NPRE412 Spring 2025
HW 11 Due 2025.04.22

- Show your work.
- This work must be submitted online as a `.pdf` through Canvas.
- Work completed with LaTeX or Jupyter earns 1 extra point. Submit source file (e.g. `.tex` or `.ipynb`) along with the `.pdf` file.
- If this work is completed with the aid of a numerical program (such as Python, Wolfram Alpha, or MATLAB) all scripts and data must be submitted in addition to the `.pdf`.
- If you work with anyone else, document what you worked on together.

1. (15 points) Which is more dangerous, 1g of ^{99}Tc or 1mg of ^{137}Cs? The Derived Air Concentrations (DAC) for these two isotopes are $3 \times 10^{-7} \left[\frac{\mu Ci}{cm^3}\right]$ and $6 \times 10^{-8} \left[\frac{\mu Ci}{cm^3}\right]$ respectively.

   Solution: With these values, Cs more toxic and 25 times more toxic than Tc.

   - Toxicity of Tc: 5.68e4 m^3
   - Toxicity of Cs: 1.44e6 m^3

   Google the specific activities in $\mu Ci/g$

   - μCi-to-Bq = 37e3
   - SA$_{Tc}$ = 630e6 / μCi-to-Bq [uCi/g]
   - SA$_{Cs}$ = 3.2e12 / μCi-to-Bq [uCi/g]

   Using Eq. 9.1, multiply the given masses by the specific activities and divide by the DAC in $\mu Ci/cc$.

   $$Toxicity_i = \frac{A_i}{DAC_i}\frac{1m^3}{1e6\ cc} \tag{1}$$

2. Characterize the materials listed below as LLW, TRU, or HLW (Tsoulfanidis, Question 9.3):

   (a) (5 points) gloves contaminated with ^{60}Co and $10Ci$ of fission products

   Solution: LLW

   (b) (5 points) a fuel rod from a BWR after 100 MWd/t burnup

Solution: HLW

(c) (5 points) shoe covers sprayed with tritiated (^3H_2O)water

Solution: LLW

(d) (5 points) uranium mill tailings

Solution: trick question, millings have their own classification. If I had to choose one of these, I would choose TRU.

(e) (5 points) 5g of irradiated LWR fuel containing 550 nCi of ^{252}Cf.

Solution: TRU

3. Describe (in less than 10 words each) the main drawback of each of the following alternative spent nuclear fuel disposal locations:

(a) (5 points) Space.

Solution: Space-crafts costs too much

(b) (5 points) Deep seabed.

Solution: Outlawed by Congress (MPRSA), not enough research

(c) (5 points) Polar Ice Sheets.

Solution: Limited retrivability, uncertainty in ice-cap movement

(d) (5 points) Surface of a remote island.

Solution: Unpredictable tropical weather, lack of infastructure, transportation costs, pirates

4. In any generic mined geologic repository design, many engineered barriers defend against the release of spent nuclear fuel into the geologic host media.

(a) (5 points) Name three geologic host media that we discussed in class.

