

2. (30 pts.) An ideal Carnot refrigerator operates between temperature reservoirs of  $-6^{\circ}\text{C}$  and  $25^{\circ}\text{C}$ . If the refrigerator uses 100 Watts to run (i.e. the rate at which work is done on the refrigerator is 100 Watts) how long will it take to change 0.4 kg of water initially at  $25^{\circ}\text{C}$  to ice at  $-6^{\circ}\text{C}$ ?

Some data:

specific heat of water =  $4190 \text{ J/kg}\cdot\text{K}$

specific heat of ice =  $2100 \text{ J/kg}\cdot\text{K}$

latent heat of fusion of water =  $3.33 \times 10^5 \text{ J/kg}$

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1st: find  $Q_c$  = heat required to freeze water at  $25^{\circ}\text{C}$  into ice at  $-6^{\circ}\text{C}$ .

$$Q_c = m c_w \Delta T_w - m L_f + m c_i \Delta T_i$$

$$= 0.4 \left[ 4190 (0 - 25) - 3.33 \times 10^5 + (2100) (-6 - 0) \right] = \underline{180,140 \text{ J}}$$

$$W = ? \text{ Use } K = \frac{Q_c}{W} \Rightarrow W = \frac{Q_c}{K}$$

$$K = K_{\text{Carnot}} = \frac{T_c}{T_H - T_c} = \frac{267.15}{298.15 - 267.15} = \frac{267.15}{31} = 8.62$$

$$W = \frac{Q_c}{K} = \frac{180,140}{8.62} = 20,900 \text{ J}$$

$$\text{Power: } P = 100 \text{ W} = 100 \frac{\text{J}}{\text{s}} = \frac{W}{t}$$

$$t = \frac{W}{P} = \boxed{209 \text{ s}}$$

