Astronomy C

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SSSS 2020

School Name: _____ Team #: _____

Participant Names: _____

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Information

- This test contains 148 questions (including multiple parts of questions).
- There is an answer sheet at the back of the test for you to record your answers.
- The number of points each question is worth is specified after the question in brackets.
- All questions asking for DSO image identification will be one point per correct image.
- Written by RiverWalker88.
- Good luck!

Constants and Conversions

CONSTANTS
Hubble's Constant = $H_0 = 70$km/s/Mpc
Stefan-Boltzmann Constant = $\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$
Gravitational Constant = G = $6.67 \times 10^{-11} Nm^2/kg^2$
Speed of light = $c = 3 \times 10^8$m/s
Boltzmann Constant = $k_B = 1.380 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$
Mass of a proton = $m_p = 1.6726 \times 10^{-27}$ kg
Mass of the sun = $M_\odot = 1.99 \times 10^{30}$kg
Radius of the sun = $R_\odot = 6.96 \times 10^5$km
Temperature of the sun = $T_\odot = 5778$K
Luminosity of the sun = $L_\odot = 3.9 \times 10^{26}$W

UNIT CONVERSIONS
1 AU = 1.5×10^{11}m
1 ly = 9.46×10^{12}km
1 pc = 3.09×10^{13}km = 3.26 ly
1 year = 31557600 seconds

Part A: DSO Identification and Analysis

1. NGC 2623
   (a) What image(s) on the image sheet depict this DSO?
   (b) What type of active galaxy is this DSO? [2]
   (c) How did this DSO form? [2]
   (d) This DSO contains a high rate of star formation. What causes this high rate of star formation? [2]
   (e) In what areas of this galaxy is star formation high? [2]
   (f) In what wavelength would we best be able to locate regions of high star formation? [2]
2. GRB 150101B
   (a) What image(s) on the image sheet depict this DSO?
   (b) What is a GRB? [2]
   (c) What event may have caused this? [2]
   (d) This event had been observed before, but with different types of waves (i.e. Not electromagnetic waves).
      i. What type of waves was it observed in? [2]
      ii. What is the name of this DSO? [2]
   (e) How far away is this object? Why is this significant to the waves we observe it in? [3]
3. MACS J1149.5+2223
   (a) What image(s) on the image sheet depict this DSO?
   (b) What does MACS stand for? [2]
   (c) What effect does the high mass of this object have on our observations of other DSOs? [2]
   (d) This DSO made it possible to observe the farthest observed star, far out in space.
      i. How far out is this star? [2]
      ii. What is this star called? [2]
   (e) What event is happening in this DSO? [2]
4. Bullet Cluster
   (a) The Bullet Cluster is shown in image A1. What additional image(s) on the image sheet depict this DSO?
   (b) How was the Bullet Cluster formed? [2]
   (c) What was significant about the energy of this event? [2]
   (d) What do the colors in image A1 represent (be specific; what color corresponds to what)? [2]
   (e) How does data from this DSO support dark matter? [3]
   (f) How does data from this DSO reject alternative theories of gravity? [3]
5. GOODS-S 29323
   (a) An artist's representation of this DSO is shown in image A2. What additional image(s) on the image sheet depict this DSO?
   (b) What is this DSO? [2]
   (c) What do the different colors mean? [2]
   (d) What does GOODS stand for? [2]
   (e) What mystery surrounds the formation of this type of object? [2]
   (f) What theory is shown in the artist's representation that might explain the mystery? [2]
6. H2356-309
   (a) What image(s) on the image sheet depict this DSO?
   (b) What is this object? [2]

(c) Light from this object shines through what formation? [2]

(d) What effect does shining through this formation have on the spectrum (be specific, give all changes to the spectrum)? [2]

(e) What specifically do most astronomers believe cause these changes? [2]

7. GW151226

(a) What image(s) on the image sheet depict this DSO?

(b) What telescope observed this DSO? [2]

(c) What interaction caused this gravitational wave? [2]

(d) Approximately $3M_{\odot}$ of mass was converted into energy. How much energy was released in gravitational waves? [5]

(e) Why are we only able to observe the gravitational waves from this object? [3]

8. M87

(a) M87 is depicted in image A3. What additional image(s) on the image sheet depict this DSO?

