

Lecture summary

- Class organization
- Atomic clocks
 - “Formula One”: $\frac{\delta f}{f} \propto \frac{1}{f} \cdot \frac{1}{\sqrt{N\tau T}}$
 - Allan deviation
- The hydrogen atom
 - Grotrian diagram
 - Wavenumber
 - Bohr model
 - Fundamental constants

Homework (due on 3/5)

1. Two accurate atomic clocks of the same type are mounted on two optical tables in the laboratory of Prof. David Wineland of NIST, Boulder, Colorado. Clock A is raised to be 1 m higher than Clock B. Calculate the difference in the fractional frequency ($\delta f / f$) between A and B, first, due to gravitational red shift; second, due to the time dilation effect. (Being further away from the center of the Earth, A moves slightly faster than B.)
2. Attached in the same email you may find an Excel file containing a dataset from a Ca^+ atomic clock located in the laboratory of Prof. Kelin Gao of CAS Wuhan Institute of Physics and Mathematics. Column A is the time of measurement; Column B is the measured deviation from the average value of the clock transition frequency. The clock transition is probed with a laser of 730 nm. Construct a plot of Allan variance of the fractional frequency deviation ($\delta f / f$) based on this dataset.
3. Textbook Exercise (1.2) The energy levels of one-electron atoms.
4. Textbook Exercise (1.12) Bohr theory and the Correspondence Principle.
5. Textbook Exercise (1.13) Rydberg atoms.

Study handouts:

- Grotrian diagram of the hydrogen atom
- CODATA fundamental constants

Reading Assignments:

- Optical Clocks and Relativity. C. W. Chou, D. B. Hume, T. Rosenband, and D. J. Wineland. Science **329**, 1630 (2010).
- Allan variance <http://www.allanstime.com/AllanVariance/>

- The National Institute of Standards and Technology (NIST) maintains an excellent collection of data that are relevant to this course. The database is available at: <http://www.physics.nist.gov/PhysRefData/contents.html>
- A short history of atomic physics in the twentieth century. D. Kleppner. Review of Modern Physics **71**, S78 (1999).