is on the x-axis, while _____ is on the y-axis.
    A. Temperature, pressure
    B. Temperature, luminosity
    C. Temperature, apparent magnitude
    D. Luminosity, apparent magnitude
    E. Radius, temperature

8. The Milky Way is a _____ galaxy.
    A. Spiral
    B. Barred-spiral
    C. Elliptical
    D. Irregular

9. A very hot star will most likely appear _____ in color to an observer on Earth.
    A. Red
    B. Black
    C. White
    D. Blue

10. The most luminous stars are _____ and _____.
    A. Big, hot
    B. Big, cool
    C. Small, hot
    D. Small, cool

11. Luminosity is a measure of_____.
    A. Power
    B. Energy
    C. Distance
    D. Temperature

12. Light years are a measure of _____.
    A. Distance
    B. Volume
    C. Time
    D. Speed

13. Which of the following portions of the electromagnetic spectrum has the shortest wavelength?

A. Infrared

B. Visible

C. Ultraviolet

D. Radio

14. Which of the following telescopes primarily observes objects in the x-ray portion of the electromagnetic spectrum?

A. Hubble

B. Spitzer

C. WISE

D. Chandra

15. White dwarfs are held up by

A. Chemical reactions

B. Nuclear reactions

C. Electron degeneracy pressure

D. Neutron degeneracy pressure

E. None of the above

16. True or false: planetary nebulae typically have white dwarfs at their center.

A. True

B. False

17. Which of the following sequences below correctly describes the evolution of the Sun from young to old?

A. Protostar, main-sequence, red giant, white dwarf

B. Red giant, main-sequence, white dwarf, protostar

C. Protostar, red giant, main-sequence, white dwarf

D. White dwarf, red giant, main-sequence, protostar

E. Red giant, main-sequence, red supergiant, protostar

18. No matter what its mass, a star spends most of its time on the _____.

A. Asymptotic giant branch

B. Red giant branch

C. Hayashi track

D. Henyey track

E. Main sequence

19. True or false: generally, more massive stars spend more time on the main-sequence than less massive stars, since they start out with more mass (fuel).

A. True

B. False

20. The sun will evolve off the main sequence when:

A. It runs out of helium in its core

B. It completely runs out of hydrogen

C. It builds up an inert helium core

D. It builds up an inert carbon core

21. What is the Messier designation of the Andromeda Galaxy?

A. M1

B. M6

C. M27

D. M31

E. M101

22. True or false: the Andromeda Galaxy is larger than the Milky Way

A. True

B. False

23. Mass transfer in multiple star systems occurs when at least one star overflows its _____

A. Chandrasekhar Limit

B. Eddington Limit

C. Roche Lobe

D. Toomre Limit

24. In a galaxy, where do stars form the most?

A. In its halo

B. In its spiral arms

C. In its nucleus

D. In the dark matter orbiting it

25. The Big Dipper is a part of which constellation?

A. Ursa Minor

B. Ursa Major

C. Cygnus

D. Canis Major

26. The Big Dipper is best described as an

A. Isotope

B. Constellation

C. Asterism

D. Star cluster

27. Order the following from most abundant to least abundant in the universe: dark energy, dark matter, and regular matter.

A. Regular matter, dark energy, dark matter

B. Dark matter, regular matter, dark energy

C. Dark energy, regular matter, dark matter

D. Dark energy, dark matter, regular matter

E. Regular matter, dark matter, dark energy

28. Which of the following best describe H II regions?

A. A region containing H_2 molecules

B. A region containing deuterium, an isotope of hydrogen with a mass number of 2

C. A region containing singly ionized hydrogen

D. A region containing both hydrogen and helium, but no other elements

29. CMB refers to

A. A period of rapid recombination during the universe's infancy

B. The oldest electromagnetic radiation in the universe, thought to be a relic of the Big Bang

C. "Combing", the process by which star formation rates in young galaxies are gradually reduced over time due to feedback

D. Cosmic Millimeter Bursts, which result from particularly energetic supernovae

30. Order the following events from most recent to oldest: recombination, Big Bang, photon decoupling, reionization.

A. Big Bang, photon decoupling, reionization, recombination

B. Reionization, photon decoupling, recombination, Big Bang

C. Big Bang, recombination, reionization, photon decoupling

D. Recombination, reionization, photon decoupling, Big Bang

31. Consider two stars, A and B, that have the same temperature. However, Star A has a radius 100 times larger than Star B. What is the ratio of their luminosities, L_A/L_B?

