Problem Set 2
Nuclear Physics 2005, by Armin Reichold
This draws on lectures 3 to 6 discussing β-decays and crossections

Q1 [Energetics of β-decay, finals 1975 Q7]

1. Explain briefly how it is possible that energy can be released both in the fusion of light nuclei and in the fission of heavy nuclei.
2. What is β-decay? What considerations determine whether or not a given nuclide in its ground state is β-active and, if so whether it will emit positively or negatively charged "β-particles"?
3. The maximum β-particle energy observed in the decay of ^3H is 18.61 keV. Making clear any assumptions you make, deduce the difference between the atomic masses of ^3H and ^3He.

Q2. [Crossections, finals 1996, Q4]
The formula $R = r_0 A^{1/3}$, where A is the nucleon number and r_0 is a constant, is used when an approximate value of the nuclear radius (R) is required. What is the justification for this formula? *(5 points)*

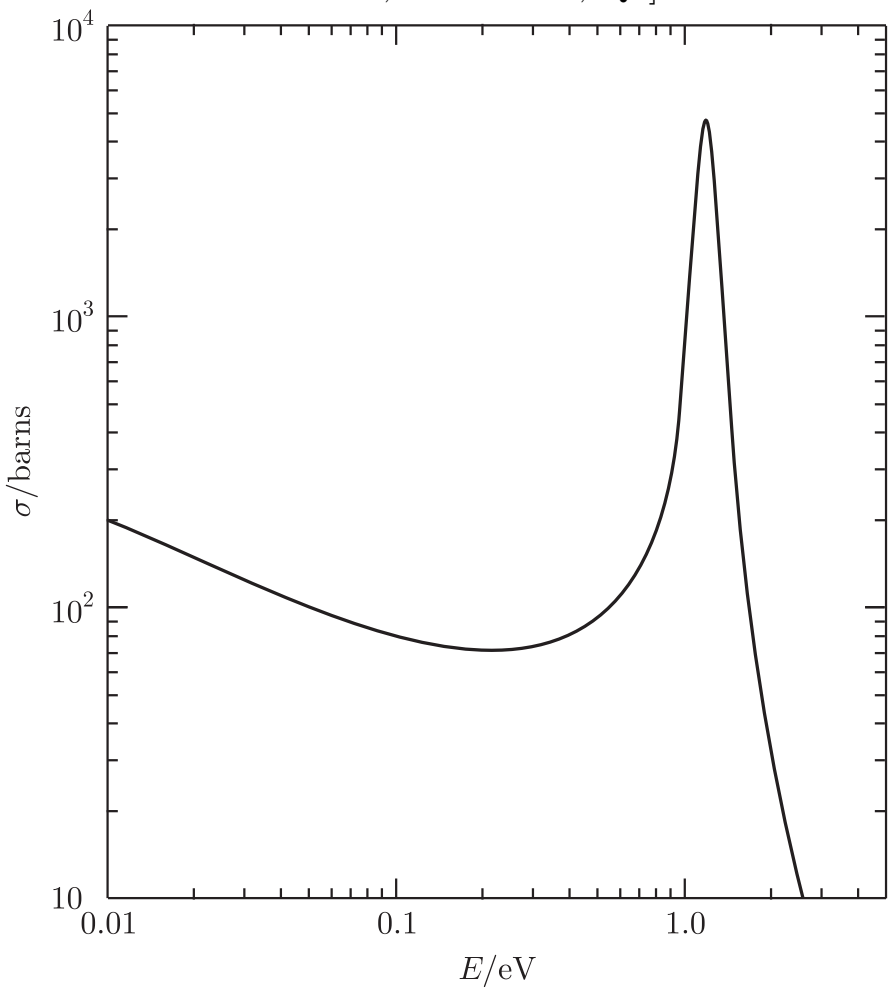
A beam of 20 MeV neutrons impinges at normal incidence on a 20 mm thick sheet of lead, ^{208}Pb. Discuss qualitatively the processes that you expect to occur in the nucleus. Make an approximate calculation of the fraction of the incident beam that interacts in the sheet. State your assumptions. *(10 points)*

Suggest a projectile which, when collided with $^7_3$Li could produce a beam of neutrons with energies above 10 MeV. Why is $^7_3$Li a good target material for this reaction? *(5 points)*

Indicate what kinds of experiments provide information about the spatial distribution of protons and neutrons in nuclei. *(5 points)*

[Density of ^{208}Pb is 11350 kg m^{-3}; $r_0 = 1.3 \times 10^{-15}$ m.]

Q3. [Crossections and Resonances, finals 1999, Q1]



The figure shows a plot of the absorption cross section for neutrons incident on rhodium (^{103}Rh) nuclei as a function of energy. Give an explanation of the shape of the curve. Estimate the mean lifetime of the relevant nuclear state. (*10 points)*

A beam of neutrons of energy 0.5 eV is incident on a rhodium target of density 12 400 kg m^{-3}. Estimate the mean free path of neutrons in the target, neglecting contributions from any other process. (*5 points)*

What radiation would you expect to be emitted in the neutron absorption process? What is the maximum energy of this radiation? How could it be measured? *(10 points)*

[The mass defect of ^{103}Rh is -0.094489 u, of ^{104}Rh is -0.093341 u, of ^{1}n is 0.008665 u.]