(b) What part of M87 is shown in image A3? [2]

(c) What wavelength is this taken in? [2]

(d) What does the orange in the image represent? [2]

(e) A jet of particles is ejected from the black hole in the center of M87. The mass of the particles would also appear to change from different observer frames. What property of the particles would describe this? [2]

(f) The particles in this jet move in a spiral motion. What might be the cause for this? [2]

(g) M87 has a significant quantity of globular clusters. How may it have gotten so many globular clusters (assuming that it did not form them all itself)? [2]

(h) What evidence of the composition of surrounding objects supports this? [2]

Part B: Conceptual Astronomy

9. What would you find on the x-axis of a typical H-R diagram? [1]
   A. Temperature, increasing from left to right.
   B. Temperature, increasing from right to left.
   C. Luminosity, increasing from left to right.
   D. Luminosity, increasing from right to left.

10. Researchers suspect that there is a maximum limit to the mass of a neutron star. What is the approximate value expected of this limit? [1]
    A. $3M_\odot$ B. $5M_\odot$ C. $8M_\odot$ D. $11M_\odot$

11. For each Harvard spectral class, give the image that shows its emission spectrum (BC1 - BC7). [0.5 each, 3.5 total]

12. For each spectral class, give the color of the star. [0.5 each, 3.5 total]

13. The evolutionary track of the Sun is shown on the answer sheet.
    (a) At what point does the sun currently land on the H-R diagram? Place a dot there labelled "C". [2]
    (b) At what point does the Sun expand and swallow up the Venus (orbit = 0.72AU)? Place a dot there labelled "F". [2]
    (c) At what point does the Sun begin to fuse elements heavier than Helium? Place a dot there labelled "He". [2]

14. Giant stars make up a very small fraction of all stars. Why, then, do giant stars make up around 40-50% of all stars that we can see with the naked eye? [3]

15. Rank each of the following mass ranges of stars from low to high by its abundance on the main sequence. [2, 0.5 each]
    i. $0\text{-}0.25M_\odot$
    ii. $0.25\text{-}0.5M_\odot$
    iii. $0.5\text{-}1M_\odot$
    iv. $1\text{-}2M_\odot$

16. (a) How do shock waves influence star formation? [3]
    (b) How can star formation feed other star formation in a sort of chain reaction through shock waves? [3]

17. There are two main methods for Hydrogen fusion in stars: The proton-proton chain and the CNO cycle.
    (a) Proton-proton chain
        i. What are the inputs for the proton-proton chain? [2]
        ii. In the first step of the proton-proton chain, a light helium nucleus if formed. Describe the process for its formation. [3]
        iii. How are gamma rays formed in the proton-proton chain? [3]
        iv. How do the gamma rays formed become visible light? [2]
    (b) CNO Cycle
        i. What does CNO stand for? [2]
        ii. A number of reactions take place during this cycle. What is the role of carbon in forming helium? [3]
        iii. What is the heaviest isotope formed in this cycle? [2]
        iv. Energy is released as two sources in this cycle. What are these sources? [2]
    (c) Which of these processes mainly occur in the sun? [2]
    (d) What mass of star does the other process begin to dominate the fusion of hydrogen? [2]
    (e) What type of star do these processes happen in? [2]

