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— Theoretical Atomic Physics —

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Winter Term

Homework (2)

Task 1: Zeeman Effect for a Hydrogen Atom

a) How many lines can be observed for an s-p transition, when a hydrogen atom is placed in a weak magnetic field. Neglect the spin of the electron.

b) How many lines can be observed for a p-d transition instead?

c) Now include the spin of the electron in your consideration. How many lines can you observe for an s-p transition (anormal Zeeman effect) in a weak magnetic field?

d) Now consider a strong magnetic field and again the s-p transition in hydrogen. How many lines are now observed?

Task 2: Stark Effect for the First Excited State of the Hydrogen Atom

a) Show that $[l_i, ri_i] = 0$. Apply this result to conclude that the matrix elements $\langle \Psi_{nlm} \,|\, z \,|\, \Psi_{n'l'm'} \rangle$ vanish when $m \neq m'$.

b) Apply degenerate (first order) perturbation theory to calculate the splitting of the $n = 2$ state of the hydrogen atom.

Task 3: Einstein Coefficients

Use Einstein's rate equation to prove the relation between the A and B coefficients

$$\frac{A_{21}}{B_{21}} = \frac{\hbar\omega^3}{\pi^2 c^3} \,.$$

Hint: The energy density is given by Planck's radiation law and the ratio between the population of two levels in thermal equilibrium is described by the Boltzmann distribution.