Astronomy 310 — Final Exam

1. The parallax of a star is 10 milli-arcseconds, and its apparent visual magnitude is 3.5. What is its absolute visual magnitude?
   (a) 5.5
   (b) 3.5
   (c) 1.5
   (d) -1.5
   (e) -3.5
2. A star has a radius of $3\,R_\odot$, and an effective temperature twice that of the Sun. What is its luminosity?
   (a) $1\,L_\odot$
   (b) $6\,L_\odot$
   (c) $49\,L_\odot$
   (d) $144\,L_\odot$
   (e) $256\,L_\odot$
3. Consider a binary system where the semi-major axis shrinks by a factor of two, due to tidal interactions. What is the change in the period (expressed as the ratio of the new period to the old period)?
   (a) $\frac{1}{2^{3/2}}$
   (b) $\frac{1}{2^{2/3}}$
   (c) $\frac{1}{2}$
   (d) $\frac{1}{2^3}$
   (e) $\frac{1}{3^2}$
4. In which sort of binary system can the stellar radii be determined from the light curve?
   (a) Eclipsing
   (b) Spectroscopic
   (c) Visual
   (d) Spectrum
   (e) Optical
5. What is the correct (temperature) ordering of the Harvard spectral classification system?
   (a) A-B-F-G-K-M-O
   (b) F-B-A-M-O-G-K
   (c) O-G-K-A-B-M-F
   (d) O-B-A-F-G-K-M
   (e) K-F-O-G-M-A-B
6. What equation can be used to calculate the relative number of atoms in each ionization stage of a given element?
   (a) Boltzmann
   (b) Saha
   (c) Fermi-Dirac
   (d) Planck
   (e) Bose-Einstein

7. In terms of the specific intensity I, what is the correct expression for the amount of radiation flowing per unit time, per unit solid angle through a unit area at an angle θ to the normal?
   (a) $I \sin\theta$
   (b) $I\theta$
   (c) $I \cos\theta$
   (d) $I \cos\theta \sin\theta$
   (e) I
8. A beam of radiation with specific intensity I is normally incident on an absorbing slab with optical thickness τ. What is the specific intensity of the radiation coming out of the slab?
   (a) I
   (b) $I\tau$
   (c) $I \log(\tau)$
   (d) $I \exp(\tau)$
   (e) $I \exp(-\tau)$
9. Which of these opacity sources does not depend on wavelength?
   (a) Bound-free
   (b) Bound-bound
   (c) Electron scattering
   (d) Free-free
   (e) H^-
10. Which of these mechanisms is responsible for the broad line profiles seen in white dwarf stars?
   (a) Thermal Doppler broadening
   (b) Pressure/Collisional broadening
   (c) Natural broadening
   (d) Turbulent broadening
   (e) Rotation
11. What is the curve of growth?
   (a) The increase in the radius R of a star as its mass M is increased.
   (b) The increase in the number of ionized atoms in an atmosphere as the effective temperature $T_{\rm eff}$ is increased.
   (c) The increase in the mass M of a star as it accretes from a binary companion.
   (d) The increase in the core radius R of a star as it burns fuel.
   (e) The increase of the equivalent width W of a line profile as the column density N of absorbers is increased.
12. Over what timescale does a star respond to departures from hydrostatic equilibrium?
   (a) Virial
   (b) Nuclear
   (c) Kelvin-Helmholtz
   (d) Dynamical
   (e) Thermal
13. According to the virial theorem, if a star without any nuclear reactions contracts, what must happen to the thermal energy?

(a) It must stay the same
(b) It must decrease by the change in gravitational energy
(c) It must increase by the change in gravitational energy
(d) It must decrease by half the change in gravitational energy
(e) It must increase by half the change in gravitational energy