18. (a) Briefly describe the triple-alpha process. [3]
    (b) What type of star does this process mainly happen in? [2]
19. (a) Describe the formation of a planetary nebula. [3]
    (b) What is the approximate mass range of stars that form planetary nebulae? [2]
20. In what sense is the term "Neutron Star" a misleading term? [2]
21. Which light curve on the image sheet matches that of a star that changes in size in order to cause pulsation? [1]
    A. BC8
    B. BC9
    C. BC10
    D. BC11
22. Why is the chromosphere of the sun only visible during solar eclipses? [2]
23. List the steps of a protostar forming from an HII region. [3]
24. (a) What is interstellar medium? [2]
    (b) Which component of the interstellar medium affects visible light observations? Why? [2]
    (c) How does interstellar medium affect the color at which we view a far star's color and brightness? [2]
    (d) What is the approximate density of interstellar medium? [2]
    (e) Describe the shape of interstellar dust. [2]
    (f) Why are we more knowledgeable about the shape of interstellar dust than we are about the composition of interstellar dust? [3]
25. (a) What is flux density? [2]
    (b) What is the unit for flux density? [2]
26. Why is gravity considered a force? [2]
27. Rank spiral, elliptical, and irregular Hubble class galaxies by low to high angular momentum. [2]
28. Quasar is short for Quasi-Stellar Radio Source. In what way is this name misleading? [2]
29. List 3 characteristics of a BL Lacertae object. [3]
30. (a) What is a Seyfert Galaxy? [2]
    (b) Why do astronomers think that these galaxies emit a majority of their light in the infrared spectrum? [2]
31. (a) What is the current definition of the cosmological constant? [2]
    (b) How did this change since the idea was proposed by Albert Einstein? [3]
32. What happens when a star gets within its Schwartzchild radius? [2]
33. There are three main assumptions of cosmology.
    (a) One of these assumptions has to do with the physical laws of the universe. Give and describe this assumption. [3]
    (b) One of these assumptions has to do with the distribution of matter in the universe. Give and describe this assumption. [3]
    (c) One of these assumptions has to do with the cosmological principle. Give and describe this assumption. [3]
34. How does Olber's Paradox contradict the view of the universe in the early 20th century (that the universe was infinite and unchanging)? [3]
35. (a) The cosmic microwave background (CMB) shows a record of what major event in our cosmic history? [2]

(b) The CMB shows a near-perfect blackbody curve, with the same intensity from all directions. What does this suggest about the universe? [1]

A. The universe is homogeneous.

B. The universe is isotrophic.

C. The universe is larger than expected.

D. The universe is gravitationally bound.

(c) How can observations of the CMB be used to determine the motion of our own galaxy? [3]

36. Around 30-40% of baryonic matter seems to be missing. However, a discovery prompted the theory of Warm-Hot Intergalactic Medium (WHIM).

(a) What is baryonic matter? [2]

(b) Describe WHIM. [2]

(c) What properties of WHIM makes it difficult to observe in X-Rays? [3]

37. A radio telescope array (also shown on the front cover) contains 3 branches of radio telescopes, equally spaced (120^o) from each other branch. The telescopes fall in four different configurations throughout the year; In configuration A, the telescopes are far spaced from each other, and in configuration D, the telescopes are located very close together.

(a) What is the full name of this telescope array? [2]

(b) What are telescope arrays like these called? [2]

(c) What is the advantage of this type of telescope? [2]

(d) What effect does the spacing of the telescopes have on the resolution and area covered of the image? In your answer, include which configuration will have the highest resolution and cover the largest region of space. [3]

(e) An astronomer uses this telescope to make observations in the 21cm band.

i. What causes emission in the 21cm band? [2]

ii. What does this emission allow astronomers to do? [2]

38. (a) How does expansion of the universe affect waves of light? [2]

(b) How can the redshift of an object be used to determine the factor of expansion of the universe after the photon was emitted? [2]

Part C: Conceptual & Calculation

39. A star has a mass of $2.8M_\odot$ and a radius of $1.7R_\odot$.
    (a) How much force (in N) must the inward pressure exert in order to prevent the star from collapsing? [6]
    (b) What is the balance between gravity and inward pressure called? [2]
    (c) How long will this star be on the main sequence? [5]

40. A (fictional) star has two planets in its (fictional) solar system, Lorem and Ipsum. Lorem is 2×10^{11} meters away from this star and is 280K in temperature. Ipsum is 2.4×10^{11} meters away from the sun.
    (a) What is the temperature of Ipsum? [6]
    (b) Which of these planets (or both, or neither) is in the "goldilocks zone" (or the area where liquid water can exist, between 0 and 100 degrees Celsius)? [2]

41. A proton in an accretion disk of a white dwarf has a velocity of 1.33×10^4m/s. This accretion disk has a diameter of 1.73×10^5km and is 8.9×10^3km thick.
    (a) What is the temperature of this accretion disk? [6]
    (b) What is the luminosity of this accretion disk? Assume that this accretion disk is cylindrical and the white dwarf in the center doesn't make a difference, and that the disk is homogeneously luminous. [6]

