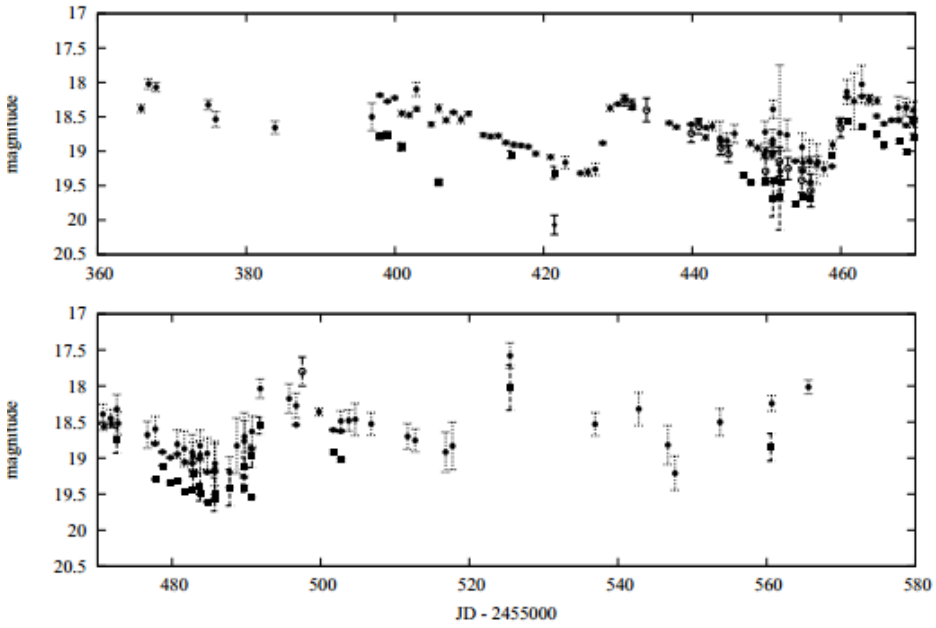
Tie-breaker: 11,000 m/s (https://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=2006-001A)

Use the diagram below to answer the next several questions.



1. This is a light curve for what type of variable star?
   - **A. Cepheid**
   - B. Semiregular variable
   - C. Luminous blue variable
   - D. Wolf-Rayet star
   - E. Pulsar
   - F. Magnetar
   - G. Eclipsing binary
   - H. X-ray binary
   - I. Gamma-ray binary
   - J. Type II supernova
2. What is the period of this variable star?
   - A. 20 days
   - **B. 31 days**
   - C. 40 days
   - D. 62 days
   - E. 100 days
   - F. 360 days
   - G. 395 days
   - H. 580 days
   - I. Cannot be determined
3. What is the absolute magnitude of this star?
   Use: $M=-2.8\log_{10}T-1.43$ T is period
   - A. -24.0
   - B. -18.7
   - **C. -5.6**
   - D. -4.1
   - E. -2.3
   - F. 17.5
   - G. 18.7
   - H. 20.0
   - I. 24.0
   - J. Cannot be determined
4. What is the distance to this star in light years?
   Use: $m-M=5\log_{10}(d)-5$ d is in parsecs, M is absolute magnitude, m is apparent magnitude
   - A. 5.6 light years
   - B. 21.5 light years
   - C. 350 light years
   - D. 1.14×10^3 light years
   - E. 1.36×10^4 light years
   - F. 1.56×10^4 light years
   - G. 6.6×10^5 light years
   - **H. 2.2×10^6 light years**
   - I. 3.26×10^7 light years
   - J. Cannot be determined

Answer the next 6 questions about the second brightest star in the constellation Orion.

