Except for questions 26 and 40 marks/answers on these sheets are not graded.

Answer *TRUE* or *FALSE* (<u>not</u> *T* or *F*) (2 pts each)

1. While it would be a slow, cold process, measuring a star's parallax from Pluto would produce a larger parallax angle than on Earth.
2. Star α and star β have the same mass, but star α has twice the radius and half the surface temperature of star β. We can conclude that these two stars have different chemical compositions.
3. Under the conditions described above, the big cool star (α) will be more luminous than the hot small star (β).
4. As a *protostar* the Sun started cooler and more luminous than it is today.
5. The Sun is slightly brighter today than it was a billion years ago.
6. *Planetary nebulae* are produced by young stars just starting to to produce a disk that will end up as planets.
7. HII is ionized hydrogen; H_2 is molecular hydrogen; ^{2}H is heavy hydrogen (deuterium).
8. HII regions are detected by the light from HI.
9. Stars are gradually polluting the ISM (interstellar medium) with metals.
10. *Dredge up*: the onion-like layers of a star are mixed by convection.
11. Regulus was born before the Sun was born.
12. In a degenerate electron gas, the electrons can have lots of kinetic energy (and hence produce high pressure) even at low temperature.
13. Other things being equal (e.g., same surface temperature), the more massive the white dwarf, the less luminous it will be.
14. *Pulsars* are stars that balloon in and out at a steady and quick rate.
15. A pulsar has been detected in the supernova remnant we call the Crab Nebula.
16. The normal-size spin and magnetic field of a star are hugely super-sized in the collapse to a neutron star: conservation laws are at work.
17. If tomorrow the Sun became a black hole, the planets would quickly be sucked into the hole.
18. Approximately speaking nothing can escape a black hole, but in fact Stephan Hawking calculated that black holes should be incandescent (but typically with so low a temperature that the light could not be detected).
19. Since *type II supernovae* (which our book calls 'core-collapse' supernovae) can produce neutron stars, we should expect them to emit lots of neutrinos.
20. *Type Ia supernovas* (which our book calls 'thermonuclear' supernovae) and novas are both thought to involve the binary companion of a white dwarf dumping material onto that white dwarf.

Give a short explanation (5 pts each)

21. Select two of the following list of stellar properties and describe how those properties could be measured from Earth: mass, radius, luminosity, temperature.

22. The following reasoning comes to an incorrect conclusion and hence must contain a logical flaw. Explain that flaw!

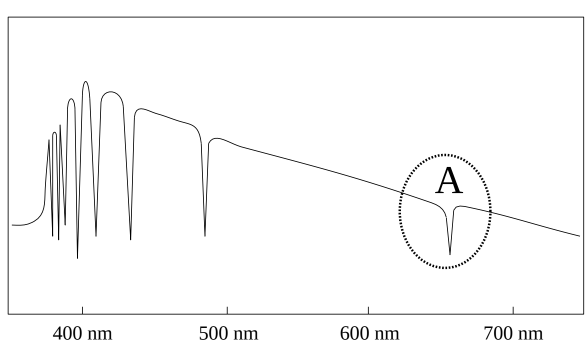
    "Stars are all made of pretty much the same stuff, and each type of stuff has characteristic absorption and emission lines, so every star's spectra has much the same set of absorption and emission lines."

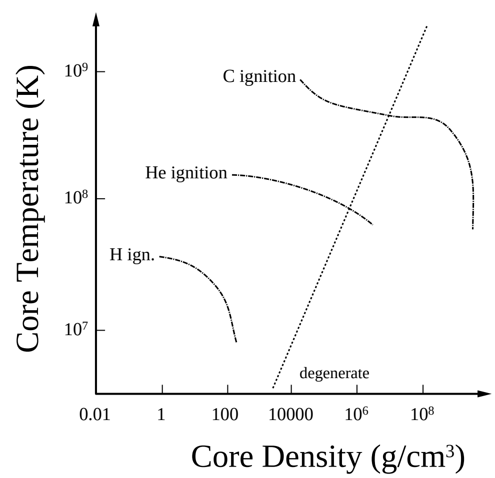
23. Consider the following list of interstellar 'clouds' discussed in class: molecular clouds, HII regions, HI clouds, 'hot vacuum'. For two of these cloud-types describe the atom-scale process that produces the light the cloud emits. That is: with what sort of light can the cloud be observed?

24. How does a white dwarf differ from a brown dwarf?

25. Where should you look to see new stars forming? What sort of telescope should you use? Why?

26. Describe (words!) how conditions at the core of the Sun change as the Sun evolves from main sequence to its final "death". Plot those conditions directly on the below right diagram.





27. The above left graph displays a somewhat simplified spectra of the A7 V star Altair. The feature labeled **A** is produced by hydrogen gas in the atmosphere of the star. Answer three of the below questions about this feature.