    This white dwarf is in a non-eclipsing binary system measured to be 208Mpc away. The light curve for this system is shown in image BC12. Assume that the proton velocity was measured at a low point in the light curve.
    (c) What type of variable is this? [2]
    (d) How many times closer does this system appear on a peak versus a low point in the light curve? [5]
    (e) What is the recessional velocity of this system? [5]

    After some time, the white dwarf suddenly brilliantly (and irreversibly) exploded!
    (f) What is this explosion called? [2]
    (g) The apparent magnitude of this explosion was measured to be 41.589. How much time had elapsed since the exploded star was measured in (a)-(e)? [6]
    (h) What was the mass of the white dwarf in parts (a)-(e)? Assume the accretion disk radiated at its Eddington Luminosity in parts (a)-(e). [6]

42. A main-sequence star has a temperature of 15,000K and a radius of 2.7×10^7km.
    (a) What is the luminosity of this star? [5]
    (b) What wavelength does this star peak in? [5]
    (c) What is the spectral type and subtype and luminosity class of this star? [2]
    (d) What is the mass of this star? [5]
    (e) How long will this star stay on the main sequence? [5]

43. A galaxy cluster has a mass of $4.81 \times 10^{14}M_\odot$, a velocity of 3.84×10^5 m/s and a luminosity of 1.53×10^{35}W.
    (a) What is the kinetic energy of this cluster? [5]
    (b) How much mass is being converted to energy per second in this cluster? [5]
    (c) What is the potential energy of all of the mass in this cluster? [6]
    (d) List three properties of a cluster that affect the overall luminosity of the cluster (Hint: List properties of the cluster as a whole, not of the galaxies inside of it). [3]
    (e) After the observations of this galaxy cluster were taken, this cluster underwent an interaction that resulted in a loss of 35% of its luminosity. Assume that this means that 35% of the luminous matter of the galaxy has been lost. Also assume that only luminous matter was lost from this cluster. Finally, assume that the kinetic energy of this cluster stays constant. This cluster is now observed to have a velocity of 4.28×10^5 m/s. What percentage of this cluster is dark matter? [6]

44. (a) About how much energy does fusing two hydrogen nuclei into a helium nucleus produce? [2]

(b) How many hydrogen fusion reactions happen per second in the sun? [5]

45. A neutron star has a 12km diameter. This neutron star has a density of 2.92×10^{18}kg/m^3.
    (a) What is the escape velocity of this neutron star (in m/s)? [5]
    (b) What is the Schwartzchild Radius of this neutron star (in m)? [5]
    (c) What is the relationship between escape velocity and Schwartzchild radius? [2]
    (d) If the mass of this star were to increase, what would happen to its radius? Its Schwartzchild Radius? [2]

46. A satellite is launched into orbit around the sun. This satellite is made of carbon fiber, which has a melting temperature of 3900K. This telescope is observing 110nm X-Rays and has an optic diameter of 3m.
    (a) How close could this satellite get to the sun without melting (in AU)? [5]
    (b) How many times per year would one particular spot of interest on the sun be able to be observed? [5]
    (c) What is the minimum distance that this telescope could still determine separate features (in meters)? [6]

47. Two (fictional) galaxies, Dolor and Sit-Amet are 8.54×10^2kpc apart. Dolor has a mass of $5.08 \times 10^8 M_\odot$ and a radius of 1.08×10^5pc. Sit-Amet has a mass of $1.4 \times 10^7 M_\odot$ and a radius of 1.4×10^3pc.
    (a) What is the gravitational attraction between these two galaxies (in N)? [5]
    (b) Sit-Amet is accelerating into Dolor. What is the acceleration of Sit-Amet into Dolor (in m/s^2)? [5]
    (c) What is this galactic interaction called? [2]

Answer Sheet: Part A

1. (a) _____
   (b) _____
   (c) _____
   (d) _____
   (e) _____
   (f) _____

2. (a) _____
   (b) _____
   (c) _____
   _____
   (d) i. _____
   ii. _____
   (e) _____
   _____
   _____
   _____

3. (a) _____
   (b) _____
   (c) _____
   _____
   (d) i. _____
   ii. _____
   _____
   _____
   _____
   (e) _____
   _____