5. What is the common name for the second brightest star in the constellation Orion?
    A. Rigel
    B. Bellatrix
    C. Alnilam
    D. Betelgeuse
    E. Mintaka
    F. Alnitak
    G. Sirius
    H. Aldebaran
6. Give the Bayer designation of this star.
    A. Alpha Orionis
    B. Beta Orionis
    C. HR 5171 A
    D. NGC 6357
    E. SN 1987A
    F. RCW 103
    G. S Doradus
7. What type of variable is this star?
    A. Cephied
    B. Semiregular variable
    C. Luminous blue variable
    D. Wolf-Rayet star
    E. Pulsar
    F. Magnetar
    G. Eclipsing binary
    H. X-ray binary
    I. Gamma-ray binary
    J. Type II supernova
8. What is the star's eventual fate?
    A. Type I supernova and then white dwarf
    B. Type I supernova with nothing left behind
    C. Type I supernova and the neutron star
    D. Type I supernova and then black hole
    E. Type II supernova and then white dwarf
    F. Type II supernova with nothing left behind
    G. Type II supernova and then neutron star
    H. Type II supernova and then black hole
9. This star is (pick the closest):
    A. 1 million years old
    B. 10 million years old
    C. 100 million years old
    D. 1 billion years old
    E. 10 billion years old
10. How much longer will this star "live" (pick the closest):
    A. 1 million years or less
    B. 10 million years or less
    C. 100 million years or less
    D. 1 billion years or less
    E. 10 billion years or less

Use Object A on the picture sheet to answer the following FOUR questions

11. What type of object is this?
    A. HII region
    B. Planetary nebula
    C. Supernova remnant
    D. Wolf-Rayet Star
    E. None of the above

12. What is the name of this object?
    A. RCW 103
    B. IC 443
    C. Alpha Orionis
    D. Geminga
    E. NGC 6357
    F. HR 5171
    G. PSR B0355+54
    H. AG Carinae
    I. S Doradus
    J. None of the above

13. What type of object(s) is/are at the center of this picture?
    A. White dwarf
    B. Black Hole
    C. Magnetar
    D. Hypergiant
    E. Gamma-ray binary system
    F. Several large young stars
    G. Nothing

14. What is surprising about this object?
    A. It is much dimmer than expected
    B. It is much brighter than expected
    C. It is spinning much slower than expected
    D. It is spinning much faster than expected
    E. It contains many more stars than expected
    F. It contains far fewer stars than expected
    G. It is much hotter than expected
    H. It is much cooler than expected

Use Object B on the picture sheet to answer the following THREE Questions

15. What type of object is this?
    A. HII Region
    B. Planetary nebula
    C. Supernova remnant
    D. Wolf-Rayet Star
    E. None of the above

16. What type of object(s) is/are at the center of this picture?
    A. Eclipsing binary system
    B. Black Hole
    C. Magnetar
    D. Hypergiant
    E. Gamma-ray binary system
    F. Several large young stars
    G. Nothing

17. What is the name of this object?
    A. RCW 103
    B. IC 443
    C. Alpha Orionis
    D. Geminga
    E. NGC 6357
    F. HR 5171
    G. PSR B0355+54
    H. AG Carinae
    I. S Doradus
    J. None of the above

Use Object C on the picture sheet to answer the following FOUR questions

*****TIE BREAKER*** 1 point for each answer**

18. What type of object is this?
    A. HII region
    B. Planetary nebula
    C. Supernova remnant
    D. Wolf-Rayet Star
    E. None of the above

19. What is the name of this object?
    A. RCW 103
    B. IC 443
    C. Alpha Orionis
    D. Geminga
    E. NGC 6357
    F. HR 5171
    G. PSR B0355+54
    H. AG Carinae
    I. S Doradus
    J. None of the above

20. What type of object(s) is/are at the center of this picture?
    A. Eclipsing binary system
    B. Black Hole
    C. Magnetar
    D. Hypergiant
    E. Gamma-ray binary system
    F. Several large young stars
    G. Nothing

21. What is surprising about this object?
    A. It is much dimmer than expected
    B. It is much brighter than expected
    C. It is spinning much slower than expected
    D. It is spinning much faster than expected
    E. It contains many more stars than expected
    F. It contains far fewer stars than expected
    G. It is much hotter than expected
    H. It is much cooler than expected

22. Geminga and PSR B0355+54 are both:
    A. Hypergiants
    B. Black holes
    C. White dwarfs
    D. Pulsars
    E. Wolf-Rayet stars
    F. Gamma-ray binary systems
    G. Planetary nebula
    H. HII regions
    I. Cepheid variables
    J. None of the above

23. Which option below explains why we see gamma ray emission from Geminga and radio emission from PSR B0355?
    A. Geminga has its torus pointing toward Earth and so we see gamma ray emission but not radio emission, while PSR B0355 has its poles pointing toward Earth and the torus pointing away and so we see radio emission instead of gamma ray emission.

