Science Olympiad
Hawk and Hornet Invitational

November 11th 2023

Astronomy C

Name(s): _____

Team name and number: _____

Score: _____/190

Directions:

- Each team will be given **50 minutes** to complete the test.
- There are three sections: §A (General Knowledge), §B (Deep-Sky Objects), and §C (Physics).
- All answers must be indicated on the test or image sheet.
- You may take apart the test, but make sure to staple it back together at the end of the event.
- Good luck!

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Section A: General Knowledge

Each question is worth 1 point unless otherwise specified for a total of 56 points

Metric Melodies The next 5 questions test your understanding of what some common measurements are really measuring

1. True or false: parsecs, light years, and astronomical units all measure distance.
   A. True
   B. False
2. Luminosity is a measure of _____
   A. Apparent brightness
   B. Temperature
   C. Radiant energy
   D. Radiant power
3. Apparent magnitude is a logarithmic measure of _____
   A. Apparent brightness
   B. Temperature
   C. Radiant energy
   D. Radiant power
4. What is stellar parallax and what is it used for? m = the star's apparent magnitude and M = the star's absolute magnitude.
   A. apparent shift of a star, finding distance through trigonometry
   B. apparent shift of a star, finding distance through distance modulus
   C. $m - M$, finding distance through trigonometry
   D. $m - M$, finding distance through distance modulus
5. What does it mean if a star has a B-V color index of -0.5?
   A. The star emits more blue light than green-yellow light
   B. The star emits more green-yellow light than blue light
   C. The star emits more blue light than violet light
   D. The star emits more violet light than blue light

Ring Around the Rosie a lot of things spin around each other in space. The next 9 questions will relate to orbits.

6. (2 points) Kepler's laws are perhaps better called Kepler's approximations. What assumptions did Kepler make? Choose all that apply.
   A. Gravity is Newtonian
   B. One of the bodies is fixed
   C. The gravitational influence of planets on each other is negligible
   D. Planets move in perfect circles
7. Oskar the planet is orbiting around Ryan the star. Image S shows Oskar and Ryan. When is Oskar's speed the fastest?
   A. When Oskar is at point A
   B. When Oskar is at point C
   C. When Oskar is at point B or D
   D. Um, actually, Oskar's speed is constant
8. Assuming a counterclockwise orbit around Ryan, what is the net change in velocity from Point B to C? _____
9. (4 points) Write an inequality comparing the following times needed to complete the orbital arc (still assuming counter clockwise orbit).
   - B to A
   - C to D
   - A to C
   - D to B
10. (3 points) Specify what type of orbit an object would be in for the following energy values.
    (a) (1 point) $E > 0$
    (b) (1 point) $E = 0$
    (c) (1 point) $E < 0$

11. While Oskar is a earth-mass planet, their radius is considerably larger than Jupiter's. Ryan is a high-mass star. Oskar is far from Ryan. Also, Oskar is very hot and Oskar's orbital plane not on our line-of-sight to Ryan. Which exoplanet detection methods is likely best suited for detecting Oskar?

    A. Radial velocity

    B. Transit

    C. Direct imaging

12. (4 points) **Short answer:** Justify why the method you chose is the best and why the other methods aren't the best.

13. Kepler's 2nd Law is a result of what physics property?

    A. Conservation of Energy

    B. Newton's Law of Gravitation

    C. Conservation of Angular Momentum

    D. Newton's Second Law

14. If orbital radius is increased by a factor of 3, by what factor does orbital period change?

    A. 27

    B. $\sqrt[2]{3^3}$

    C. 3

    D. $\sqrt[3]{3}$

You are my Sunshine but the sun is nothing special because there are a lot of stars. The next 10 questions are about stars.

15. Most stars are mainly composed of:

    A. Stardust

    B. Hydrogen

    C. Helium

    D. Fire

16. A star that is 5770K has a _____peak wavelength than star that is 7690K. In addition, the 5770K star emits _____energy at every wavelength.

    A. shorter, more

    B. shorter, less

    C. longer, more

    D. longer, less

17. (4 points) List the following stellar classifications from hottest to coldest: K, G, O, B, A, F, M

18. (2 points) TW Hydrae is a K6 star. What does the 6 mean?

19. T Tauri stars are more luminous than main sequence stars of the same spectral class. This suggests that they are _____than main sequence stars.

    A. hotter

    B. larger

    C. closer

    D. denser

20. (6 points) Rank the following Yerkes Classifications from 1 (Least Luminous) to 6 (Most luminous)

    - Ib
    - III
    - IV
    - Ia
    - V
    - II

21. (3 points) T Tauri stars are protostars with a mass less than 2 $M_\odot$. Herbig Ae/Be stars are 2-8 $M_\odot$ protostars. Why don't we have a classification for protostars more massive than 8 $M_\odot$?

