Table 1 The 8 stages in the life of the sun. The size is relative to its size at present. Abbreviations: M for million ($10^6$) and B for billion ($10^9$). Read section 17.3 of the textbook.

| | | *Lifetime* | *Temperature* | | *Radius* |
|---|---|---|---|---|---|
| | | | *Center* | *Surface* | |
| 1 | Interstellar Cloud | 0.1Myr | 10K | 10K | $10^8$ |
| 2 | Protostar | 10Myr | 1MK | 4000K | 6 |
| 3 | Main-sequence Star | 10Byr | 15MK | 5600K | 1 |
| 4 | Red Giant | 1.3Byr | 50MK | 3000–5000K | 3–100 |
| 5 | Helium Burning Star | 100Myr | 200MK | 5000K | 10 |
| 6 | Double Shell-burning Red Giant | 20Myr | 250MK | 3000–5000K | 3–500 |
| 7 | Planetary Nebula | 0.1Myr | | 3000K | 1000 |
| | Star in center | | 300MK | 100,000K | 0.01 |
| 8 | White Dwarf (newly formed) | | 200MK | 50,000K | 0.01 |

1. The solar system including the sun is 4.6 billion year old. Consider a carbon nucleus that eventually became part of my hand. That nucleus existed before the sun formed.
    a. (3 pts.) Describe a possible environment of that carbon nucleus 1 billion years ago.
    b. (3 pts.) Describe a possible environment of that carbon nucleus 5 billion years ago.
    c. (3 pts.) Describe a possible environment of that carbon nucleus 8 billion years from now when the sun is gone.
2. The Life of the Sun.
    a. (2 pts.) Why is no lifetime given for the white dwarf stage?
    b. (2 pts.) Why is the central temperature of stages 4, 5, and 6 hotter than that of the present sun?
    c. (2 pts.) For which stages will the earth be inside the sun? (The earth is 100 solar radii from the sun.) The answer changes over the course of some stages.
    d. Construct (10 pts.) a timeline of the sun from its time as an interstellar cloud to its end as a white dwarf. Include the stages in the table. Use a scale for which 100 million years is one cm. You will have to draw some parts of the timeline on your paper with a compressed scale. Indicate (1 pt.) where the sun is at the present. Indicate (1 pt.) where the earth was born.
    e. (6 pts.) For stages 2-7, how is the sun producing energy?
    f. (4 pts.) Simplicio reasons, “For stage 8, the sun has run out of fuel to burn. Therefore it will not produce any light.” Correct Simplicio’s misconception, and explain to him why he is wrong.
3. The present distance to Hoag’s Object is 300 Mpc, and its speed is 18,000 km/s. For Hubble’s constant, use the value 60 km/s/Mpc, which is equal to 0.061/Byr? A Mpc is $3.1\times10^{19}$ km. A year is $3\times10^{16}$ s.

a. (3 pts.) Three billion years ago, Hoag's Object was moving away from us at about the same speed. What is the reason for that?

b. (3 pts.) How far from us was Hoag's Object at that time?

c. (3 pts.) What was the value of Hubble's constant at that time?

4. Simplicio reasons, "The universe is expanding. Hoag's object and the solar system, being part of the universe, are expanding too. Therefore the earth is steadily moving away from the sun, and Hoag's object is steadily moving away from us, and Hoag's object is getting bigger."

a. (4 pts.) Modify Simplicio's statement so that it is correct.

b. (4 pts.) What is the root cause of Simplicio's misconception?