    (a) How would **A** change in a A7 I star?

    (b) How would **A** change if Altair were moving towards the Earth at high speed?

    (c) How would **A** change if Altair were spinning rapidly?

    (d) How would **A** change if there were fewer hydrogen atoms in Altair's atmosphere?

28. Draw a Hertzsprung-Russell diagram. Properly label axes. Show star paths (and direction) that:

    (a) show a star increasing its temperature while keeping its luminosity constant

    (b) show a star increasing its temperature while keeping its radius constant

29. In question 37, I ask you to report the evolution of the Sun. Describe briefly here how the evolution of stars much more massive than the Sun (say, 30 $M_\odot$) and stars much less massive than the Sun (say, $\frac{1}{10}$ $M_\odot$) differs from that of the Sun.

30. Sketch the HR diagram (label axes!) of an old star cluster and a young star cluster. Why the difference?

31. Our book asserts that "most of the carbon in your body was produced long ago inside a star". What is the basis of such a sweeping statement? How did those atoms get out of that star and end up here on Earth? What were those atoms doing during the billions of years before they became part of your body?

32. Name and describe two types of variable stars.

33. Describe a *pulsar*. Include: how it is formed, how it is observed, and typical radius.

34. Describe a *white dwarf*. Include: how it is formed, how it is observed, and typical radius.

35. Describe a *black hole*. Include: how it is formed, how it is observed, and typical radius.

Write out a complete answer (10 pts each)

36. Answer the following questions using the below data.

Star Name	Absolute Magnitude M_V	Apparent Magnitude m_V	Spectral Type	Luminosity Class
1. Canopus	−4.7	−0.7	F0	Ib
2. Wolf 359	16.7	13.5	M8	V
3. Gacrux	−2.5	1.6	M3	II
4. λ Ser	4.4	4.4	G0	V
5. El Nath	−1.1	1.7	B7	III
6. α UMa	−0.7	1.8	K0	III
7. α Aqr	−3.8	3.0	G2	I
8. Achernar	−2.5	0.5	B3	V
9. β Aqr	−3.5	2.9	G0	I

Which star...

(a) would look the brightest in the sky?
(b) could not be seen with the unaided eye?
(c) has the highest surface temperature?
(d) has the lowest surface temperature?
(e) has the largest radius?
(f) has the smallest radius?
(g) is furthest away?
(h) is 10 pc away?
(i) is a blue-white giant star?
(j) is most similar to the Sun?

37. A star like the Sun is believed to go through the following stages: planetary nebula, protostar, red giant, double shell burning (asymptotic giant), He flash, main sequence, and white dwarf. Describe (in words) the characteristics of each stage. Order these stages from first to last, and locate them on an HR diagram. For two of these situations draw a cross-section of the Sun displaying the internal structure. Remember to label the axes of your HR diagram!

38. I described several principles of stellar evolution including: (A) the virial theorem, (B) the Russell-Vogt theorem, (C) sequential thermonuclear fusion leading to nonburnable iron. *Define* each of the above and describe (in words!) an *example* showing its role in stellar evolution. For each example locate (with "**A**", "**B**", "**C**") either on your HR diagram for question 37 or the plot associated with question 26, where the role you described in words can be seen in action.

39. The open cluster NGC 6231 includes more than two dozen O and B stars, including the B1Ia star ζ^1 Sco. While ζ^1 is one of the most luminous stars in our Galaxy, at a magnitude of 4.7 it is just barely visible to the unaided eye. Only 0.1° from ζ^1, the star ζ^2 has an apparent magnitude 3.6 and spectral type K4III. ζ^1 Sco has an apparent color redder than the F2III star β Cas; ζ^2 Sco has an appropriate color just a bit bluer than Aldebaran. Use this information (and the following statements) to answer any **four** of the below questions.

    (a) Is ζ^1 Sco older or younger than the Sun (or is it impossible to tell with just this data)? Explain.

    (b) How would we know that ζ^1 Sco is B1Ia rather than having a spectral type similar to β Cas? (I.e., what data are used to determine spectral type?)

    (c) What could cause this inappropriate red color in what should be a blue star?

    (d) Is ζ^2 Sco also a member of the open cluster NGC 6231? Explain.

    (e) Is ζ^2 Sco older or younger than the Sun (or is it impossible to tell with just this data)? Explain.

    (f) Books report that the typical absolute magnitude of a B1Ia star like ζ^1 Sco, is $M \approx -9$. Using the apparent magnitude of 4.7, we can calculate a distance modulus corresponding to about 5,500 pc. This is probably *not* a very accurate distance to ζ^1 Sco. Why? Is the actual distance likely to be more than 5,500 pc, less than 5,500 pc, or just totally indeterminant?

40. The below diagram shows the winter hexagon. Eight of these dots represent stars you should know. Circle these "important" stars and label with the name and spectral type of the star.