PHYS/ENVS 3070

Homework Assignment #8:

Problem #1:

I have a business proposal for growing energy with a pine forest. I plan to have 10,000 acres of land with planted pine trees. Assume the pine trees gain net biomass at the "summer day" rate (quoted in Table 5.3) throughout the year. Every year, I harvest the trees and burn them in a power plant to generate electricity.

How much electricity can I generate each year in kiloWatt-hours?

(3 points total) Table 5.3 from the textbook quotes a plant production rate for a pine forest of 6 grams/meter^2/day in the summer. The question above says to assume that rate for every day throughout the year. Thus, we have 365 days a year, for 10,000 acres = 4×10^7 meters^2.

Grams of pine trees = 6 (g/m^2/day) x 365 days x (4×10^7 m^2) = 8.7×10^{10} g

The textbook states that wood has about 4300 calories/gram or equivalently 0.005 kiloWatt-hours/gram (when burned). Thus, the total heat energy is 4.3×10^8 kiloWatt-hours. This is the heat energy, which now needs to run a heat engine to produce electricity (at about a 35% efficiency). Thus, we get 1.5×10^8 kiloWatt-hours of electrical energy each year.

If I wanted to remain cost competitive (e.g. 10 cents per kiloWatt-hour), what would my yearly costs have to be?

If we wanted this to cost 10 centers per kiloWatt-hour, we need our business (the land, growing the trees, harvesting them, burning them) to cost about 15 million dollars each year. In reality it needs to cost less, since most businesses want to make a profit.

Problem #2:

Estimate the number of BTU that would be generated annually in the United States of America if all the municipal waste were incinerated. Assume 1000 pounds per year per person of burnable waster at 4300 BTU/pound.

What fraction of the total annual energy usage in the United States would this represent?

(2 points) There are approximately 300 million people in the United States. Thus, (300 x 10^6 people) x (1000 pounds/person) x (4300 BTU/pound) = 1.3 x 10^{15} BTU. This is to be compared with 100 QBTU used in energy in the USA each year.

Problem #3:

Decide which of the following statements are true (T) or false (F).

(2 points total)

A. The fuel rods in a commercial thermal light water reactor such as BWR have in them (initially) UO2 pellets with the U-235 enriched to nearly 100%.

False. In the textbook Table 6.1 it states a typical UO2 pellet has 2.8% of U-235.

B. In the textbook, the breeder reactor will have to be used (eventually) if we are to continue to have energy from fission because we will need to use the U-238 instead of U-235.

True. The breeder reactor helps convert the U-238 into Plutonium which can also be used as fuel for reactors. This will extend the supply of fissionable material by a big factor.

C. After the control rods are inserted into a reactor and it is shut down, a great deal of energy release continues in the core. This is because of the large heat capacity of the mass of the core.

False. It is mostly due to radioactivity in the fission products that continue to release energy for some time.

D. In a typical fission of a Uranium nucleus, the number of neutrons emitted is about two to three.

True. It is these additional neutrons that allow for the possibility of a chain reaction.

E. The largest amount of radiation we receive from natural sources comes from radon gas.

True. A listing of these different sources is in the lecture notes.

Problem #4:

In a 2000 MegaWatt (electrical output) nuclear power plant, about how many uranium nuclei are fissioning per second?

Hint: Calculate the energy per second of heat energy. Then using the energy per individual fission reaction, calculate the number of fission reactions in that one second time period.

(2 points) The 2000 MegaWatts(e) is the electrical power output of the plant. If we assume a 30% efficiency at converting the fuel energy into electrical, it means that we must input ~ 2000/0.3 ~ 6000 MegaWatts of fission power or 6000 MegaJoules per second.

Each uranium fission reaction loses a mass of approximately 3×10^{-28} kilograms. Using $E = mc^2$, we find that the energy per uranium fission ~ 3×10^{-11} Joules per nuclear fission.

Thus, the total number of uranium nuclei fissioning per second is 6000×10^{6} Joules / 3×10^{-11} Joules/fission = 2×10^{20} fissions per second.

Problem #5:

Decide which of the following statements are true (T) or false (F).

(2 points total)

A. Critical mass refers to the maximum amount of fissionable material that will sustain a nuclear chain reaction.

False. It should be that critical mass refers to the minimum amount (not the maximum). See textbook Section 6.2.

B. As estimated by NUREG-1150, the probability for a nuclear reactor to release a significant amount of radioactive material is greater than 1 in 500 per year per reactor.

False. The textbook in Section 6.8 summarizes the NUREG-1150 report as indicating that the probability per reactor year for core damage and large releases of radioactivity for internal events ranges between 0.000001 - 0.000007 per reactor per year. Thus, it is less than 1 per 100,000.

C. A pen that has a mass of 15 grams has an equivalent energy of 300,000 kiloWatt-hours.

False.