

## Homework 02 (25Sep23)

Name: your name

Guidance:

- Upload your answers in the Blackboard submission portal as:  
lastname-firstname-homework-xx.pdf or lastname-firstname-homework-xx.ipynb

### Table of Problems

- **Problem 1 (10 pts)** Atom density formula proof.
- **Problem 2 (10 pts)** D-He-3 fusion.
  - 2.1)(5 pts) Q value.
  - 2.2)(3 pts) Compare to D-T?
  - 2.3)(2 pts) He-3 production.
- **Problem 3 (35 pts)** UMLRR Co-60 sphere source.
  - 3.1)(5 pts) Activity.
  - 3.2)(2 pts) Mass.
  - 3.3)(5 pts) Final mass.
  - 3.4)(3 pts) Mass loss.
  - 3.5)(10 pts) Alternative mass loss.
  - 3.6)(10 pts) Electricity conversion.
- **Problem 4 (35 pts)** Production of radionuclide.
  - 4.1)(5 pts) Reaction.
  - 4.2)(10 pts) Mathematical model.
  - 4.3)(20 pts) Maximum activity.
  - 4.4)(10 pts) Maximum flux.
- **Problem 5 (10 pts)** Heat decay for 1 GW(t) operation in 1 year.
  - 5.1)(2 pts) 1 day.
  - 5.2)(2 pts) 1 month.
  - 5.3)(2 pts) 1 year.
  - 5.4)(4 pts) Repeat for 6-month operation.

### Problem 1 (10 pts)

In Problem 1 of Homework 1, you used a formula to calculate the atom density of U-235. State the formula and prove it mathematically.

### Problem 2 (10 pts)

**2.1)(5 pts)** A proposed fusion reaction is as follows:  ${}^2\text{H} + {}^3\text{He} \rightarrow {}^4\text{He} + {}^1_1\text{p}$ . Calculate the  $Q$  value of the reaction and the partition of energy of the products.

Answer:

**2.2)(3 pts)** Is this reaction a better proposition than the D-T reaction? Explain why or why not.

Explanation:

**2.3)(2 pts)** How can  ${}^3\text{He}$  be produced?

Answer:

### Problem 3 (35 pts)

The UMLRR advertised a  ${}^{60}\text{Co}$  sphere with activity  $A = 100\text{ kCi}$ .

**3.1)**(5 pts) Does the activity stay the same with time? If not, what is the value in 1 year?

Answer:

**3.2)**(2 pts) Is the mass of the sphere after 1 year more than the initial mass, less or the same? Why?

Answer:

**3.3)**(5 pts) Calculate the initial mass of the sphere and final mass after 1 year.

Answer:

**3.4)**(3 pts) Calculate the mass loss.

Answer:

**3.5)**(10 pts) Find an alternative way to calculate the mass loss and compare with 2.4).

Answer:

**3.6)**(10 pts) If the energy emitted in one year by the  $^{60}\text{Co}$  source could be converted in electricity, how long a typical residence in Massachusetts could be powered for in 2023? (assume a conversion efficiency of 20%).

Answer:

#### Problem 4 (35 pts)

A stable nuclide  $X$  is reacted with particle  $n$  (*e.g.* a neutron) to give a radionuclide  $Y$  with radioactive decay constant  $\lambda_Y$ . Denote  $c_{X0}$  as the concentration of  $X$  when the reaction starts, assume there is no  $Y$  when the reaction starts, and that  $Y$  does not react with the particle  $n$ . It is of practical interest to know the maximum activity of  $Y$  and at what time the maximum is reached. Please address the sub-items below.

**4.1)**(5 pts) Write the reaction mechanism.

Answer:

**4.2)**(10 pts) Setup the mathematical model and state your assumptions.

Answer:

**4.3)**(20 pts) Calculate the maximum activity of  $Y$  and when it occurs relative to the beginning of the reaction.

Answer:

**4.4)**(10 pts) Often times when designing the irradiation apparatus for the reaction in Problem 3.1), the particle  $n$  spatial flux magnitude is wanted for a given production activity maximum  $A_{Y,\max}$ . Derive the equation needed to find this flux value and explain how to solve it.

Answer:

#### Problem 5 (10 pts)

A nuclear fission reactor operates at a power of 1.5 GW(t) for 1 year. Calculate the heat decay power:

**5.1)**(2 pts) 1 day after shutdown.

Answer:

**5.2)**(2 pts) 1 month after shutdown.

Answer:

**5.3)**(2 pts) 1 year after shutdown.

Answer:

**5.4)**(4 pts) Repeat the above for 6 months of operation and compare results.

Answer: