Physics 418, Homework Assignment
Due in Class, Wednesday, February 4, 2004

1. Isaac Asimov in his novel *The Gods Themselves* describes a universe where the most stable nuclide with A=186 is **not** $^{186}_{74}$W but rather $^{186}_{94}$Pu. This is claimed to be a consequence of the ratio of the strengths of the strong and electromagnetic interactions being different from that in our universe. Assume that only the electromagnetic coupling constant, α, differs and that both the strong interaction and the nucleon masses are unchanged. How large must α be in order that $^{186}_{82}$Pu, $^{186}_{88}$Pu and $^{186}_{94}$Pu are stable?

2. In the Liquid Drop Model, the binding energy for nuclei is:

$$\mathrm{B(Z,A) = a_vA - a_sA^{2/3} - a_c\frac{Z^2}{A^{1/3}} - a_a\frac{(A-2Z)^2}{A}} + \frac{\delta}{\mathrm{A}^{1/2}}$$

The Coulomb term in the semi-empirical mass formula (aka. liquid drop model) is $a_cZ^2/A^{\frac{1}{3}}$. Try to estimate the value of a_c with simple electrostatics. First, show that the potential energy due to electrostatic forces on a uniformly charged shpere of total charge Q and radius R is $3Q^2/(20\pi\epsilon_0 R)$. Estimate a_c by using $R = 1.25 \times A^{\frac{1}{3}}$, the values for a_v, a_s, a_a given in lecture, and the binding energy (not mass!) of $^{184}_{74}$W. For the binding energy, use the value given in: **http://atom.kaeri.re.kr/ton/**.

3. The α-decay of a ^{238}Pu (τ = 127 years) nuclide into a long-lived ^{234}U (τ = 3.5 x 10^5 years) daughter nucleus releases 5.49 MeV kinetic energy. The heat so produced can be converted into useful electricity by radio-thermal generators (RTG's). The *Voyager 2* space probe, launched 20-Aug-1977, flew past four planets, including Saturn, which it reached on 26-Aug-1981. Saturn's separation from the Sun is 9.5 AU (1 AU = Earth-Sun distance).

   - How much plutonium would an RTG on Voyager 2 have to carry in order to deliver at least 400 W electrical power when the probe flies past Saturn? Assume a power conversion efficiency of 6.2%.
   - How much electric power would then be available at Neptune, 30.1 AU from the Sun, on 24-Aug-1989?
   - For comparison: the largest-ever "solar paddles" used in the space laboratory *Skylab* would have produced 10.5 kW from an area of 730 m^2, 1 AU from the Sun. What area of solar cells would *Voyager 2* have needed if those were its power source?

4. Griffiths: Problem 1-3.

5. Fraunhofer diffraction by a circular disk with diameter D produces a ring-shaped diffraction pattern with the first minimun at an angle $\theta = 1.22\lambda/D$. Calculate the angular separation of the diffraction minima of α particles with energy E_{kin} = 130 MeV scattered of a ^{59}Co nucleus. The nucleus should be considered as an impenetrable disk.