Physics 111: General Physics I—Mechanics and Thermodynamics

Problem 1: (20 pts.) A nuclear power plant operates with a high-temperature reservoir of $600\,^\circ\mathrm{C}$ and a cool-temperature reservoir of $350\,^\circ\mathrm{C}$. The plan operates at 75 percent of its maximum theoretical efficiency. If the plant produces electric energy at the rate of $1.3\,\mathrm{GW}$, how much exhaust heat is discharged per hour?

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First, compute the maximum theoretical efficiency. Be sure to convert the temperatures to Kelvin.

$$e_{\text{max}} = 1 - \frac{T_c}{T_h} = 1 - \frac{350 + 273}{600 + 273} = 0.286$$

Then the power plant's actual efficiency is 75% of the maximum, or

$$e = 0.75\, e_{\text{max}} = 0.214\,.$$

The amount of work done in 1 hour is $1.3 \times 10^9\,\text{J/s} \times 3600\,\text{s} = 4.68 \times 10^{12}\,\text{J}$.

Then, use the efficiency to compute Q_h

$$e = \frac{W}{Q_h} \Rightarrow Q_h = \frac{W}{e} = \frac{4.68 \times 10^{12}\,\text{J}}{0.214} = 2.187 \times 10^{13}\,\text{J}$$

Finally, use conservation of energy to compute Q_c.

$$Q_h = W + Q_c \Rightarrow Q_c = Q_h - W = 1.71 \times 10^{13}\,\text{J}$$