A503: Short Answer Problem Set

1. How many optically active electrons does [OIII] have? What is the electron configuration in the ground state (i.e. ns np etc.)? What are the multiplets of the ground terms (i.e. different L and S possibilities)?

2. What makes ${}^1D_2 \rightarrow {}^3P_2$ forbidden. Can this transition be seen (i.e. is it truly 'forbidden')?

3. For a neutral hydrogen gas cloud at what temperature will equal numbers of electrons be in the $n = 1$ and $n = 2$ states (assume Boltzmann equilibrium)?

4. A galaxy is measured to have the following line fluxes (Balmer lines already corrected for underlying absorption), all in units of f_λ:
   [OII] λ 3727: 1.24 $\times 10^{-16}$
   [OIII] λ 5007: 4.64 $\times 10^{-17}$
   Hα: 1.66 $\times 10^{-16}$
   Hβ: 4.92 $\times 10^{-17}$

   What is the flux of [OIII] λ 4959? Assuming Case B (Hα/H$\beta = 2.85$), use the Balmer decrement to correct all the measured line fluxes for dust [use Cardelli, Clayton & Mathis 1989, ApJ, 345, 245 to calculate k(λ) and assume R_V=3.1]. Using the R_{23} calibration of Kewley & Dopita (2003) as parameterised by Kobulnicky & Kewley (2004), astro-ph/0408128, calculate log (O/H)+12 for this galaxy (assuming a metallicity on the upper branch). What is this in solar units (state the source of your solar value)?

5. Starting from the equation given in the lecture relating N(HI) to E(B–V), derive an equation for the relation between A_{1500} (the extinction at $\lambda = 1500$Å) and N(HI) in the SMC. Use Table 1 in Pei (1992, ApJ, 395, 130) and state any assumptions you use. Comment on whether we expect DLAs (N(HI) $\geq 2 \times 10^{20}$ atoms cm^{-2}) to severely redden their background QSOs.

6. A cluster of stars has total $Q(HI) = 10^{51.4} s^{-1}$ and ionizes a region with radius R_s=200 pc. Assuming the on-the-spot approximation, what is the density of the gas? What is ξ, i.e. the ratio of N(HI):N(H) at $r = 0.5R_s$ (assume an average a_ν, ignore any optical depth from the diffuse component and assume constant densities)? What is the mass of ionized gas with R_s?

7. A quasar has a power law continuum $L_\nu = L_1(\frac{\nu}{\nu_H})^{-1.7}$, where ν_H corresponds to the ionization potential of HI. Assuming that the abundance of He is 10%:
   (a) Show that $Q(HeI) = 0.365Q(HI)$ and $Q(HeII) = 0.094Q(HI)$
   (b) Write down an expression, in terms of $\alpha(HI), \alpha(HeI)$ and $\alpha(HeII)$, for $R(HeII)/R_s$ and $R(HeIII)/R_s$

8. From Allen's Astrophysical Quantities, prepare a table of the ionization potentials (in Rydbergs) of the elements C, N, O, Ne, Mg, Si and S from A I to A VIII (where they exist). For each element, mark between the ions the positions of the IPs of HI, HeI and HeII. Box the dominant ion in the HI and the HeII zones. Circle the dominant ion in the HeI, HII zone, e.g.

   Oxygen | 1.001 | 2.58 | 4.04 5.69 ...
   Put boxes around 1.001 and 4.04 and a circle around 2.58.

Total marks: 50