Given:

The Mars Curiosity Rover uses a radioisotope thermoelecric generator (RTG) which uses the heat from nuclear decay to generate electricity. Curiosity uses 4.8 kg of plutonium-238 dioxide which has a power density of 0.54 W/g. The average temperature of the heat source is 550°C and the average temperature of the external sink is 230°C. **Note:** ^{238}Pu has a half-life of 87.7 years; which means the power output will decrease by 0.787% per year.

$$m_{fuel} := 4.8kg \quad q'_{fuel} := 0.54\frac{W}{gm} \quad T_H := 550\,°C \quad T_L := 230\,°C$$

Required:

What is the maximum rate of power production for this thermoelectric generator? Curiosity actually produces 110 W of electrical power and outputs 2 kW of heat waste. What is the actual thermal efficiency of the RTG?

Solution:

The actual work output of the RTG is defined as

$$W'_{out,rtg} := 110W$$

The actual heat rejected by the RTG is defined as

$$Q'_{L,rtg} := 2kW$$

The Carnot efficiency of the system is given by

$$\eta_{th,rev} := 1 - \frac{T_L}{T_H} = 38.88\cdot\%$$

The theoretical heat supplied to the RTG is given by

$$Q'_{H,fuel} := m_{fuel}\cdot q'_{fuel} = 2.592\cdot kW$$

The maximum rate of power production for the RTG is then found by

$$\eta_{th} = \frac{W'_{out}}{Q'_H} \quad \text{or} \quad \boxed{W'_{out,max} := \eta_{th,rev}\cdot Q'_{H,fuel} = 1.008\cdot kW}$$

The actual heat supplied to the RTG is given by

$$Q'_{H,rtg} := W'_{out,rtg} + Q'_{L,rtg} = 2.11\cdot kW$$

The actual thermal efficiency is then given by

$$\boxed{\eta_{th,rtg} := \frac{W'_{out,rtg}}{Q'_{H,rtg}} = 5.21\cdot\%}$$