

Physics 4261: Homework 9 (due Apr. 3, 2017)

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9.1. **Foot 8.2 Doppler broadening** The two fine-structure components of the $2s-2p$ transition in a lithium atom (CVP Note: he refers here to ${}^7\text{Li}$) have wavelengths of 670.961 nm and 670.976 nm (in a vacuum).

- (a) (CVP) What are the levels involved in these transitions?
- (b) (original) Estimate the Doppler broadening of this line in a room-temperature vapor.
- (c) (original) Comment on the feasibility of observing the weak-field Zeeman effect in lithium. (Hint: What field would be needed to see the Zeeman effect? What defines the weak-field regime and how does this compare?)

9.2. **Foot 8.4 Hyperfine structure in laser spectroscopy**

- (a) What is the physical origin of the interaction that leads to hyperfine structure in atoms?
- (b) Show that hyperfine splittings obey an interval rule which can be expressed as

$$\Delta E_{F,F-1} = A_{nlj}F,$$

i.e. the splitting of two sub-levels is proportional to the total angular momentum quantum number F of the sub-level with larger F .

- (c) The naturally-occurring isotope of cesium (${}^{133}\text{Cs}$) has a nuclear spin of $I = 7/2$. Draw a diagram showing the hyperfine sub-levels, labelled by the appropriate quantum number(s), that arise from the $6^2S_{1/2}$ and $6^2P_{3/2}$ levels in cesium, and the allowed electric dipole transitions between them.
- (d) Explain the principle of Doppler-free saturation spectroscopy.
- (e) The figure shows the saturated absorption spectrum obtained from the $6^2S_{1/2}$ - $6^2P_{3/2}$ transition in a vapor of atomic cesium, including the cross-over resonances which occur midway between *all* pairs of transitions whose frequency separation is less than the Doppler width. The relative positions of the saturated absorption peaks within each group are given below in MHz:

A	B	C	D	E	F
0	100.7	201.5	226.5	327.2	452.9
a	b	c	d	e	f
0	75.8	151.5	176.5	252.2	353.0

Using these data and the information in the diagram, determine the extent to which the interval rule is obeyed in this case and deduce the hyperfine parameter A_{nlj} for the $6^2S_{1/2}$ and $6^2P_{3/2}$ levels.

- (f) Estimate the temperature of the cesium vapor. (The wavelength of the transition is 852 nm.)

9.3. Foot 8.8