Science Olympiad CSE 2022

# Astronomy C Test

# KEY

**Directions:**

- **Do not open the test until told to start!**
- **Each team will be given 50 minutes to complete the test.**
- **There are three sections: Section A (General Knowledge), ~~Section B (Deep Sky Objects)~~, and Section C (Calculations).**
- **Try to use 2-3 significant figures in calculations**
- **Good luck!**

Written by: Ethan Chen (Novi '25)

Questions? Email ethankchen6@gmail.com

# Section A (General Knowledge) (61 pt)

1. What are standard candles? (1 pt)
    a. Objects with a varying apparent magnitude
    b. Objects with a varying absolute magnitude
    c. Objects with a known apparent magnitude
    **d. Objects with a known absolute magnitude**

2. Why are standard candles so important? (1 pt)
    a. Can help determine average brightness of certain stars
    **b. Can help determine distance to objects in space**
    c. Not important in Astronomy
    d. Determines age of stars

3. Which of the following are standard candles? Select all that apply. (3 pt)
    a. Type II Supernovae
    **b. W Virginis Stars**
    **c. Type I Cepheids**
    **d. Type Ia Supernovae**

4. Where are white dwarfs found on the Hertzsprung-Russell Diagram? (1 pt)
    e. Center
    f. Top right
    g. Lower Right
    **h. Lower Left**

5. Kepler's Second Law relates what two orbital properties? (1 pt)
    a. Orbital Velocity and Orbital Period
    **b. Orbital Area and Orbital Period**
    c. Mass and Orbital Area
    d. None of the above

6. Kepler's Third Law is derived by equating what two forces? (1 pt)
    **a. Gravitational Force and Centrifugal Force**
    b. Gravitational Force and Orbital Velocity
    c. Gravitational Force and Tidal Force
    d. Centrifugal Force and Tidal Force

7. Cepheid and RR Lyrae variable stars pulsate due to what element in their stellar atmospheres? (1 pt)
    a. Hydrogen
    b. Carbon
    **c. Helium**
    d. Oxygen

8. If the said element above is more ionized, it is then more opaque, allowing less radiation to escape and absorbing more. (0.5 pt)
    **a. True**
    b. False

9. Cepheids and RR Lyrae variable stars follow what relation? (1 pt)
    a. Mass-Radius Relationship
    b. Luminosity-Mass Relationship
    c. Period-Mass Relationship
    **d. Period-Luminosity Relationship**

10. A star has a Yerkes Classification of K2 III. Using an HR Diagram, what is it's effective temperature, absolute magnitude and solar luminosity respectively? (1 pt)
    a. **4200 K, 0, 50 $L_\odot$**
    b. 5000 K, -0.4, 100 $L_\odot$
    c. 4900 K, 0.3, 40 $L_\odot$
    d. 6000 K, -2.2 , 630 $L_\odot$

11. A star has an effective temperature, absolute magnitude, solar luminosities respectively of 6500 K, 4, 5 $L_\odot$. What is the star's Yerkes Classification? (1 pt)

a. F3 IV
b. A0V
**c. F6 V**
d. F0 Ia

12. What is the average range of a period for a Type I Cepheid Variable Star? (1 pt)
    a. Few hours
    b. 1-10 Years
    c. Irregular
    **d. 1-50 Days**

13. How many times more massive are Type II Cepheids than the sun? (1 pt)
    a. 1- 20 Solar masses
    b. 1-2 Solar masses
    **c. 0.4-0.8 Solar masses**
    d. Varies widely

14. What are the end states of stars after nuclear fusion from lowest mass to highest mass. (3 pt)
    a. Black Hole, Neutron Star, White Dwarf
    b. Red Giant, Neutron Star, Black Hole, White Dwarf
    c. Red Giant, White Dwarf, Neutron Star, Black Hole
    **d. White Dwarf, Neutron Star, Black Hole**

15. What is the only way a Neutron Star can be formed? (1 pt)
    **a. Type II Supernovae**
    b. Type Ia Supernovae
    c. 2 White Dwarfs Colliding
    d. Recurrent Novae

16. What are Population I stars? (1 pt)
    **a. Metal-Rich, Younger Stars,**
    b. Metal-Rich, Older Stars

c. High-Mass, Old Stars
d. Metal-Poor, Younger Stars

17. Carbon Stars are a type of star with an abundance of carbon in the atmosphere. This is a result of what stage of stellar evolution? (1 pt)
    a. Main Sequence
    b. T-Tauri Stage
    c. Red Giant Branch
    **d. Asymptotic Giant Branch**

18. What occurs on the Asymptotic Giant Branch? (1 pt)
    a. Hydrogen begins to burn in the core
    b. Helium begins to burn in the core
    c. Hydrogen begins to burn in a shell
    **d. Helium begins to burn in a shell**