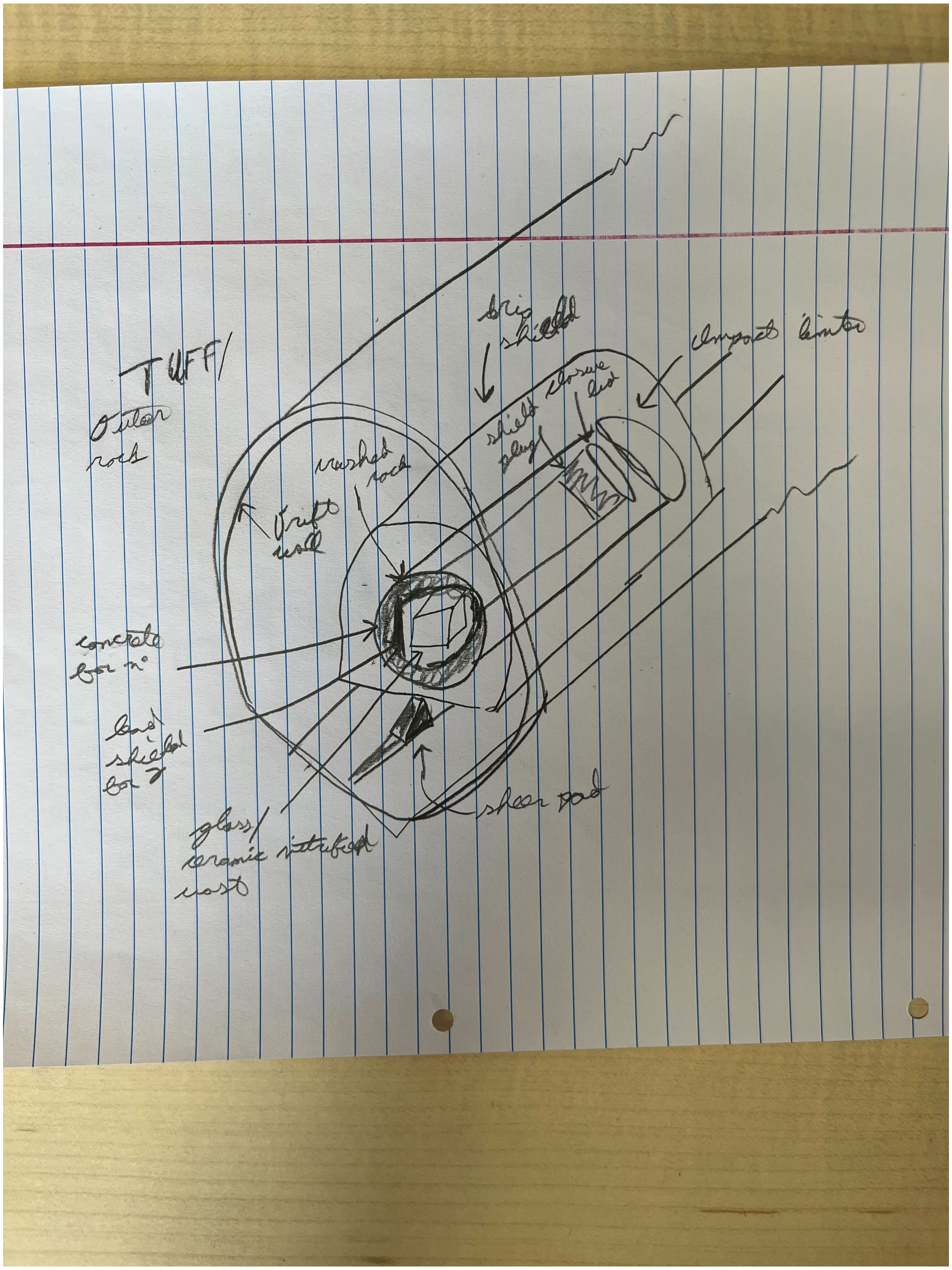
Solution: salt, tuff, granite

(b) (5 points) List as many layers of engineered barriers as you can.

Solution: drift wall, drip shield, glass/ceramic waste package, gamma shield (lead), impact limiter, neutron shield (concrete), shear pads, shield plug, closure lid

(c) (10 points) Draw a diagram and label the placement of these engineered and natural barriers together.

Solution:



5. (15 points) A power reactor operated for 300 effective full-power days (EFPD) at 1050 MW(e) with an efficiency of 33%. What is the decay power generated in the core 20 min after shutdown?

Assume only 235U fissions. (Tsoulfanidis, Question 9.6) (Hint: Use equation 9.9).

Solution: Power 20 min after shutdown is 54.13 MW_{th}.

Use Eq. 9.7 for the function $F(t,\infty)$

$$F(t,\infty) = \sum_{i=1}^{23} \frac{\alpha_i}{\lambda_i} e^{-\lambda_i t} \tag{2}$$

Use Eq. 9.9 for the power as a function of time.

$$P(t,T) = \frac{P_0}{Q} \left[F(t,\infty) - F(t+T,\infty)\right] \tag{3}$$

Using T = 300 days = 2.592e7 s, t = 20 min = 1200 s, P0 = 1050 MW_e / 0.33, Q = 203 MeV.

6. (5 points) We talked in class about the reference man. Who is the reference man?

Solution: The reference man is the average man used in dosimitry and toxicity calculations. He is meant to be a good representation of the average person.