MECH6003 & MECH5103
Introduction to Nuclear Engineering and Health Physics
Quiz 3
Fall 2021

Part 1: True/False statements. Designate each statement as true or false by writing a *T* or *F* beside the statement number.

1. The "front end" of the nuclear fuel cycle describes the process of converting natural uranium, as U_3O_8, into UO_2 for nuclear fuel.

2. Nuclear fuel used in the light water reactors must be enriched by about 4% in ^{235}U because the capture cross section, σ_c, of water reduces the neutron inventory.

3. The Gray is a unit of absorbed dose and is equal to 1 Joule/kg.

4. The equivalent dose is a weighted absorbed dose.

5. The risk of stochastic effects associated with exposure to radiation increase with increasing dose and have no threshold below which effects are not observed.

6. Moderation of neutron energy increases with increasing mass of the target nucleus.

7. The neutron can lose all its energy in a collision with the hydrogen nucleus.

8. Radiation weighting factors, W_r, are used to modify the absorbed dose to account for biological effectiveness.

9. The absorbed dose produced by neutron interaction in tissue is due to the direct ionization and excitation of hydrogen in tissue.

10. Most of what is known about the health effects related to radiation exposure has been derived by studies of survivors from Hiroshima and Nagasaki atomic bombs.

11. Occupational radiation exposure limits have been established to prevent deterministic effects and limit the risk of stochastic effects.

12. Cataracts and erythema (reddening of the skin) are examples of deterministic effects of radiation exposure.

13. The failure of the federal government to provide a permanent disposal site for used nuclear fuel is a combination of political and technical obstacles.

14. The heat exchanger/steam generator in a boiling water reactor (BWR) is used to convert water into steam from heat produced in the core.

15. A typical 1000 $MW_{electric}$ power plant that uses coal requires 9000 tons of coal each day while only 3 kg/day of ^{235}U is used in a 1000 $MW_{electric}$ nuclear power plant. (This is an interesting fact and Is TRUE).

16. The build-up of ^{239}Pu in nuclear fuel is a result of neutron absorption in ^{238}U.

17. Two interactions involving capture reactions of thermal neutrons in the body tissue are $^{1}H(n,\gamma)^{2}H$ and $^{14}N(n,p)^{14}C$ which represent the major source of dose from neutrons exposure.

18. The dose from a quantity of beta-emitting radioactive contamination on the skin is calculated by determining the energy deposited in the basal cells located at a density thickness $t_d = 0.007$ g/cm^2 below the surface of the skin.

19. The major source of radiation exposure to the US population is from medical procedures that involve x-rays, CAT scans, diagnostic imaging, and nuclear medicine procedures.

20. The effective half-life associated with a radioactive material deposited in an organ or tissue of the body is calculated as the sum of the radiological half-life and the biological half-life.

Part 2: Multiple Choice Questions. Circle the most appropriate choice for each question

1. Water is an important component in a nuclear reactor because
   a. it moderates neutrons to thermal energy
   b. it transfers heat from the fuel
   c. it reduces leakage of neutrons by reflecting them back into the core
   d. all the above
   e. none of the above

2. Boron is used in the core of a nuclear reactor
   a. to aid in controlling K_{eff}
   b. as a "burnable" poison in a control rod in the form of boron carbide (B_4C)
   c. as boric acid to adjust the neutron population, especially with fresh fuel
   d. all the above
   e. none of the above

3. Used nuclear fuel
   a. is stored several years at the reactor to permit decay of short-lived fission products.
   b. can be reprocessed to separate fission products from usable uranium and plutonium
   c. contains about 80% of the uranium originally in the "fresh" fuel
   d. all the above
   e. none of the above

4. Deuterium, ^2H_2O, in the CANDU reactor
   a. is used as a moderator
   b. is used as a coolant
   c. enables natural uranium to be used as the fuel
   d. all the above
   e. none of the above

5. The largest share of energy released in the fission of ^{235}U goes to
   a. gamma radiation
   b. beta particles
   c. fission fragments
   d. neutrons
   e. neutrinos

