QFT II

homework VII (Nov. 14)

- **At the head of your report, please write your name, student ID number and a list of problems that you worked on in a report (like "II-1, II-3, IV-2").**

1. **Hyperfine structure, Lamb shift** [C or D]

   (evaluate for yourself whether your achievement is worth D or C)
   Explore as much as you like on hyperfine structure and/or Lamb shift, by reading textbooks or literatures. [Fine structure: see homework V-1] Here are some suggestions on the literature, though they will probably not be the only options.

   (a) Hyperfine structure: a book by Bethe and Salpeter, "Quantum Mechanics of One- and Two-Electrom Atoms," Springer, 1957; a free copy of the relevant part of this book seems to be available on-line as a pdf file (hosted by uni-freiburg; I wish it is a leagal copy).

   (b) Lamb shift: a combination of Landau–Lifshitz vol.4 (QED) section 123 and Peskin–Schroeder section 7.5 (eq. (7.94)) will do the job; I am not sure, though, whether sufficient attention is paid to the sign ± 1 in Landau–Lifshitz vol.4 section 123. [Bjorken Drell section 8.7 should also contain relevant discussion, though I have not taken time to see it recently.]

2. **An approximation in the Bethe-Salpeter equation** [C]

   (a) In the Bethe–Salpeter equation applied to non-relativistic systems, we often replace the propagator in the 2PI kernel K by its "approximation,"

   $$\frac{1}{(\omega'')^2 - |\vec{p}''|^2} \Rightarrow \frac{1}{-|\vec{p}''|^2}. \tag{1}$$

   Pick up a non-relativistic system of your favorite where a bound state is formed, and verify that the integral in the right-hand side of the Bethe–Salpeter equation

   $$G = (2\pi)^4 \delta^4(p - p') D_a D_b + D_a D_b \int \frac{d^4 p''}{(2\pi)^4} KG \tag{2}$$

   is dominated by a region where $(\omega'')^2 \ll |\vec{p}''|^2$.