Power systems

First semester 2022-2023 **Name (Print):**
Topic 2
13/01/23
Time Limit: 90 Minutes Total: 100 points

---

1. Figure 1 shows a schematic of a hybrid power plant that combines a concentrated solar power plant and a nuclear reactor. The solar plant consists of a central tower and a field of mirrors that collect sun radiation. The nuclear reactor is a Pressurized Water Reactor (PWR). Both systems are connected by means of a thermal energy storage (TES) system. Some information of the plant is provided below:

   - Molten salt hot and cold temperatures: $860°K$ and $550°K$
   - Effective area of sun collection in the solar field $1000000m^2$
   - Molten salt heat capacity: $1490J/kgK$
   - Electrical generator efficiency: $\eta_g = 93\%$
   - Turbine mechanical efficiency: $\eta_m = 92\%$
   - Nominal thermal nuclear power: $1500MW$
   - Overall radiation to heat efficiency $\eta_{sun} = 55\%$
   - Primary circuit pressure: $150bar$ (check Table 1)
   - Primary circuit temperatures: $600°K$ and $570°K$
   - Secondary circuit pressure: $71bar$ (check Table 1)
   - At the exit of the SG you have pure saturated steam
   - The inlet SG enthalpy is: $147kJ/kg$
   - The enthalpy at the turbine's outlet is: $1833kJ/kg$

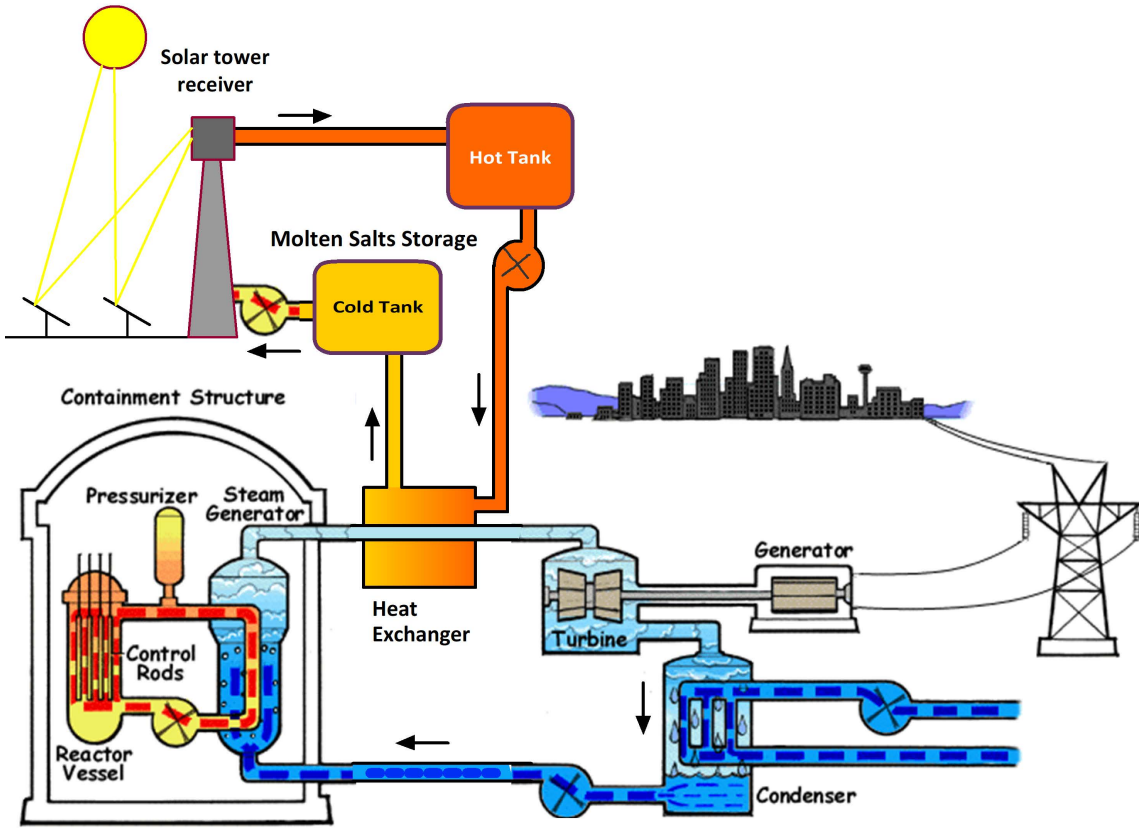

Figure 1: Scheme of the nuclear-solar hybrid thermal power plant.