A. 1

B. 100

C. 10,000

D. 1,000,000

32. Based on the information from Question 43, which star has the higher (i.e. larger positive number; for example, we would say that 1 is higher than -3) absolute magnitude?

A. Star A

B. Star B

C. Impossible to say

33. Based on the information from the previous question, which star has the higher (i.e. larger positive number; for example, we would say that 1 is higher than -3) apparent magnitude?

A. Star A

B. Star B

C. Impossible to say

34. True or false: a hot star's blackbody spectrum will peak at a longer wavelength than that of a cool star.

A. True

B. False

35. Two telescopes in space (i.e. they don't have to worry about interference from the Earth's atmosphere) of equal size observe the night sky in different wavelengths. Generally, which one will have the better angular resolution?

A. The one observing in long wavelengths

B. The one observing in short wavelengths

Section B

Use the attached Image Set for the questions in this section. Each part/subpart is worth 1 points for a total of 28 points.

36. (a) Which constellation is shown in image 1?
    (b) What is the name of the brightest star in this constellation?

37. (a) Which DSO is shown in image 2?
    (b) What do astronomers think is at the center of the image?

38. (a) Which image shows the Rho Ophiuchi cloud complex?
    (b) Circle one word from the following pair: this DSO contains mostly (young/old) stars.

39. (a) Which image shows the Sombrero Galaxy?
    (b) What is the Messier designation for this object?

40. (a) Image 4 shows a composite image of NGC 5128. Which telescope collected the data shown in blue in this image?
    (b) Which other image also shows this object?
    (c) This DSO is notable for having a high star formation rate. What event do astronomers think caused this?

41. (a) Image 6 shows the first star outside of the Solar System to ever have its angular diameter measured. What's this star's name?
    (b) Which image shows the constellation that this star is in?
    (c) Which area of the H-R diagram does this star fall on? Choose from white dwarf, main sequence, supergiants, or giants.

42. (a) Image 9 shows the Sirius star system, which consists of two stars, Sirius A and Sirius B. When both stars had just formed, which one was more massive?
    (b) What is the white "X" shape shown on the image called?
    (c) If I looked at an image of this system taken by the Chandra telescope, which star (A or B) would appear bigger? Explain why.

43. (a) Which image shows the Dragonfish Nebula?
    (b) In which wavelength is this image?
    (c) Which telescope collected the data to make this image?
    (d) Is it possible to see this DSO in visible light? Why or why not?

44. (a) Which image shows M60?
    (b) One notable fact about this DSO is that its isophotes are shaped like boxes, not ellipses. What are isophotes?
    (c) What type of galaxy is M60? Choose from elliptical, irregular, spiral, or barred-spiral.

45. (a) What DSO is shown on the cover of this exam?
    (b) This DSO will spend the majority of its pre-main sequence life on which track?
    (c) This DSO is the prototype for a class of moderately-massed protostars. What is the name of their higher-mass analog?
    (d) Which other image shows this DSO?

Section C

Use the attached Image Set for the questions in this section. Each part/subpart is worth 2 points for a total of 38 points. *Note: a couple of parts are specifically marked as "challenge" parts. These go well beyond what you would normally be expected to know for this event - please don't waste time thinking about them if you haven't finished the test already!*

46. Consider a star with a radius of $0.8R_\odot$ and a temperature of 5400 Kelvin.
    (a) What is the luminosity of this star, in Watts?
    (b) Consider a planet orbiting this star at a distance of 0.8 AU. What is the energy flux that this star receives from its parent star, in Watts per square meter?
    (c) *Challenge:* what is the equilibrium temperature of this planet, in Kelvin? Assume that the planet absorbs 80% of the light that hits it.