19. What happens directly before the horizontal branch of an HR diagram? (1 pt)
    **a. Helium Flash**
    b. Ignition of Hydrogen Fusion
    c. Type Ia Supernova
    d. Roche-Lobe Overflow

20. What is the minimum mass for a Core-Collapse supernovae to occur? (1 pt)
    **a. 8 Solar Masses**
    b. 2 Solar Masses
    c. 1 Solar Masses
    d. 10 Solar Masses

21. What is a Core-Collapse Supernovae called? (1 pt)
    **a. Type II Supernovae**
    b. Type Ic Supernovae
    c. Type Ia Supernovae
    d. Type III Supernovae

22. A phenomenon in Binary Star systems: Roche-Lobe Overflow, occurs at which lagrange point? (1 pt)
    a. **L1**
    b. L2
    c. L3
    d. L4

23. What could occur as a result of Roche-Lobe Overflow? Select all that apply (4 pt)
    a. **Accretion Disks**
    b. **X-ray binaries**
    c. **Decrease in Orbital Period**
    d. **Increase in Velocity**

24. What are two examples of plots astronomers use to study binary systems? Select all that apply (2 pt)
    a. HR Diagrams
    b. **Light Curves**
    c. Period-Luminosity Plots
    d. **Radial Velocity Plot**

25. The shift of wavelengths from an object orbiting another, can tell us what about the object? (1 pt)
    a. Orbital Period
    b. Semi-Major Axis
    c. **Orbital Velocity**
    d. Orbital Eccentricity

26. What is the Eddington Luminosity? (1 pt)
    a. Maximum luminosity of a White Dwarf in equilibrium
    b. Maximum luminosity of a Neutron Star in equilibrium
    c. **Maximum luminosity of a Star in equilibrium**
    d. None of the Above

27. What is the average absolute magnitude of a Type Ia Supernovae? (1 pt)
    **a. -19.3**
    b. 4.84
    c. -15
    d. 0

28. The radius of a White Dwarf gets bigger as mass increases (0.5 pt)
    a. True
    **b. False**

29. The capture of the accretion stream in a magnetic cataclysmic variable is known as? (1 pt)
    a. Shocking
    **b. Threading**
    c. Accretion
    d. Capture

30. Identify what letter RR Lyrae Variables would be found in the HR Diagram below. (1 pt)
    a. D
    b. E
    c. F
    d. B
    e. A

31. Explain how a Type Ia Supernovae Occurs (5 pt)

**White Dwarf with a companion main sequence star. MS Star evolves off the Main sequence and swells into a giant star, then it fills its roche lobe and any mass that passes over the roche lobe, accretes onto the White Dwarf. Once the White Dwarf passes the Chandrasekhar Limit, it explodes in a Type Ia Supernova.**

32. Explain the Kappa-Mechanism for Pulsating Variable stars, include the relationship between opacity and ionization of helium. (6 pt)

**When the star is at its lowest brightness, it is also at its lowest radii. The Helium in the atmosphere at that point is ionized, so it traps radiation, heating the star. As the helium atmosphere traps radiation, the star expands. As the star expands it cools, and the helium does not become ionized. The star then releases radiation, and contracts, restarting the cycle.**

33. T-Tauri Stars, a pre-main sequence "star" , is not powered by nuclear fusion. Yet they are still brighter and larger than a main sequence star, why? (4 pt)

**T-Tauri "Stars" are powered by the release of gravitational potential energy, as it contracts towards the Main Sequence, until hydrogen fusion starts in the core.**

34. Explain why Red Giants are cooler than Main Sequence stars (4 pt)

**As the star moves off the main sequence, the core runs out of hydrogen to burn. The core contracts, as it cannot support the pressure against gravity, but the contraction only causes the remaining hydrogen to burn even faster. The extra energy from the contraction heats the outer layers, causing them to expand, and then cool as surface area increases.**

35. Explain how a Novae occurs and the difference between Classical and Recurrent Novae (5 pt)

**Similar to Type Ia Supernovae, a White Dwarf accretes mass into a hydrogen atmosphere. As more matter is accreted onto the WD, temperature rises, and when a critical temperature of 20 million Kelvin is reached, thermonuclear fusion ignites the hydrogen, blasting it off the surface, and increasing luminosity by a thousand factors.**

**Classical Novae are just like as explained above, while Recurrent Novae repeat this process, again feeding off the mass of the primary**

# Section C (Calculations) (65 pt)

1. O Class Main Sequence Stars are among the largest stars in the universe, with luminosities hundreds of thousands of times larger than the sun.

    a. An Astronomer observes such a star, and observes an apparent magnitude of 13.7, peak wavelength of 80 nm with a radius of 0.079808 AU. What is the distance to the star in kpc? (3 pt)