B. Geminga has an accretion disk that periodically novas producing gamma ray bursts while BSR B0355 contains many complex molecules that emit radio waves in the star formation process.
C. Geminga has a much stronger magnetic field than PSR B0355. Gamma ray emission is produced during the intense storms in the magnetosphere of Geminga. BSR B0355 has weaker storms that produce lower energy radio emission.
D. The rate at which Geminga is spinning is faster than PSR B0355. The faster the spin the higher energy emission. Geminga rotates about 5 times per second while BSR B0355 rotates once every 6.5 hours.

Use the following information about hydrogen absorption lines in a galaxy far, far away for the next THREE questions

Absorptions lines of hydrogen, normally measured to be at 4.861 x 10^{-7} m and 6.563 x 10^{-7} m are measured in a particular galaxy to be 4.931 x 10^{-7} m and 6.658 x 10^{-7} m. Assume a Hubble Constant of 70 (km/s)/Mpc

24. What is the redshift of this galaxy?

A. 0.070
B. 0.070 x 10^{-7} m
C. 0.0141
D. 0.0144
E. 0.095
F. 0.095 x 10^{-7} m

25. How fast is this galaxy moving away from Earth?

A. 4.32 x 10^{3} km/s
B. 3 x 10^{8} km/s
C. 3.83 x 10^{3} km/s
D. 2.1 x 10^{7} km/s
E. 2.85 x 10^{7} km/s

26. How far away is this galaxy from the Earth?

A. 61.7 light years.
B. 2.01 x 10^{8} light years
C. 5.00 x 10^{5} light years
D. 1 light year
E. 12 parsec
F. 61.7 x 10^{6} light years
G. 6.31 x 10^{7} light years
H. 2.01 x 10^{9} light years

27. List the fuel in each shell of the largest and oldest multiple – shell burning super giant from the core outward. **(4 pt)** **0.5 pts each and 0.5 point for correct order**

Silicon, Magnesium, Neon, Oxygen, Carbon, Helium, Hydrogen

28. Does a 70 solar mass star or a 0.5 solar mass star live longer? Why? **(3 pt)**

    A 0.5 solar mass star lives longer because even though it has less fuel it burns it at a much slower rate.

29. Use the Period Luminosity relationship for Type I Cepheid variables determine the distance to a star that has a period of 25 days and an apparent magnitude of 4.0. (5 pts)
    0.5 points for each of the two following equations.
    Use: $M=-2.8\log_{10}T-1.43$ T is period
    AND: $m-M=5\log_{10}(d)-5$ d is in parsecs, M is absolute magnitude, m is apparent magnitude

    M=-5.34 (intermediate step, 1 point)

    d= 2400 light years or 740 parsec (FINAL ANSWER - 2 sig figs, 3 points)

30. If the star in the question above was a Type II Cepheid variable instead of a type I Cepheid, determine the distance. (4 pts)

Type II Cepheids are 1.6 magnitudes fainter
M=-5.34 +1.6 = -3.74 (intermediate step, 1 point)
d = 1200 light years or 350 parsec (FINAL ANSWER - 2 sig figs, 3 points)

31. Use the Period Luminosity relationship for Type I Cepheid variables. What is the apparent magnitude for a Cepheid variable that is 245 parsecs away and has a period of 20 days? (5 pts)
    0.5 points for each of the two following equations.
    Use: $M=-2.8\log_{10}T-1.43$ T is period
    AND: $m-M=5\log_{10}(d)-5$ d is in parsecs, M is absolute magnitude, m is apparent magnitude

M=-5.07 (intermediate step, 1 point)
m=1.9(FINAL ANSWER - 2 sig figs, 3 points)