4. (a) _____
   (b) _____
   _____
   (c) _____
   _____
   (d) _____
   _____
   (e) _____
   _____
   _____
   _____
   (f) _____
   _____
   _____
   _____

5. (a) _____
   (b) _____
   (c) _____
   _____
   (d) _____
   _____
   (e) _____
   _____
   (f) _____
   _____

6. (a) _____
   (b) _____
   (c) _____
   (d) _____
   _____
   (e) _____

7. (a) _____
   (b) _____
   (c) _____
   _____

(d) _____

(e) _____

8. (a) _____

(b) _____

(c) _____

(d) _____

(e) _____

(f) _____

(g) _____

(h) _____

Answer Sheet: Part B

9. _____

10. _____

11. A: _____

B: _____

F: _____

G: _____

K: _____

M: _____

O: _____

12. A: _____

B: _____

F: _____

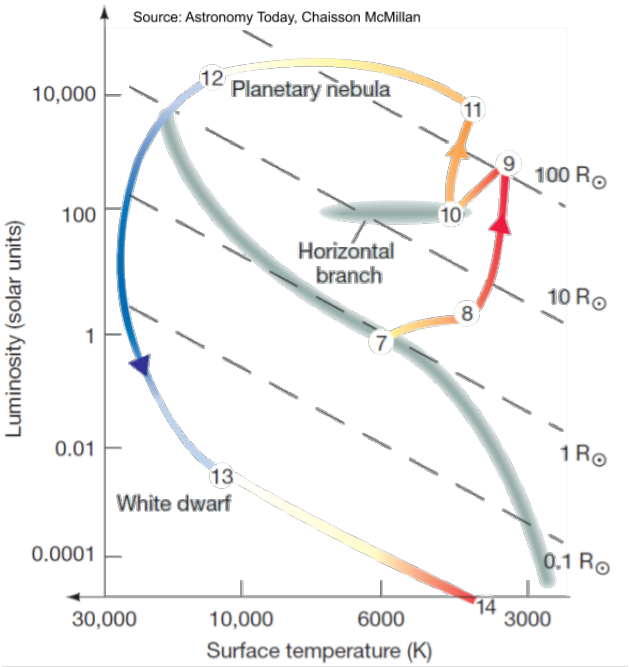
G: _____

K: _____

M: _____

O: _____

13.



14. _____

15. 1-_____ 2-_____

3-_____ 4-_____

16. (a) _____

(b) _____

17. (a) i. _____

ii. _____

iii. _____

iv. _____

(b) i. _____

ii. _____

iii. _____

iv. _____

(c) _____

(d) _____

(e) _____

18. (a) _____

(b) _____

19. (a) _____

(b) _____

20. _____

21. _____

22. _____

23. _____

24. (a) _____

(b) _____

(c)

(d)

(e)

(f)

25. (a)

(b)

26.

27. 1- 2-

3-

28.

29.

30. (a)

(b)

31. (a)

(b)

32.

33. (a)

(b)

(c)

34.

35. (a)

(b)

(c)

36. (a)

(b)

(c)

37. (a)

(b)

(c)

(d)

(e) i.

ii.

38. (a)

(b)

Answer Sheet: Part C

39. (a)

Final Answer: _____

(b)

(c)

Final Answer: _____

40. (a)

Final Answer: _____

(b) _____

41. (a)

Final Answer: _____

(b)

Final Answer: _____

(c) _____

(d)

Final Answer: _____

(e)

Final Answer: _____

(f) _____

(g)

Final Answer: _____

(h)

Final Answer: _____

42. (a)

Final Answer: _____

(b)

Final Answer: _____

(c) _____

(d)

Final Answer: _____

(e)

Final Answer: _____

43. (a)

Final Answer: _____

(b)

Final Answer: _____

(c)

Final Answer: _____

(d) _____

_____

(e)

Final Answer: _____

44. (a) _____

(b)

Final Answer: _____

45. (a)

Final Answer: _____

(b)

Final Answer: _____

(c) _____

_____

(d) _____

46. (a)

Final Answer: _____

(b)

Final Answer: _____

(c)

Final Answer: _____

47. (a)

Final Answer: _____

(b)

Final Answer: _____

(c)