Course 47202 – Introduction to Future Energy

Module Nuclear Power

Exercise 1

Fission of one U-235 atom releases about 200 MeV of energy. How many megawatt-days (MWd) thermal energy is released from fission of 1g ^{235}U?

$$Q = 200\,\text{MeV} \cdot \frac{6.023 \cdot 10^{23}\,\text{mol}^{-1}}{235\,\text{g mol}^{-1}} \cdot 1.6 \cdot 10^{-19}\,\frac{\text{J}}{\text{eV}} \cdot \frac{1\,\text{d}}{24 \cdot 3600\,\text{s}}$$

$$\approx 0.95\,\text{MWd g}^{-1}$$

Exercise 2

In a BWR or PWR, steam is generated with a temperature of about 290 °C. (a) If river water used to receive excess heat has a temperature of 20 °C, what is the maximum possible conversion efficiency of the reactor's thermal energy into electricity? (b) Nuclear power plants typically have conversion efficiencies of 34 %. Why is this efficiency less that the ideal efficiency?

(a) $\eta = \frac{T_i - T_o}{T_i} = \frac{270}{290 + 273} \approx 48\%$

(b) *Non-isentropic processes in turbine and pumps imply deviations from an ideal Rankine cycle, in part due to water droplets forming in the turbine.*

Exercise 3

A 1000 MW_e nuclear power plant has a thermal conversion efficiency of 33%. (a) How much thermal power is rejected through the condenser to the cooling water? (b) What is the flow rate (kg/s) of the condenser cooling water if the temperature rise of this water is 12 °C? Specific heat of water is about 4180 J kg^{-1} C^{-1}.

(a) 1000 MW ×(1-0.33)/0.33 = 2000 MW

(b) $M = \frac{Q}{C_V \Delta T} = \frac{2000\,MJs^{-1}}{4180\,JK^{-1}kg^{-1}12K} \approx 40{,}000\,kg\,s^{-1}$

Exercise 4

What are the advantages and disadvantages of using (a) light water, (b) heavy water, and (c) graphite as a moderator in a power reactor?

Moderator	*Advantages*	*Disadvantages*
Light water	*Good moderator* *Inexpensive*	*Neutron absorber* *Tritium production*
Heavy water	*No absorption* *Natural uranium*	*Expensive* *Tritium production*
Graphite	*No absorption* *Inexpensive*	*Poor moderation* *Wigner energy* *C-14 waste*

Exercise 5

Why can a heavy-water moderated reactor use a lower enrichment uranium fuel that a light-water moderated reactor?

Neutron loss due to absorption is less in heavy water than in light water, yielding a higher fission probability in a heavy water reactor.

Exercise 6

Over the period of one year, what mass (kg) of fission products is generated by a 1000 MW_e power reactor?

*Approx. 1000 kg: 365 days * 0.9 (capacity factor) *3 kg/GW_ed*