**402 $\pm$ 10 kpc**

    b. There appears to be a lot of interstellar material in the direction of the star. Due to interstellar extinction (interstellar reddening), the distance above is inaccurate due to the dust in the interstellar medium. Given a extinction rate of 9.3 $\frac{mag}{kpc}$, calculate the adjusted distance in kpc. (5 pt)

**400 $\pm$ 10 kpc**

    c. Calculate the mass and main sequence lifetime of the star in solar masses and myr respectively. (5 pt)

**41.4457 $\pm$ 3 Solar Masses**

**0.904 $\pm$ 0.25 myr**

2. In 1861, a comet passed near Earth and was visible to the naked eye for 3 months. Given a semi-major axis of 55.1 AU, orbital eccentricity of 0.985, calculate the following

    a. Year of the next Perihelion (2 pt)

**$2270 \pm 5$**

b. Orbital Velocity at Perihelion(m/s) (5 pt)

**$349.9887583\ \frac{m}{s} \pm 20$**

**Using Either Vis-Viva or Kepler's 2nd Law can work**

c. Orbital velocity at Aphelion (km/s) (5 pt)

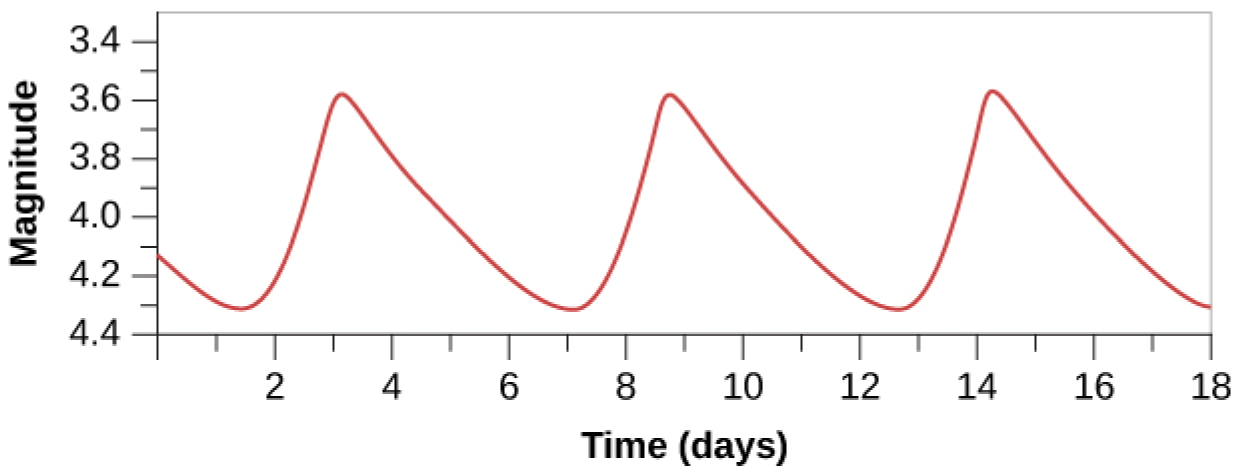
**$46.3151 \frac{km}{s} \pm 20$**

**Using Either Vis-Viva or Kepler's 2nd Law can work**

d. Apparent Magnitude of the Sun at Aphelion (3 pt)

**$-16.54478 \pm 0.25$**

3. A Type II Cepheid Variable Star is observed for 18 days, with the light curve shown below.




a. Using the formula for the average absolute magnitude of a Type II Cepheid, calculate the distance to the star in light years (5 pt)

**484.20879 ly $\pm$ 15**

b. If the star pulsates between a peak wavelength of 828.571 nm and 690.476 nm, using its average absolute magnitude, how much does the radii of the star change? (6 pt)

**18.56481 R☉ $\pm$ 1**

4. 42 pc away, we observe a binary star system with a smaller companion in a circular orbit, and a main sequence companion. The system has a period of 16 days, inclination of 82° with an angular separation of 7.152 mas.

   a. Find the total mass of the system. (Hint: Adjust for inclination!) (6 pt)

      **14.4694±0.25 Solar Masses**

   b. A star has an observed radial velocity of $50 \frac{km}{s}$. What is the mass of this star? (10 pt)

      **10.934±0.25 Solar Masses**

   c. What is the semi major axis of the smaller star in meters? (4 pt)

      **3.41193 ∗ 10e10 meters (any close answer is good)**

   d. Using the Roche Limit formula below, determine if the secondary star will accrete mass from the primary. Assume the density of star 1 to be $49 \frac{kg}{m^3}$ and the secondary to be $240.5 \frac{kg}{m^3}$ and the radius of the primary to be 6.775 solar radii (6 pt)

$$d = \left(\frac{2p_1 R_1^3}{p_2}\right)^{1/3}$$

**3.49 * 10e9 meters is smaller than the separation of 0.3 AU, so no.**