ASTR 545
SPRING 2018
Mid-term Exam (170 Points)

1. **True/False Questions. (60 points; 4 points each)** Write a "T" following the statement if *all* the statement is true or an "F" if *any part* of the statement is false. If the statement is false, provide a brief explanation (in complete sentence form) of how/why the statement is false. Stay in the space alloted (be brief and to the point).

(a) The optical portion of a stellar continuum us known as the Balmer continuum.

(b) A K0 V star has a redder $B-V$ than a K0 Ia star by about +0.5.

(c) The AB magnitude system is based upon a theoretical source with a constant flux density, f_ν, the value of which is designed to give $V_{\rm vega} = V_{\rm AB}$ in the Johnson-Cousins photometric system.

(d) On the Strömgren system, the index c_1 is an indicator of a stars metallicity, with a value of $c_1 = 0$ for solar metallicity stars.

(e) In a given stellar atmosphere, the thermal Doppler width, $\Delta\lambda_{\rm D}$, of the Hα line will have the same value as that of the Hβ line.

(f) A bound-bound absorption process is one in which a photon changes direction after collision with a free electron, and to an excellent approximation does not change energy.

(g) The reason the continuum of an O star spectrum has the underlying shape of a blackbody spectrum is that a dominant opacity in the atmosphere is H$^-$ ion scattering, which has a cross section that is flat with wavelength.

(h) It is true that $g/g_\odot = (M/M_\odot)^\alpha (L/L_\odot)^{-\beta} (T/T_\odot)^\gamma$ for stars of any spectral class, where g is surface gravity, M is mass, L is luminosity, and where $\alpha = 1$, $\beta = 2$ and $\gamma = 4$.

(i) The ionization energy of a bound electron in a hydrogen atom is $\chi = R(1 - 1/n^2)$, where R is the Rydberg constant and n is the principle quantum number of the energy level in which the bound electron resides.

(j) For a fixed temperature, as the electron pressure increases, all ionization fractions of a given ion will decrease.

(k) The only condition for both the Boltzmann equation and the Saha equation to hold is that the gas must be in radiative equilibrium.

(l) The total Damping constant of an absorption line due to a transition from lower level "l" to upper level "u" is the sum of the Einstein A coefficients of spontaneous decay from the upper level plus the sum of the Einstein A coefficients of spontaneous decay from the lower level.

(m) One would expect that rotational broadening of absorption lines in the spectra of G, K, and M stars to be quite common, where as it would be very rare in B, A, and F stars.

(n) The bound-bound Gaunt factor, $g_{\rm II}(n)$, provides the number of possible states that an electron can occupy energy level E_n in a hydrogen atom.

(o) The total mean molecular weight in a gas depends on $\sum(x_k/A_k)$, and is independent of the ionization conditions in the gas.

2. **Multiple Choice. (50 points; 5 points each)** Mark an "X" in the best response.

(a) The Balmer decrement is due to
[ ] the ionization edge of ground state ($n = 1$) neutral hydrogen
[ ] line blending of higher order Lyman lines
[ ] the ionization edge of first excited state ($n = 2$) neutral hydrogen
[ ] line blending of higher order Balmer lines
[ ] the Ca II H-K break of cool stars

(b) As surface gravity increases, absorption line shapes change such that
[ ] the higher $\log g$, the broader the lines
[ ] the lower $\log g$, the broader the lines
[ ] the higher $\log g$, the narrower the lines
[ ] the effects of $\log g$ on line shapes is random
[ ] the line shapes aren't effected by $\log g$

(c) A given stellar spectrum has strong H Balmer lines and G-band absorption that is roughly as strong as that of the H_γ line. The spectral class of the star is roughly
[ ] A0
[ ] A5
[ ] F0
[ ] F5
[ ] G0

(d) The *natural* width of an absorption line is on the order of
[ ] 10^{-8} Å
[ ] 10^{-6} Å
[ ] 10^{-4} Å
[ ] 10^{-2} Å
[ ] 1 Å

(e) Consider an absorption line from, for example, Hα. On the flat part of the curve of growth, for a fixed equivalent width, the larger the Doppler b parameter
[ ] the smaller the columnn density will be
[ ] the larger the column density will be
[ ] the column density does not depend on b
[ ] the column density could be larger or smaller (need more information)
[ ] the narrower the absorption profile be

