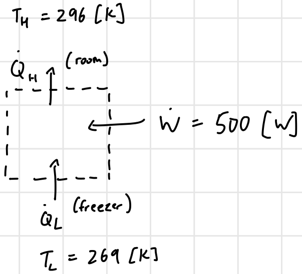
# Example

A modern chest freezer consumes about 500 W of power, and has a coefficient of performance of 3.5. The food cabinet is at about -4°C, while the surrounding kitchen air is at 23°C.

a) Calculate the rate at which heat is removed from the food and the rate at which heat is rejected to the kitchen.

b) At what rate is entropy i) removed from the food? ii) transferred to the kitchen air? Does this violate the 2nd Law?

c) At the next design symposium, a team proposes a thermoelectric freezer that operates between the same temperatures, but with a COP of 12. What is the net entropy generated by this cycle? Is this possible? What is the maximum COP possible for this cycle?



a. $COP_R = \frac{\dot Q_L}{\dot W_{net,\,in}}$

$\dot Q_L = 580\ [W] \times 3.5 = \boxed{1750\ [W]}$ Rate of heat removed from food

$0 = \dot Q_L - \dot Q_W + \dot W_{in}$

$\dot Q_H = \dot Q_L + \dot W$

$= 1750\ [W] + 500\ [W] = \boxed{2250\ [W]}$ Rate of heat entering kitchen

b. i) $\overset{SS}{\cancel{\frac{dS}{dt}}} = \underbrace{\sum \frac{\dot Q_k}{T_k}}_{\text{rate of entropy transfer}} + \dot S_{gen}$

$0 = \frac{\dot Q_L}{T_L}\ \text{in} - \frac{\dot Q_H}{T_H}\ \text{out} + \dot S_{gen}$

$\dot S_{gen} = -\frac{\dot Q_L}{T_L} + \frac{\dot Q_H}{T_H} = -\frac{1750\ [W]}{269\ [K]} + \frac{2250\ [W]}{296\ [K]} = 1.09\ [W/K]$

$\boxed{\dot S_{gen} > 0 \quad \therefore \text{ Second law is satisfied}}$

ii) $COP_{R,max} = \frac{1}{T_H/T_L - 1}$

$= \frac{1}{\frac{296[K]}{269[K]} - 1} = \boxed{9.66}$

∴ Not valid

Net entropy generated is same as above