22. (2 points) A star of 5 Solar Masses is contracting on the way to ignite nuclear fusion in its core. Is this a T-Tauri or Herbig Ae/Be Star? What is the contraction called?

    A. T Tauri

    B. Herbig Ae/Be

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23. There are 2 jets sticking out of a T Tauri star. What are these jets most likely?

    A. Herbig Haro objects

    B. bowshock

    C. Protostar jets

    D. T Tauri jets

24. What stage of stellar evolution contains the "Blue Loop"?

    A. Main Sequence

    B. Horizontal Branch

    C. Planetary Nebula Phase

    D. Subgiant Branch

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25. What will the radial velocity method for detecting exoplanets not indicate?

    A. Radius of the Planet

    B. Orbital Momentum of the Planet

    C. Mass of the Planet

    D. Ratio of Orbital Radii of Star/Planet

26. Which of these Spectral Classes would have the strongest H lines?

    A. O

    B. B

    C. A

    D. F

27. What mechanism can cause an exoplanet to radiate more heat than it recieves from its parent star?

    A. Kelvin-Helmholtz Mechanism

    B. Rossiter–McLaughlin effect

    C. Kramer's Law

    D. Tully-Fisher Relation

28. (2 points) Select all the options that the transit method for detecting exoplanets can indicate to astronomers directly

    A. Ratio of Radii

    B. Momentum of the System

    C. Orbital Velocity of the Planet

    D. Transit Depth in ppm

29. The majority of planets detected from the transit method are

    A. Super Earths

    B. Super-Neptunes

    C. Hot Jupiters

    D. Mini Saturns

30. (5 points) What interaction would cause an exoplanet to spiral inwards towards its host star? _____

Section B: DSOs
Total of 68 points

1. (a) (1 point) Which image(s) show NGC 1333?
   (b) (1 point) What telescope took that image?
   (c) (2 points) Why is the wavelength that the image was taken significant?
   (d) (1 point) What are the dimensions of NGC 1333 viewed from Earth? (in arcseconds)
   (e) (1 point) What objects were discovered by the Hubble Space Telescope in NGC 1333?
   (f) (2 points) The proportion of Low Mass Brown Dwarfs that have a stellar disk around them suggests what?
2. (a) (1 point) Which image(s) show Luhman 16?
   (b) (1 point) How far away is the system in parsecs?
   (c) (2 points) What is the angular separation of the Luhman 16 AB system in arcseconds? What distance does this correspond to?
   (d) (2 points) Luhman 16 B is a special brown dwarf in that it is variable in luminosity: what is this variation caused by?
   (e) (2 points) Despite Luhman 16 AB's close proximity to the Solar System, why wasn't it discovered earlier?
3. (a) (1 point) What DSO is shown in Image B?
   (b) (1 point) What part of the EM spectrum is the image taken in?
   (c) (1 point) What telescope took the photo?
   (d) (1 point) What angular area does this DSO take up in the sky in $degrees^2$
   (e) (2 points) In 1827, what star erupted and caused astrophysicists to develop new models of stellar evolution
   (f) (1 point) There are eight known of what type of object in this DSO?
4. (a) (1 point) What image(s) show HR 8799?
   (b) (1 point) What is significant about the method used to discover the exoplanets?
   (c) (1 point) Some of the planet's spectra in the system show similarities with T-Type Brown Dwarfs, what absorption bands would we expect from some of the planets in the system?
   (d) (2 points) What telescope took a timelapse of the HR 8799 system's orbits? What spectrum was used?
   (e) (2 points) In 2009. The Spitzer Space Telescope discovered a dust halo between some of the planets' orbits. Why is this significant?
5. (a) (1 point) What DSO is depicted in Image D?
   (b) (1 point) Glare from the parent star is blocked using what tool?
   (c) (1 point) What is the apparent magnitude of this DSO?
   (d) (2 points) The spectrum of this DSO was seen to have some variability, what was the source of this?

6. (a) (1 point) What image(s) shows Wasp-18b (Either the Exoplanet or Parent Star)

   (b) (1 point) What method of detection was used for Wasp-18b?

   (c) (2 points) By what factor of flux does Wasp-18b receive from its parent star, than Earth does from the Sun?

   (d) (2 points) Why is Wasp-18's X-ray emission surprising to Astronomers?

   (e) (2 points) What is the apparent magnitude of Wasp-18? Is it visible to the naked eye?

7. (a) (1 point) Which image(s) show HH 7-11?

   (b) (2 points) What is the name of the star that is causing the emission of HH 7-11?

   (c) (2 points) HH 7-11 seems to be aligned linearly in the sky. What does this indicate about the source star?