(f) For Vega, which is true on the Vega magnitude system
[ ] $m_U = 0$
[ ] $m_V = 0$
[ ] $m_B = 0$
[ ] $B - V = 0$
[ ] all of the above are true

(g) Consider a gas in ionization equilibrium at fixed T, P, and mass fractions. Identify the response for which it is true that *all* the listed quantities depend on the ionization conditions.
[ ] $n_{\rm N}$, $\mu_{\rm N}$, n_e, μ_e
[ ] n_k, n_{jk}, f_{jk}, n_e
[ ] $\rho_{\rm N}$, Φ_{jk}, ρ_e, μ_e
[ ] f_{jk}, n_e, μ_e, n_{jk}
[ ] ρ_e, α_k, f_{jk}, μ_e

(h) Indicate which of the following stellar property or measured value is used fo the Morgan-Keenan (MK) classification system.
[ ] mass
[ ] metallicity
[ ] relative strength/broadening of absorption lines
[ ] color index
[ ] effective temperature

(i) The type of pressure broadening the most strongly influences the shape of an Hα absorption line is
[ ] $n = 2$ linear Stark broadening
[ ] $n = 3$ resonance broadning
[ ] $n = 4$ quadratic Stark boradening
[ ] $n = 5$ damped broadening
[ ] $n = 6$ van der Waals broadning

(j) If I observe an absorption line with an unsaturated Gaussian core and Lorentzian wings, I am probably seeing ______________ on the ______________ of the cruve of growth.
[ ] a thermally broadened line; linear part
[ ] a thermally broadened line; flat part
[ ] a thermally broadened line; square root part
[ ] a thermally and pressure broadened line; linear part
[ ] a thermally and pressure broadened line; square root part

3. **Knowledge Spot Check. (60 points; 6 points each)** Provide your best answer to the following short questions. In some cases, the answer can be a direct recall; it's OK to just to give the answer (in a sentence and with units). In other cases, a short statement or calculation may be in order. You can work on scratch paper for this part, but you must provide your complete answer in the space provided, so be precise in your presentation. Do not present derivations of formulae, but do present the formulae you use, if any. Don't be overly detailed, but for full credit **be specific**.

(a) The mean free path of a photon is 2000 meters and the gas has a cross section for absorption of $\sigma = 1 \times 10^{-20}$ cm^2. What is the number density of the absorbing material?

(b) If the optical depth at wavelength λ in an absorption line is $\tau_\lambda = 2/3$ at the line center, the flux *decrement*, $1 - I_\lambda/I^0_\lambda$, at the line center is?

(c) Within an order of magnitude, the the radius, $R/R_\odot$, of an O main sequence star is? Within an order of magnitude, the the radius, $R/R_\odot$, of an M main sequence star is?

(d) The hydrogen mass fraction of a star is $X = 0.7032$ and the mass fraction of the metals is $Z = 0.0219$. What is the mass fraction of helium in this star, Y? If all the metals are iron, what are the abundance ratios, $\alpha_{\rm H}$, $\alpha_{\rm He}$, and $\alpha_{\rm Fe}$?

(e) Explain the utility of (reason for applying) the Unsöld Approximation when computing the bound-free hydrogen absorption cross section.

(f) The difference (or a condition that can be relaxed) between strict thermodynamic equilibrium and local thermodynamic equilibrium is?

(g) Explain what a Voigt profile is (what functions and what physical parameters are incorporated and how)?

(h) If $[\mathrm{X/H}] = -0.3$ is determined for a stellar atmosphere of a distant star, and the solar logarithmic abundance of X is $\hat{A}_x = 8$ on a scale where $\hat{A}_{\mathrm{H}} = 12$, what is n_x/n_{H} in the distant star?

(i) Someone measures the Balmer decrement in two A0 stars, α Sith and β Jedi. They tell you that that the decrement is stronger in β Jedi than in α Sith. Apply all you know as to what the decrement is physically dependent on, and describe the possible physical differences between α Sith and β Jedi (don't just say "X could be different", but compare the two stars and explain your reasoning).

(j) Explain/describe what free-free absorption is (draw a picture if need be). In optical and infrared spectra of stars, what is the dominant atom/ion contribution to the free-free absorption cross section? Is this most important in cool stars or hot stars? Explain your answer to the last question.