Problem Sheet 14

Due date: 03 May 2018 **12:00**

For full credit, you should hand in a tidy and efficiently short presentation of your results and how they come about, in a manner that can be understood and reproduced by your peers. All problems and solutions are for your personal use only. Please do not pass solutions or problems on to incoming or other students who have not taken the course (yet). Noncompliance with these rules is a breach of academic integrity.
Handwritten solutions must be on 5x5 quadrille paper; electronic solutions must be in .pdf format.
I reserve the right to award zero points for any illegible, chaotic or irreproducible section of your homework.
News and .pdf-files of Problems also at home.gwu.edu/~hgrie/lectures/nupa-18I/nupa-18I.html.

1. The Pion-Nucleon Scattering Length in χEFT, Part II (**15P**): This is the second part of your "**Capstone Project**" for this course. I have outlined it in the lecture, but here are the details.

   a) (**3P**) Prove that for a spinor at rest $\gamma_0\, u[p = (M, \vec{0})] = u[p = (M, \vec{0})]$.

   b) (**5P**) Now, use these amplitudes in zero-momentum scattering $\vec{p} = \vec{k} = \vec{p}' = \vec{k}' = 0$ to derive the scattering lengths a^+ and a^-.

   c) (**3P**) What are the scattering lengths in the chiral limit, $m_\pi \to 0$? In addition, provide an intuitive reason.

   d) (**4P**) Calculate numerical values (in fm). If they agree with the LO χEFT result quoted in the lecture, you have won. If not, factors and/or signs are wrong.
   The estimate of he theoretical uncertainty alone is worth** 2.5 **points!

2. Scattering Low-Energy Neutrons on Protons (**5P**): This plot with caption from [Bürkle/ Mertens, Few-B. Sys. **22** (1997) 11] is the differential cross section for np scattering in the cm frame.

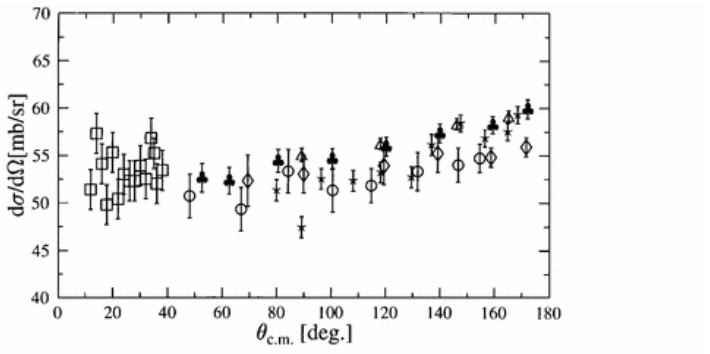

Fig. 1. Comparison of differential n-p cross-section data at 14.1 MeV: ○ J. C. Allred et al. [1]; ◇ J. D. Seagrave [2]; △ T. Nakamura [3]; □ A. Suhami et al. [4]; ⋆ I. Basar [5]; ♣ S. Shirato et al. [6]

   a) (**2P**) *From this plot*, argue why the pn potential cannot be Coulombic, $V_{np}(r) \not\propto \frac{1}{r}$.

   b) (**3P**) *From this plot*, estimate the np scattering length, i.e. the range of the interaction. Why do you not get the scattering length, $a_{np} \sim 20$fm?