Section A (65 points)

1. Iron
2. Chandrasekhar mass
3. Every type Ia supernova has the same absolute magnitude
4. Disk Instability Model and Mass Transfer Burst Model
5. Triple-alpha process
6. Globular clusters
7. Horizontal branch
8. Interstellar extinction
9. (a) Hayashi track
   (b) Hydrostatic equilibrium
   (c) Convection
   (d) Hydrogen ion
10. Decrease
11. Rate of ionization and rate of recombination
12. Gravitational contraction
13. T Tauri star
14. Extremely low gas densities
15. Blue-shifted absorption trough and red-shifted emission peak
16. Significant mass loss
17. (a) Mira variable star
    (b) Asymptotic giant branch
    (c) Number of excited pulsation modes; Miras are in one, semiregular are in 2-3
18. (a) RR Lyrae
    (b) Constant absolute magnitude and/or period-luminosity relation similar to Cepheids
    (c) Horizontal branch
19. A shell of ejected matter
20. Angular momentum
21. Magnetic flux
22. Wien's law
23. Rayleigh-Jeans law
24. Energy curve under Rayleigh-Jeans Law goes to infinity as wavelength decreases
25. Red giant
26. True
27. White dwarf
28. Yes

Section B (65 points)

1. (a) Light curve
   (b) Omicron Ceti
   (c) 90
2. (a) Image B9
   (b) W, SW
   (c) Offset between explosion and geometric center
3. (a) ASASSN-16oh
   (b) He II
   (c) 1.3
4. (a) 390-440
   (b) Counterclockwise, clockwise
   (c) Inner disk warm, low-mass companion
   (d) There has only been two observing epochs, so no trend can be concluded.
5. (a) LP 40-365
   (b) 0.28 (1/2 for 0.14)
   (c) 8.914
   (d) It is the bound remnant of a mostly disrupted white dwarf rather than the donor star.
6. (a) Image B2, B13
   (b) 1700000
   (c) Early K/late G dwarf companion, X-ray (accreting) binary system, OB stars, Wolf-Rayet stars
7. (a) V1331 Cyg
   (b) R
   (c) A distance of that length on the image corresponds to 10 arcseconds.
   (d) 449
8. (a) Jansky, $10^{-26}\,\mathrm{kg\,s^{-2}}$ (1/2 for $\mathrm{W\,m^{-2}\,Hz^{-1}}$)
   (b) Contamination by strong background cloud emission
   (c) 200, mid-far infrared (1/2 for infrared)
9. (a) Orion Nebula
   (b) Extremely variable radio sources and Trapezium stars
10. (a) Image B6
    (b) M5V
    (c) Magnetic

Section C (70 points)

1. (a) $2.54 \times 10^{-6}\,\mathrm{sr}$
   (b) $1.237 \times 10^{13}\,\mathrm{Hz}$
   (c) $1.34 \times 10^{-13}\,\mathrm{W\,m^{-2}}$
   (d) 1.86
   (e) $15.7\,\mathrm{L_\odot}$
   (f) These are from cold, dense molecular or dust clouds. They absorb the UV radiation from star-formation gas and re-emit in mid-to-far infrared.

2. (a) 8.522 kpc
   (b) $4.8\,\mathrm{R_\odot}$
   (c) $0.46\,\mathrm{M_\odot}$
   (d) The blue side limit is due to high surface temperature at which partial ionization occurs very close to the surface, limiting the pulsation. The red-side limit corresponds to strong convection effects at lower temperature that prevent pressure buildup, or countering the positive feedback from opacity mechanism.
   (e) Blazhko effect

3. (a) 0.866
   (b) WD size should be much smaller than the companion star which are typically red giants or at least much larger than earth radius. Mostly the accreting material around the WD is causing the large magnitude change. The gas transferred from the secondary star is filling the orbits around the WD, creating a shrouded region (Roche lobe) that is much bigger than the WD itself. The flare region, with denser gas (stronger influxes of gas ionized by the strong magnetic field) is potentially the main area blocking the secondary star.
   (c) M-type based on the continuum part of the spectrum.
   (d) 4.37 nm
   (e) $1.0 \times 10^{6}\,\mathrm{km}$
   (f) 0.0100 AU
   (g) $0.43\,\mathrm{M_\odot}$
   (h) $0.97\,\mathrm{M_\odot}$

4. (a) The period change is $4.43\,\mathrm{s\,yr^{-1}}$. Increasing period indicates larger radius, so it is going through the instability strip from left to right (likely for the first time, with high T_{eff}).

   (b) This is a Cepheid, and period change is $-3.10\,\mathrm{s\,yr^{-1}}$ (period getting shorter). It is going through the instability strip from right to left (likely the second or fourth crossing of the instability strip).

   (c) This is a RV Tauri star (larger amplitude, much longer period, less regular). The decreasing period is consistent with its post-red giant phase, evolving to the blue in the HR diagram.

   (d) The slope is basically e^2 so fluctuation in period is 0.7 days (Accept 0.6-0.9). This is much larger than the period change of $81\,\mathrm{s\,yr^{-1}}$ for the overall reduction of periods.