47. Suppose that one summer night, you're sitting at an observatory with your friend and looking at the night sky. Normally, you'd worry about light pollution, but this observatory is on top of a mountain far from nearby cities or towns. One of your goals for the night is to observe two stars in a nearby cluster, Star A and Star B.
    (a) During your observations, you notice that the energy flux from Star A is four times that of Star B. Based on this information, what is the difference between their apparent magnitudes? In other words, what is $m_A - m_B$?
    (b) A friend of yours notes that since both stars are part of the same cluster, you can probably approximate them as having the same mass, allowing you to estimate their radii. Is this the case? Why or why not?
    (c) Suppose that you want to estimate the absolute magnitude of one of these stars. What's one way you could do it? Assume that the cluster is relatively nearby.

48. Since hydrogen is the most abundant element in the universe, mapping the concentration of hydrogen in galaxies is crucial to helping astronomers understand how normal matter is distributed and how galaxies evolve.
    (a) A friend of yours suggests that you simply use a visible-light telescope and look for hydrogen! Give one astrophysics-based reason why this wouldn't work (i.e. don't just say something like "telescopes would need to be more sensitive than they are right now").
    (b) It turns out that while visible light don't work very well, radio waves do. One big advantage radio waves have is that they can easily travel through the interstellar medium without getting blocked - why is this the case?
    (c) Interstellar space consists largely of neutral hydrogen (which astronomers call "H I"). How many protons, neutrons, and electrons are in one atom of neutral hydrogen?
    (d) Describe the process through which a neutral hydrogen atom would emit radio waves that we could see.

49. Although all stars produce energy through nuclear reactions, they transport it different ways. In this question, we'll examine some reasons behind the internal structures of different classes of stars. For the purposes of this question take a "very massive star" to have a mass greater than $4M_\odot$, a "Sun-like star" to have a mass less than $4M_\odot$ but greater than $0.4M_\odot$, and a "very low mass star" to have a mass of less than $0.4M_\odot$.
    (a) Circle one word from each pair: at the centers of very massive stars, the temperature is very (high/low) and the pressure is very (high/low), causing a very (large/small) pressure gradient throughout the star.

(b) Circle one word from each pair: in very massive stars, the density of their outermost layers is very (high/low), so they are optically (thin/thick). As a result, energy travels through this region mainly by (radiation/convection).

(c) Circle one word from each pair: in the center of Sun-like stars, the (high/low) temperature ionizes atoms, (increasing/decreasing) the opacity, allowing energy to be transferred largely by (radiation/convection).

(d) Unlike Sun-like stars and very massive stars, energy in very low mass stars is transferred almost entirely due to convection. Why is this the case?

50. Stars are formed by the collapse of large clouds of gas, a deceptively complicated process filled with some interesting thermodynamics. This collapse is thought to have several parts and is an active area of research in astronomy and physics.

(a) Astronomers generally believe that at first, the collapse of a cloud is isothermal. What does "isothermal" mean?

(b) As the cloud continues to collapse, it becomes denser. How would this impact its optical depth? *Hint: optical depth effectively refers to how opaque something is; for example, more opaque objects have higher optical depths.*

(c) Towards the end of the end of cloud's contraction (i.e. when it has already become much denser than it was before), do we expect its temperature to increase, decrease, or stay the same as it continues to contract?

(d) How does your answer to the previous part affect the *rate* at which the cloud contracts? *Hint: as given by the ideal gas law, temperature and pressure are proportional to each other when other variables are held constant.*

(e) *Challenge:* During the last portion of the cloud's collapse, as described in part (c), how do you expect the entropy of the cloud to change? Assume that the collapse of the gas cloud happens very slowly.