Nebulae: Sample exam questions

1. Distinguish between the terms natural, thermal and collisional broadening of spectral lines. Write down formulae that represent the profiles of spectral lines broadened by these processes, defining all terms that are used, and sketch the form of the spectral lines. Explain clearly how the pressure affects the relative importance of the different processes.

(15 marks)

Write down the equation of radiative transfer, and its formal solution, for radiation passing through a medium. If the source function is constant along a path through the medium, derive an expression for the emergent specific intensity.

(15 marks)

Use this result to explain why some sources display absorption line spectra, and others emission line spectra. Give one example of each.

(10 marks)

2. Define the three Einstein coefficients $A_{21}$, $B_{12}$ and $B_{21}$.

(6 marks)

Explain what is meant by the principle of detailed balance and the Boltzmann law. Hence, derive an expression for the mean intensity of radiation in thermal equilibrium in terms of the Einstein coefficients.

(12 marks)

By requiring that the expression derived above equal the Planck function at all frequencies, derive the Einstein relations between the coefficients.

(10 marks)

Two energy levels have statistical weights $g_1$ (for the lower level) and $g_2$, and populations $n_1$ and $n_2$. The frequency of a photon emitted or absorbed during a transition between them is $\nu$. At temperature $T$ what ratio between $n_1$ and $n_2$ do you expect (i) when local thermodynamic equilibrium applies, (ii) out of LTE, and (iii) in a maser source?

(12 marks)