14. If the pressure everywhere in the star follows the relation $P \propto \rho^\gamma$, for some arbitrary constant γ, what sort of structure does the star have?
    (a) Isothermal
    (b) Adiabatic
    (c) Isobaric
    (d) Polytropic
    (e) Degenerate
15. Which of these mass-fraction combinations corresponds most closely to Solar abundance?
    (a) $X = 0.7, Z = 0.02$
    (b) $X = 0.7, Z = 0.0001$
    (c) $X = 0.9$, $Z = 0.01$
    (d) $X = 0.3$, $Z = 0.002$
    (e) $X = 0.4$, $Z = 0.4$
16. In a star in thermal equilibrium, what must be true if L_r is locally constant (i.e., doesn't vary with radius)?
    (a) M_r is constant
    (b) ϵ is zero
    (c) T decreases outward
    (d) P decreases outward
    (e) $\nabla = \nabla_{\mathrm{ad}}$
17. Which of these energy transport mechanisms is *not* always operational in any given part of a star?
    (a) Conduction
    (b) Radiation
    (c) Convection
18. What happens when a star exceeds the Eddington limit at its surface?
    (a) The star collapses to a neutron star.
    (b) The star undergoes a supernova.
    (c) Convection sets in.
    (d) A magnetic field is generated.
    (e) Radiation pressure blows the surface layers off in a wind.
19. Which of these expressions is a criterion for convection to begin?
    (a) $\nabla_{\mathrm{ad}} > \nabla$
    (b) $\nabla_{\mathrm{rad}} > \nabla_{\mathrm{ad}}$
    (c) $\Gamma < 1$
    (d) $\frac{\mathrm{d}\ln T}{\mathrm{d}\ln P} > 1$
    (e) $\frac{T}{\rho^{2/3}} < 1200$

20. Which of the following elements has the largest binding energy per nucleon?

    (a) ${}^{56}_{26}\mathrm{Fe}$
    (b) ${}^{4}_{2}\mathrm{He}$
    (c) ${}^{238}_{92}\mathrm{U}$
    (d) ${}^{12}_{6}\mathrm{C}$
    (e) ${}^{56}_{28}\mathrm{Ni}$

21. What do the CNO cycle and the PP chain have in common?

    (a) Fraction of energy released as neutrinos
    (b) Rate of production of ${}^{4}_{2}\mathrm{He}$
    (c) Total rest mass / energy produced per ${}^{4}_{2}\mathrm{He}$ created
    (d) Sensitivity to temperature
    (e) Dependence on metalicity

22. According to the Vogt-Russel theorem, which two parameters uniquely determine the structure and evolution of a star?

    (a) Radius and effective temperature
    (b) Composition and radius
    (c) Luminosity and effective temperature
    (d) Mass and composition
    (e) Mass and radius

23. Put the components of the solar atmosphere in the correct in-out order

    (a) Chromosphere–corona–photosphere
    (b) Photosphere–chromosphere–corona
    (c) Corona–photosphere–chromosphere
    (d) Photosphere–corona–chromosphere
    (e) Chromosphere–photosphere–corona

24. What do the cores of low-mass and high-mass main sequence stars have in common?

    (a) Both have a uniform composition
    (b) Both are burning hydrogen
    (c) Both are convective
    (d) Both are radiative
    (e) Both are contracting

25. Which of these nuclear reactions doesn't occur during the pre-white dwarf evolution of a $1\,M_\odot$ star?

    (a) PP chain
    (b) CNO cycle
    (c) Carbon burning
    (d) Triple alpha

26. What element is enriched by incomplete CNO-cycle burning?

    (a) Hydrogen
    (b) Neon
    (c) Carbon
    (d) Nitrogen

(e) Oxygen

27. What is the reason why a $10\,M_\odot$ main-sequence star has a convective core?
    (a) The opacity is large in the core
    (b) The opacity is small in the core
    (c) The nuclear energy generation has a high temperature sensitivity
    (d) There are compositions gradients in the core
    (e) The core is contracting

28. Which of these is the principal element produced during a helium flash?
    (a) Hydrogen
    (b) Helium
    (c) Carbon
    (d) Oxygen
    (e) Silicon

29. In what evolutionary stage of a star would you expect to find an isothermal core surrounded by a hydrogen-burning shell?
    (a) After the helium flash
    (b) Shortly after the end of the main sequence
    (c) At the beginning of the main sequence
    (d) On the asymptotic giant branch
    (e) Toward the end of the main sequence

30. Where in a $1\,M_\odot$ star would you expect to find the CNO cycle occurring?
    (a) Core hydrogen burning
    (b) Core helium burning
    (c) Core carbon burning
    (d) Shell hydrogen burning
    (e) Shell helium burning

31. Stars above $\approx 1.1\,M_\odot$ evolve briefly toward higher effective temperatures at the end of their main-sequence lifetimes. What process is responsible for this blueward evolution?
    (a) Hydrogen shell ignition
    (b) Helium shell ignition
    (c) Overall Kelvin-Helmholtz contraction
    (d) Onset of convection
    (e) Core degeneracy