Table 1: Some properties of water at the primary and secondary pressures

Pressure	Sat. liq. enthalpy	Sat. vap. enthalpy	Liquid Cp	Sat. Temp.
150 bar	1610 kJ/kg	2610 kJ/kg	8 kJ/kgK	615 K
71 bar	1272 kJ/kg	2771 kJ/kg	5 kJ/kgK	559 K

(a) (15 points) Roughly draw the T-S diagram for the three fluid circuits: Nuclear primary circuit, Steam generator circuit and the molten salts circuit. Indicate the isobaric and isoentropic processes.

(b) (15 points) What are the mass flows in the primary and secondary circuit of the PWR?

(c) (15 points) 'For the next 2 weeks, your company has predicted that the average daily solar radiation at the site will be $7kWh/m^2/day$. If you want to operate the plant continuously at the highest constant power, what will be the molten salt mass flow from the hot tank to the cold tank?'

(d) (20 points) In these conditions, what will be the Rankine cycle efficiency? and the electrical power output of the plant?

(e) (15 points) For 1 day (24h) of the proposed time period, Draw orientatively a plot with the evolution of: the massflow from the hot tank to the cold tank, the massflow from the cold tank to the hot tank and the hot tank volume.

2. (10 points) The nuclear core of the reactor is composed of $40t$ of UO_2 at an enrichment of 5%. During reload, the fuel is extracted from the reactor with an average fuel burn up of $70000MWd/tU$. How many years has the fuel been in the reactor before its extraction to the spent fuel pool?

3. (10 points) Figure 2 shows the fission cross section spectrum for different nuclides. Use the figure to explain the most typical path a neutron follows in a PWR, (the one that leads to typical fission).

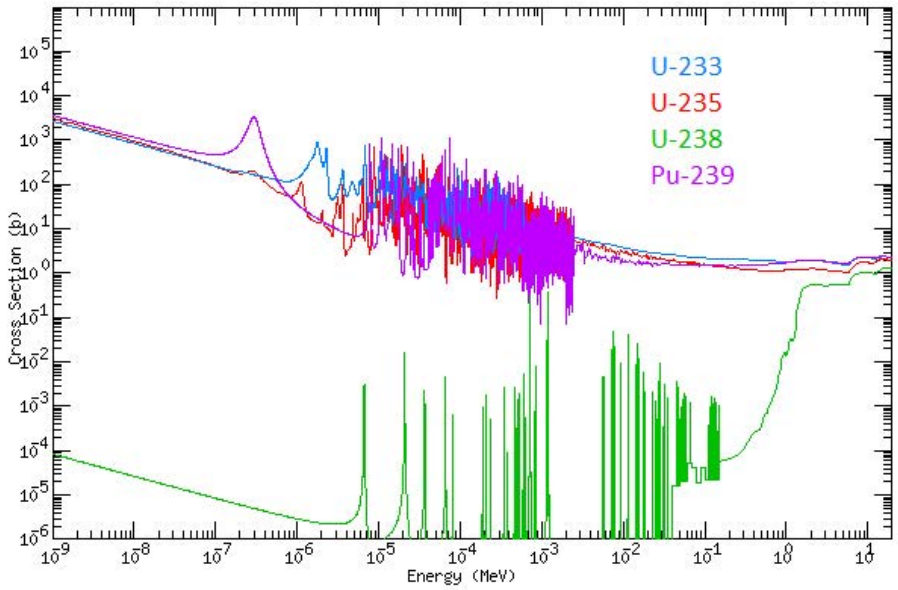

Figure 2: Fission cross section for different nuclides