

PHYS 301

Thermodynamics and Statistical Mechanics

Homework Assignment 11

Due date: Monday May 4 2026 5pm, submitted on UNM Canvas

Question 1 (5 points).

Thermal pollution: A river with a water temperature $T = 20^\circ\text{C}$ is to be used as the low temperature reservoir of a large power plant, with a steam temperature of $T = 500^\circ\text{C}$. If ecological considerations limit the amount of heat that can be dumped into the river to 1500 Megawatts, what is the largest electrical output that the plant can deliver? If improvements in hot-steam technology would permit raising T by 100°C , what effect would this have on the plant capacity?

Question 2 (5 points).

A room air conditioner operates as a Carnot cycle refrigerator between an outside temperature T_h , and a room at a lower temperature T_l . The room gains heat from the outdoors at a rate $A(T_h - T_l)$; this heat is removed by the air conditioner. The power supplied to the cooling unit is P .

- (a) Show that the steady state temperature of the room is

$$T_l = (T_h + P/2A) - [(T_h + P/2A)^2 - T_h^2]^{1/2}. \quad (1)$$

- (b) If the outdoors is at 37°C and the room is maintained at 17°C by a cooling power of 2 kilowatts, find the heat loss coefficient A of the room in W K^{-1} .

Question 3 (5 points).

Geothermal energy: A very large mass M of porous hot rock is to be utilized to generate electricity by injecting water and utilizing the resulting hot seam to drive a turbine. As a result of heat extraction, the temperature of the rock drops, according to $dQ_h = -MCdT_h$, where C is the specific heat of the rock, assumed to be temperature independent.

- (a) If the plant operates at the Carnot limit, calculate the total amount W of electrical energy extractable from the rock, if the temperature of the rock was initially $T_h = T_i$, and if the plant is to be shut down when the temperature has dropped to $T_h = T_f$. Assume that the lower reservoir temperature T_l , stays constant.
- (b) Give a numerical value, in kilowatt-hours (kWh), for $M = 10^{14}$ kg (about 30 km^3), $C = 1 \text{ J g}^{-1} \text{ K}^{-1}$, $T_i = 600^\circ\text{C}$, $T_f = 110^\circ\text{C}$, and $T_l = 20^\circ\text{C}$. Be careful with units! Compared this number to the total electricity produced in the world in 2024, which was about 30,850 TWh (1 TWh = 10^{12} Wh).