32. What does the Schönberg-Chandrasekhar limit correspond to?
    (a) The maximum central temperature that a convective core can have
    (b) The maximum mean density that a non-degenerate core can have
    (c) The maximum boundary pressure that an isothermal core can have
    (d) The maximum total mass that a white dwarf can have
    (e) The maximum core mass that a neutron star can have

33. What opacity source is responsible for the Hayashi line?
    (a) Bound-free

(b) Bound-bound
(c) Electron scattering
(d) Free-free
(e) H^-

34. What is always true of a star lying on the Hayashi line?
    (a) It is fully convective
    (b) it is fully radiative
    (c) It has core helium burning occurring
    (d) It has shell hydrogen burning occurring
    (e) It is losing mass
35. What physical conditions are most favorable to electron degeneracy?
    (a) Low temperature and high density
    (b) High temperature and low density
    (c) High temperature and high density
    (d) Low temperature and low density
36. What quantum-mechanical principle is responsible for electron degeneracy?
    (a) The Heisenberg uncertainty principle
    (b) Schrodinger's cat
    (c) The Pauli exclusion principle
    (d) Wigner's friend
    (e) The Einstein-Podolski-Rosen paradox
37. What is the cause of first dredge up?
    (a) Convective mixing on the asymptotic giant branch
    (b) Convective mixing on the red giant branch
    (c) Radiative levitation on the horizontal branch
    (d) Mass loss on the main sequence
    (e) Thermal pulses on the asymptotic giant branch
38. What element is typically brought to the surface during third dredge up?
    (a) Silicon
    (b) Carbon
    (c) Nitrogen
    (d) Oxygen
    (e) Neon
39. Between which two evolutionary stages (in order) does the helium flash occur?
    (a) Main sequence, red giant branch
    (b) Asymptotic giant branch, red giant branch
    (c) Horizontal branch, main sequence
    (d) Red giant branch, horizontal branch
    (e) Asymptotic giant branch, horizontal branch
40. Place the evolutionary stages in the correct order
    (a) Main sequence – red giant branch – horizontal branch – asymptotic giant branch

(b) Horizontal branch – main sequence – asymptotic giant branch – red giant branch
(c) Asymptotic giant branch – main sequence – red giant branch – horizontal branch
(d) Main sequence – horizontal branch – red giant branch – asymptotic giant branch
(e) Red giant branch – main sequence – horizontal branch – asymptotic giant branch

41. In the core of a star above $10\,M_\odot$, what happens after nuclear burning reaches ${}^{56}_{26}\mathrm{Fe}$?
   (a) It slowly cools off
   (b) It collapses
   (c) It explodes
   (d) It becomes isothermal due to conduction
   (e) It burns the ${}^{56}_{26}\mathrm{Fe}$ to make ${}^{56}_{28}\mathrm{Ni}$

42. What sorts of nuclei are produced during r-process nucleosynthesis?
   (a) Neutron-rich
   (b) Electron-rich
   (c) Low-A
   (d) Proton-rich
   (e) Low-Z

43. What element is always seen in the spectrum of a type II supernova?
   (a) Helium
   (b) Silicon
   (c) Hydrogen
   (d) Carbon
   (e) Oxygen

44. What phenomenon precedes complete envelope ejection during the final AGB phase of a low-mass star?
   (a) Core collapse
   (b) Thermal pulses
   (c) Carbon ignition
   (d) Core helium flash
   (e) Neutronization

45. During core-collapse in a high-mass star, what fraction of the energy is released as neutrinos?
   (a) 1%
   (b) 10%
   (c) 50%
   (d) 90%
   (e) 99%

46. What sort of star will the central star of a planetary nebula cool down to become?
   (a) White dwarf
   (b) Brown dwarf
   (c) Red dwarf
   (d) Neutron star
   (e) Black hole

47. Why is conduction so efficient in white dwarfs?
    (a) Lack of hydrogen/helium
    (b) Electron degeneracy
    (c) High density
    (d) High temperature
    (e) Lack of photons
48. How are type Ia supernova most likely formed?
    (a) Collapse of an accreting white dwarf
    (b) Collapse of a massive star
    (c) Merger of two black holes
    (d) Degenerate C/O ignition in an accreting white dwarf
    (e) Explosion of a quark star
49. What is the typical radius of a neutron star?
    (a) 1 km
    (b) 10 km
    (c) 100 km
    (d) 1,000 km
    (e) 10,000 km
50. Why don't free neutrons decay in neutron stars?
    (a) The temperature is too low
    (b) The strong nuclear force inhibits the decay
    (c) The decay is endothermic
    (d) All of the possible electron states are already occupied
    (e) The density is not high enough