   (d) (2 points) The HH 7 Bow Shock in the HH 7-11 system marks the end of what?

   (e) (1 point) Which of the Herbig-Haro Objects is located closest to the source star?

8. (a) (1 point) What image shows TW Hya?

   (b) (1 point) TW Hya is significant for being the closest what?

   (c) (1 point) TW Hya is not yet a main sequence star. If it were to become a main sequence star, what would its spectral classification be?

   (d) (1 point) Surprisingly, in 2016, an organic chemical essential to life was detected in TW Hya's debris disk. What was the chemical?

9. (a) (1 point) What images show 2M 1207?

   (b) (1 point) How far apart in arcseconds is 2M 1207B from 2M 1207A? (Small Angle Formula)

   (c) (2 points) The initial distance estimate to the 2M 1207 system was 70 pc, but in 2005 a new distance estimate was given to be 53 pc using the Moving-Cluster method. Describe how this method works

   (d) (1 point) Why is that image of 2M 1207 significant?

10. (a) (1 point) Which images show WASP-43b?

    (b) (2 points) It was thought that WASP-43b's orbit was decaying. How was this disproven? What telescope disproved it?

    (c) (2 points) Given the Apparent magnitude of WASP-43 as 12.4, how many times dimmer is WASP-43 than Sirius (-1.46)?

    (d) (1 point) WASP-43 was detected using the transit method, but how was it detected again using a similar method?

    (e) (2 points) What spectral class is WASP-43? Is this star more dense or less dense than the Sun?

Section C: Astrophysics
Total of 66 Points

1. Oskar the planet orbits around Ryan the star. Ryan the star has a surface temperature of around 10,000 K and a radius of 1,638,400 km. Oskar the planet is the same size as Earth and orbits with a semi-major axis of 2 AU.

   (a) (3 points) What is the luminosity of Ryan in solar luminosities?

   (b) (3 points) At what wavelength, in nanometers, does the blackbody curve of Ryan peak? What region of the electromagnetic spectrum is this in (X-ray, ultraviolet, visible, infrared, radio)?

   (c) (5 points) What is the equilibrium temperature of Oskar, assuming full redistribution of heat around the planet and an albedo of 0.8? Would liquid water be stable on the planet, assuming that the atmospheric surface pressure of Oskar is equal to that of Earth?

2. The star Sirius lies 2.64 pc away from Earth. The orbits of Sirius A and Sirius B vary from 3" to 11". The orbital period of the system is 50.128 years.

   (a) (5 points) What is the minimum and maximum distance (in AU) from Sirius A to B?

   (b) (3 points) What is the total mass of the Sirius Star System? (In Solar Masses)

   (c) (3 points) If the apparent magnitude of Sirius is -1.46 and the difference in brightness between Sirius A and B is 9120x, what is the apparent magnitude of Sirius B?

3. The star WASP-12 was recorded to have radial velocity amplitude of 226.5878 m/s over a period of 1.0914 days. The orbital inclination is 83.37 degrees.

   (a) (5 points) If there is suspected to be a planet around this star, what would its mass be (in kilograms)?

   (b) (5 points) Assuming the star's luminosity is evenly distributed across its surface, what is the change in apparent magnitude as the planet passes in front of the star? The radius of the planet is 1.90x the radius of Jupiter (which is $6.691 \cdot 10^7$ m) and the radius of the star is 1.657 solar radii

   (c) (3 points) If the solar luminosity of WASP-12 is 4.05x and the planet orbits at 0.0234 AU, the planet would receive how many times more flux than Earth does?

4. A binary star system in a circular orbit consisting of a K3IV star and a White Dwarf have a combined semi-major axis of 1.3 AU. The solar luminosities of the K3IV and the White Dwarf are 9.22 and 0.056 respectively. The White Dwarf is accreting mass at a rate of 10^{-6} Solar Masses a year.

   (a) (3 points) What is the combined absolute magnitude of the star system?

   (b) (5 points) If the solar masses of the K3IV and the White Dwarf are 1.7 and 1.08 respectively, how far is each star from the barycenter of the system? (In AU)

   (c) (5 points) What is the orbital velocity of each star? (In km/s)

   (d) (5 points) What is the rate of energy generation of the accreting mass onto the White Dwarf? (In Solar Masses) (Hint: Do something to the Gravitational Potential energy equation and assume distance between two stars is constant)

   (e) (5 points) What is the absolute magnitude of the system now? By what factor is this system brighter than just the White Dwarf and Primary Star with no accretion?

   (f) (3 points) How much time will it take for the White Dwarf to surpass the Chandrasekhar Limit in years?

   (g) (5 points) Because the K3IV Primary Star is losing mass, in 360,000 years, what is the combined semi-major axis of the system? How much has it changed since when we first saw the system?