Massachusetts Institute of Technology

Department of Physics

Course: 8.701 — Introduction to Nuclear and Particle Physics
Term: Fall 2020
Instructor: Markus Klute

Problem Set 6
handed out November 20th, 2020

Problem 1:   Nuclear Fission Reactor [20 points]

Describe briefly the type of reaction on which a nuclear fission reactor operates.

Why is energy released, and roughly how much per reaction?

Why are the reaction products radioactive?

What is the role of a moderator?

Are light or heavy elements preferred for moderators, and why?

Problem 2:   Nuclear Fusion [20 points]

Give the three nuclear reactions currently considered for controlled thermonuclear fusion.

Which has the largest cross section?

Give the approximate energy released in the reactions.

Problem 3: Deuteron [20 points]

A neutron and a proton can undergo radioactive capture at rest: $p+n \to d+\gamma$. Find the energy of the photon emitted in this capture process. Is the recoil of the deuteron important?

Problem 4: Interaction of photons with matter [20 points]

Discuss the interaction of photons with matter for energies less than 10 MeV. List the types of interaction that are important in this energy range. Describe the physics of each interaction and sketch the relative contribution of each type of interaction to the total cross section as a function of energy. Note: we will discuss this topic in the week after Thanksgiving. You can prepare by reading the particle data group review on interaction of particles with matter.

Problem 5: Proton decay [20 points]

The possible radioactive decay of the proton can be tested in a very large reservoir of water instrumented with devices to detect Cerenkov radiation produced by the products of the proton decay.

Suppose that you have built a reservoir with 10000 metric tons of water. If the proton mean life time τ_p is 10^{32} years, how many decays would you expect to observe in one year? Assume that your detector is 100% efficient and that protons bound in nuclei and free protons decay at the same rate.

A possible proton decay is $p \to \pi^0 + e^+$. The neutral pion immediately (in 10^{-16}s) decays to two photons, $\pi^0 \to \gamma\gamma$. Calculate the maximum and minimum photon energies to be expected from a proton decaying at rest.

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