HW 2:

1. What are the main areas of nuclear science?

2. Based on http://www2.lbl.gov/abc/wallchart/ answer the following questions:

   a) What is the neutron number of ^{101}Mo?
   b) What is Magnetic Resonance Imaging?
   c) What is the age and temperature of the Universe?

   Explain your answers.

Symmetry: the secret of nature

Wikipedia: A symmetry of a physical system is a physical or mathematical feature of the system (observed or intrinsic) that is preserved or remains unchanged under some transformation.

“The role of symmetry in Fundamental physics”: David Gross

http://www.pnas.org/content/93/25/14256.full

“Einstein’s great advance in 1905 was to put symmetry first, to regard the symmetry principle as the primary feature of nature that constrains the allowable dynamical laws. Thus the transformation properties of the electromagnetic field were not to be derived from Maxwell’s equations, as Lorentz did, but rather were consequences of relativistic invariance, and indeed largely dictate the form of Maxwell’s equations.”

“With the development of quantum mechanics in the 1920s symmetry principles came to play an even more fundamental role. In the latter half of the 20th century symmetry has been the most dominant concept in the exploration and formulation of the fundamental laws of physics. Today it serves as a guiding principle in the search for further unification and progress.”

The role of symmetries

- Provide conservation laws and quantum numbers. (In 1918 Emmy Noether proved her famous theorem relating symmetry and conservation laws.)
- Summarize the regularities of the laws that are independent of the specific dynamics/boundary conditions.
- The theory of representations of continuous and discrete groups plays an important role deducing the consequences of symmetry in quantum mechanics.
- Any quantum state can be written as a sum of states transforming according to *irreducible representations of the symmetry group*. These special states can be used to <u>classify</u> all the states of a system possessing symmetries and play a fundamental role in the analysis of such systems through quantum numbers and associated selection rules.
- Much of the texture of the world is due to mechanisms of <u>symmetry breaking</u>.
    - Explicit symmetry breaking (the symmetry violation as a small correction and approximate conservation laws are present)
    - Spontaneous symmetry breaking (the laws of physics are symmetric but the state of the system is not). Example: crystals (translational invariance), magnetism (rotational invariance), superconductivity (particle number). Thus for every broken global symmetry there exist fluctuations with very low energy. These appear as massless particles (Goldstone bosons).

Symmetries of the nuclear Hamiltonian
(exact or almost exact)

1. **Translational invariance**
2. **Galilean invariance (or Lorentz invariance)**
3. **Rotational invariance**
4. Time reversal
5. Parity (space reflection)
6. Charge independence and isobaric symmetry
7. Baryon and lepton number symmetry
8. Permutation between the two nucleons (imposed by the exclusion principle)

Continuous transformations (appear to be universally valid) — items 1–3

Dynamical symmetries
Apply in certain cases, provide useful coupling schemes

1. Chiral symmetry (broken by a quark condensate; valid for massless quarks)
2. SU(4) symmetry (Wigner supermultiplet)
3. SU(2) symmetry (seniority)

Local symmetries (important for gauge theories)
Different transformations at different points of spacetime