Chapter 19 Problem 33 †

Given
$T_C = 0°C = 273\ K$
$T_H = 32°C = 305\ K$
$P = 12\ kW$
$L_f = 334\ kJ/kg$

Solution
a) Find the coefficient of performance for the freezer.

Assuming the freezer operates with an efficiency similar to the Carnot cycle, the coefficient of performance is

$$COP = \frac{T_C}{T_H - T_C} = \frac{273\ K}{305\ K - 273\ K} = 8.53$$

b) Find the amount of water it can freeze in one hour.

The heat extracted from the water is related to the coefficient of performance. Expressing these as rates of energy we get

$$COP = \frac{Q_C}{W} = \frac{\Delta Q_C/\Delta t}{\Delta W/\Delta t}$$

$$\frac{\Delta Q_C}{\Delta t} = COP\frac{\Delta W}{\Delta t}$$

The amount of heat extracted in one hour is

$$\Delta Q_C = \frac{\Delta Q_C}{\Delta t}(t) = COP\frac{\Delta W}{\Delta t}(t) = (8.53)(12\ kW)(3600\ s)$$

$$\Delta Q_C = 3.69 \times 10^5\ kJ$$

The heat released during the phase change of water is

$$\Delta Q = mL_f$$

$$m = \frac{\Delta Q}{L_f} = \frac{3.69 \times 10^5\ kJ}{334\ kJ/kg} = 1.10 \times 10^3\ kg$$

† Problem from Essential University Physics, Wolfson