ASTR 121
Exam I
50 points
February 28, 2006
Do not open this exam until instructed to do so.

1. General Information

WRITE your NAME on your exam booklet.

SIGN the Honor Pledge.

It is a good idea to read the entire exam, then answer first the questions you are most certain about. Do not spend time on difficult problems before answering easier ones.

The value of each part of each question is noted. Answer written questions with concise, complete sentences. Show all work for quantitative problems.

All exams will be collected at 12:15 PM. You are welcome to leave early if you finish early. If you do so, please exit as quietly as possible so as not to disturb those still working.

2. Useful Numbers

$G = 6.67 \times 10^{-11}$ m^3 s^{-2} kg^{-1}
$c = 3 \times 10^8$ m s^{-1}
$g = 9.8$ m s^{-2}
$k_B = 1.38 \times 10^{-23}$ kg m^2 s^{-2} K^{-1}
$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
1 year $= 3.16 \times 10^7$ s
1 AU $= 1.5 \times 10^8$ km
1 radian = 206,265 arcseconds (so 1 pc = 206,265 AU)
The sun is a G2 V star with surface temperature $T = 5800$ K
1 $M_\odot = 2 \times 10^{30}$ kg
1 $L_\odot = 4 \times 10^{26}$ W
1 $R_\odot = 7 \times 10^5$ km
Bolometric solar absolute magnitude: $M_{\odot,bol} = 4.74$

3. General Knowledge Questions

1. (2 points) Give the sequence of spectral types in the usual order.

2. (2 points) What distinguishes MK type **I** stars from type **V** stars? Address both the spectral indication and the physical difference.

3. (9 points) Describe the evolution of a 1 $M_\odot$ star from the main sequence to its death. Sketch the structure of the star at each stage.

4. (2 points) Massive stars are rare. Imagine if stars of $M > 8M_\odot$ never formed at all. What consequence would this have for life as we know it?
   (Hint: think about what your body needs to function.)

5. (2 points) Consider two stars with apparent magnitudes $m_1 = 3$ and $m_2 = 4$.
   Which is brighter?
   Suppose they are both G2 **V** stars. Which is closer?

6. (2 points) We would like to harness the power of fusion to supply our energy needs. The CNO cycle is the most efficient method stars use to convert H to He. Does the CNO cycle seem like a promising approach for a terrestrial reactor? Why?

7. (7 points) Sketch an H-R diagram. Label the axes and the various branches occupied by stars.

8. (2 points) Why is there an abundance difference between elements with odd and even atomic numbers?

9. (1 point) What property of stars determines where they reside along the main sequence?

4. Quantitative Questions

10. (5 pts) Binary Star Masses

    Consider a binary system containing two main sequence stars. The brighter star is observed to have a luminosity $L = 11.3\ L_\odot$. The period and semimajor axis of the orbit are 20 years and 10 AU.
    Determine the mass of each star (in $M_\odot$).

11. Betelgeuse — biggest star in the sky?

    The bright red star Betelgeuse in the constellation Orion is a type M2 **I**ab supergiant (surface T = 3600 K). It has a parallax $p = 0.0076''$ and a bolometric apparent magnitude of -1.6.

    a) (1 points) How far away is Betelgeuse?

    b) (2 points) What is the bolometric absolute magnitude of Betelgeuse?

    c) (2 points) What is the luminosity of Betelgeuse (in solar luminosities)?

    d) (2 points) What is the radius of Betelgeuse?
    How does this compare with the size of our solar system?
    (Mars orbits at 1.5 AU; Jupiter at 5.2 AU.)

12. Sirius

    The bright star Sirius has a mass of 2 $M_\odot$.

    a) (1 points) What is the luminosity of Sirius?

    b) (2 points) What is the main sequence lifetime of Sirius?
    Assume the sun will live 12 Gyr.

    c) (3 points) A star like Sirius will exist as a red giant for a period that is 7% of its main sequence lifetime. Suppose its average luminosity during the red giant phase is 200 $L_\odot$.
    During which phase of life will Sirius produce more energy?

13. (3 points) Wolf 359[1]

    The nearby M6 **V** star Wolf 359 has a parallax of $0.419''$, a proper motion of $4.696''$/yr, and a radial velocity of 14.9 km/s.
    What is its space velocity?

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[1] Fans of Star Trek will recognize this star as the location of the battle where the Borg defeated StarFleet in *The Next Generation*.