Answer Key

<u>Section A:</u> Stellar Evolution and General Knowledge [50 pts.]

1. Outward pressure from nuclear fusion balances gravity. The pressure temperature thermostat from expansion and contraction maintains equilibrium.
2. Nuclear fusion
   (a) Proton-proton chain
   (b) CNO cycle
3. Asymptotic Giant Branch
4. Convection zone extends down where fusion is taking place. Fusion products are mixed into the outer layers.
5. Early AGB
6. Henyey track
7. (a) Tolman-Oppenheimer-Volkoff Limit
   (b) Upper mass boundary for neutron stars
   (c) 2-3 M_{sun}
8. (a) Eddington Limit/Luminosity
   <u>Bonus:</u>
$$L_{edd} = \frac{4\pi G M c m_p}{\sigma_T}$$
9. Temperature, rotation, magnetic field strength, composition (any combination of the previous)
10. Maximum mass for a white dwarf
11. (a) Red Giant
    (b) The helium core must be degenerate
12. States the maximum mass of a non-fusing, isothermal core that can support an enclosing envelope.
13. Type I SN do NOT have hydrogen lines while Type II do.
14. Type Ia SN
15. (a) Initial Mass Function
    (b) A function that describes the distribution of initial masses for a population of stars. Used to determine the mass distribution of a population of stars.
16. (a) Population II stars are typically older
    (b) Population II stars typically have a lower metallicity
    (c) Population II stars typically have a higher proper motion
    (d) Population II stars are typically found in globular clusters and the nucleus of a galaxy
17. (a) Red giant/supergiant with a neutron star
    <u>Bonus:</u> HV 2112 discovered in the SMC

18. (a) Supermassive black hole
    (b) Sagittarius
    (c) Sgr A*

19. (a) OBAFGKM
    Bonus: Wolf-Rayet

20. Morgan-Keenan system

21. 88

22. (a) Plank's Radiation Law
    Bonus:

$$L_\lambda = \frac{2hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1}$$

where $k = 1.38 \times 10^{-23}$ J K^{-1} and $h = 6.626 \times 10^{-34}$ J s.

23. States that the structure of a star, in hydrostatic and thermal equilibrium with all energy derived from nuclear reactions, is uniquely determined by its mass and the distribution of chemical elements throughout its interior.

24. The Kelvin-Helmholtz contraction is when the gravitational potential energy liberated by the collapse becomes the main source of the object's luminosity. This occurs for protostars reaching the main sequence (i.e. the Hayashi track).

25. (a) Forbidden spectral lines are the green tint caused by a particular electron transition in doubly ionized oxygen. Due to the structure of oxygen, it requires a very long time to remain in the higher energy state before emitting a photon and dropping back to the lower state. Only if the ion is left undisturbed during this time will we actually see forbidden lines - thus making their appearance on Earth very unlikely.
    (b) Emission nebulas emit forbidden lines due to its low density. There is plenty of time for an excited ion to emit its photon.

26. Helium white dwarfs could have resulted from a red giant in a binary system losing its outer layers to its companion, thus leaving the bare helium core. However, the distances would have to be just right for that to happen. Stars less than 0.5 M_{sun} never get hot enough to fuse helium, thus it is theorized that they would evolve into a helium white dwarf. However, the universe is not old enough for those stars to completely consume their hydrogen cores just yet.

27. Plasma

28. The expansion of space in the early universe around 10^{-36} to 10^{-32} seconds after the big bang. Explains why the universe appears isotropic.

29. (a) White dwarf and red giant companion
    (b) WR stars without their hydrogen layer
    (c) WR stars without their hydrogen and helium layers
    (d) Stars with a mass greater than 8 M_{sun}

30. For a stable, self-gravitating, spherical distribution of equal mass objects (stars, galaxies, etc), the potential energy must equal the kinetic energy, within a factor of two.

31. Eddington Valve/κ Mechanism. Proposed by Author Stanley Eddington.

32. Blazhko Effect describes the variation in period and amplitude in RR Lyrae variable stars.

<u>Section B:</u> Calculations [25 pts.]

1. 2.62 pc
2. 0.980 ± 5%
3. 37 pc
4. 80. M_{sun}
5. 65 L_{sun}
6. 10.0 ± 5%
7. 5800 ± 5% K
8. 1.593×10^6 km

<u>Section C:</u> More Math Problems [35 pts.]

1. 295 ± 10% μm
2. 1.06×10^5 ± 10% km/s
3. 7.64 ± 10% cm
4. (a) 113 ± 10% km/s away
   (b) 89.4 ± 10% km/s
   (c) 144 ± 10% km/s
5. 0.946c
6. (a) 1.44×10^{38} ± 10% kg m^2
   (b) 1.34×10^{42} ± 10% J
   (c) -8.74×10^{30} ± 10% W
   (d) Magnetic dipole radiation

<u>Bonus:</u> Johannes Kepler