6. Absorbed dose
   a. is defined as the amount of ionization produced per unit mass of air
   b. is defined as the amount of energy deposited per unit mass and applies to any type of radiation in any absorber.
   c. is measured in Roentgens and applies only to X or γ radiation
   d is measured in ergs
   e. none of the above

7. Which of the following is NOT a source of radioactive contamination in the primary coolant of a nuclear reactor (PWR or BWR)
   a. faulty fuel cladding
   b. diffusion of fission product gases through the cladding
   c. neutron activated corrosion products such as ^{60}Co, ^{54}Mn, ^{55}Fe
   d. coffee grounds
   e. none of the above

8. The most significant component of natural background radiation is
   a. cosmic radiation
   b. radon
   c. terrestrial radiation
   d. ^{40}K
   e. all of the above

9. Radiation weighting factors, w_r
   a. were adopted to account for different biological response to different types of radiation
   b. are applied to the absorbed dose to determine equivalent dose
   c. represent the relative biological effectiveness for that type of radiation to induce stochastic effects at low doses
   d. all the above
   e. none of the above

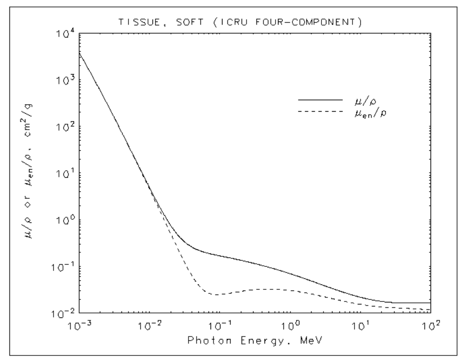
10. The fabrication of nuclear fuel
    a. involves the conversion of yellowcake (U_3O_8) into UO_2 powder that is compressed under high temperature and pressure to form ceramic pellets
    b. involves sealing pellets into long tubes of zircaloy metal to form fuel rods
    c. involves arranging about 200 fuel rods into a fuel assembly
    d. all the above
    e. none of the above

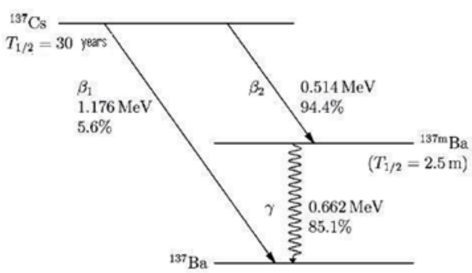
Part 3: Questions. You are required to solve questions #1 and #2. Question #3 is for extra credit.

3-1. A portion of the body receives a dose of 0.15 mGy from radiation with a radiation weighting factor W_r = 6 and 0.22 mGy from radiation with W_r = 10.

a. What is the total absorbed dose?
b. What is the total equivalent dose?

3-2. A worker receives whole body radiation exposure from a 55 x 10^{10} Bq point source of ^{137}Cs located at a distance of 10 meters. The decay scheme for ^{137}Cs shows that it decays by beta emission that is accompanied 85.1% of the time with a 0.662 MeV photon. The value of μ/ρ at 0.662 MeV is 0.08360 cm^2/g. Calculate the dose rate (Gray/hour) delivered to the worker by the source.





EXTRA CREDIT

3-3. A female worker inhales 10 Bq of ^{241}Am. The chemical form of the inhaled particles is rather soluble so that the biological half-time in the lungs is only 50 days. The weighted average alpha particle energy emitted by ^{241}Am is 5475.8 MeV. The mass of the female lung is 800 g. The radiological half-life of ^{241}Am is 432.7 y.

a. Calculate the initial absorbed dose rate to the lungs of the worker in units of Gy/day.

b. Calculate the annual (365 day) integrated absorbed dose to the lungs given that the biological half-life is 50 days.

$$\dot{D}_o = \frac{q_{Bq} \cdot E_{\frac{MeV}{dis}} \cdot 1.6x10^{-13} \frac{Joule}{MeV} \cdot 86{,}400 \frac{\sec}{day}}{M_{kg} \frac{Joule/kg}{Gy}}$$

$$D_{t=0,t=\tau} = \frac{\dot{D}_o}{\lambda_{eff}} \left(1 - e^{-\lambda_{eff}\,\tau}\right)$$

c. Calculate the 50 year integrated absorbed dose to the lungs.