

**NPRE 201: Energy Systems**  
**Homework #4**

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1) Briefly describe the process of Nuclear Fission.

Find nucleus that will be unstable if a neutron is absorbed  
Make that nucleus absorb the neutron  
Nucleus fissions into smaller parts (usually uneven masses) and a few neutrons  
Prompt neutrons repeat cycle

2) Say Uranium-235 has a binding energy of 7.8 MeV/nucleon. It fissions into Barium-141 and Krypton-92 with binding energies of 8.4 MeV/nucleon and 8.6 MeV/nucleon respectively. How much energy is released from this fission?

$$(141 * 8.4 + 92 * 8.4) - (235 * 7.8) = 124.2 \text{ MeV}$$

3) About how many times more powerful is a fission reaction than a combustion reaction like burning carbon?

- a) 5 million  
c) 50 million
- b) 20 million  
d) 500 million

4) Circle/Bold/Underline the fuel quantities (it may be more than one) that yield as much energy as one U-235 nuclear fuel pellet when being used as a fuel:

- a) 3 Barrels of Oil  
c) 1 Ton of Coal
- b) 17,000 ft<sup>3</sup> of natural gas  
They are all equivalent

5) Calculate the energy of a neutron traveling at 2.2 km/s (in Europe this would be written 2,2 km/s). What energy level is this neutron at? Use the common formula for kinetic energy based on mass and velocity.

$$T = \frac{1}{2} * m * v^2 = \frac{1}{2} * 1.675 * 10^{-27} * 2,200 \frac{m}{s} = 1.8425 * 10^{-24} J = 1.5 * 10^{-11} \text{ MeV}$$

This is a thermal neutron

6) Which of the following is an experimental fusion reactor? And what do the letters in the name stand for?

- a) PWR  
c) LMFBR
- b) ITER  
d) PULSTAR

Name: International Thermonuclear Experimental Reactor

7) Name and explain the potential benefits and problems of nuclear power (at least two of each).

Pros

- Cheap Energy once plant is built
- Safe Energy source

Cons

- People do not think it is safe
- High level nuclear waste

8) Briefly explain the differences between a pressurized water reactor (PWR) and a boiling water reactor (BWR).

BWRs allow the water to boil into steam, while PWRs pressurize the water high enough to where there is no steam generated in the main loop. The PWR is used to indirectly heat a secondary loop to generate steam, but the BWR uses the steam generated to directly spin a turbine.

9) Circle all acceptable fuel types for a CANDU reactor.

- |                     |                            |
|---------------------|----------------------------|
| a) Mixed oxide fuel | b) Weapons grade plutonium |
| c) Natural uranium  | d) Natural thorium         |

10) Which of the following countries has never operated a High Temperature Gas-Cooled Reactor?

- |           |                            |
|-----------|----------------------------|
| a) France | b) United States           |
| c) China  | d) Germany                 |
| e) Japan  | f) all have operated HTGRs |

11) What proportion of the original sample of Plutonium-239 will remain after 100,000 years? Show your calculations.

$$\exp\left(\frac{-\ln(2)}{24,100 \text{ years}} * 100,000 \text{ years}\right) = .05635 = 5.635\%$$

12) Why might breeder reactors become a more popular source of power?

- a) The waning supply of U-235
- b) They are safer than LWRs
- c) They produce more fuel than they consume
- d) Pu-238 is a better fuel than U-235

13) Name some benefits of Fusion Power over Fission Power:

Cheaper & effectively infinite fuel  
Fuel not able to be turned into nuclear weapons  
No risk of runaway reaction  
No risk of radiation exposure

14) Which of the following byproducts pose the most immediate hazards in nuclear waste? Circle all that apply.

- a) Plutonium-241
- b) Americium-241
- c) Cesium-137
- d) Strontium-90

Explain your answer: Long lived and radioactive

15) After how much time does the radiotoxicity per unit weight of spent nuclear fuel become comparable to that of the original uranium ore from which it was derived?

- a) A few tens of thousands of years
- b) 100 years
- c) About one million years
- d) 1,000 years

16) Which of the following is considered “high level” radioactive waste? Circle all that apply.

- a) Used fuel from a nuclear reactor
- b) Corroded metal fuel casing
- c) Contaminated coolant
- d) Reprocessed fuel

17) In one of the lectures we covered the RBMK reactor that was used at Chernobyl. What key element used in all current US nuclear power plants was missing from the Chernobyl structure?

The moderator and coolant were different in the RBMK reactor, but in the US, both are water or heavy water. This separation caused a positive thermal reactivity coefficient, so the reactor became more energetic the higher the temperature.

19) It is estimated that each year about how many Americans are either studied or treated with nuclear medicine techniques?

- a) 3.5 Million
- b) 30 Million
- c) 10 Million
- d) 550,000

20) Which of the following will expose a person to the most amount of radiation in one year?

- a) Medical X-Rays
- b) Color Television
- c) A Coast-to-Coast Roundtrip airline flight
- d) Living next to an operating nuclear power plant

23) A 75 kg nuclear power plant worker is exposed to  $5 \times 10^{14}$  MeV of radiation. Will he or she become ill? Show your calculations.

$$5 \times 10^{14} \text{ MeV} * \frac{1 \text{ J}}{6.24 \times 10^{12} \text{ MeV}} * \frac{1}{75 \text{ kg}} = 1.07 \frac{\text{J}}{\text{kg}} * \frac{100 \text{ rad}}{1 \frac{\text{J}}{\text{kg}}} = 106.84 \text{ rad}$$

He or she will have light radiation sickness and potentially higher.