Homework-7 Solutions

Q 6-22

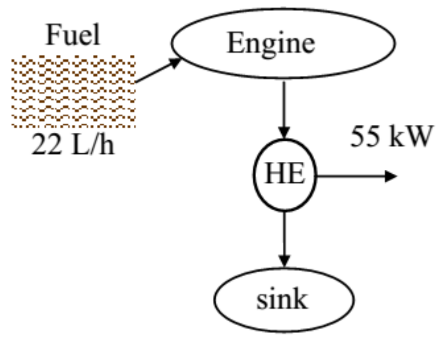
The power output and fuel consumption rate of a car engine are given. The thermal efficiency of the engine is to be determined.

Assumptions The car operates steadily.

Properties The heating value of the fuel is given to be 44,000 kJ/kg.

Analysis The mass consumption rate of the fuel is

$$\dot{m}_{\text{fuel}} = (\rho \dot{V})_{\text{fuel}} = (0.8 \text{ kg/L})(22 \text{ L/h}) = 17.6 \text{ kg/h}$$



The rate of heat supply to the car is

$$\begin{aligned}\dot{Q}_H &= \dot{m}_{\text{coal}} q_{\text{HV,coal}} \\ &= (17.6 \text{ kg/h})(44{,}000 \text{ kJ/kg}) \\ &= 774{,}400 \text{ kJ/h} = 215.1 \text{ kW}\end{aligned}$$

Then the thermal efficiency of the car becomes

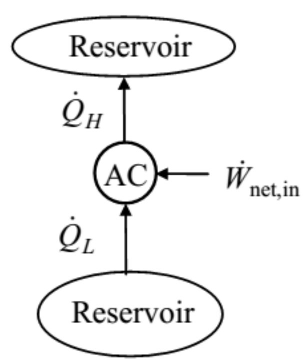
$$\eta_{\text{th}} = \frac{\dot{W}_{\text{net,out}}}{\dot{Q}_H} = \frac{55 \text{ kW}}{215.1 \text{ kW}} = 0.256 = \mathbf{25.6\%}$$

Q 6-40

The cooling effect and the rate of heat rejection of an air conditioner are given. The COP is to be determined.

Assumptions The air conditioner operates steadily.

Analysis Applying the first law to the air conditioner gives



$$\dot{W}_{\text{net,in}} = \dot{Q}_H - \dot{Q}_L = 2.5 - 2 = 0.5 \text{ kW}$$

Applying the definition of the coefficient of performance,

$$\text{COP}_\text{R} = \frac{\dot{Q}_L}{\dot{W}_{\text{net,in}}} = \frac{2.0 \text{ kW}}{0.5 \text{ kW}} = \mathbf{4}$$

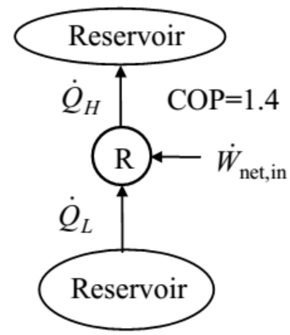
Q 6-41

The power input and the COP of a refrigerator are given. The cooling effect of the refrigerator is to be determined.

Assumptions The refrigerator operates steadily.

Analysis Rearranging the definition of the refrigerator coefficient of performance and applying the result to this refrigerator gives

$$\dot{Q}_L = \text{COP}_\text{R}\,\dot{W}_\text{net,in} = (1.4)(3\text{ kW}) = \mathbf{4.2\ kW}$$



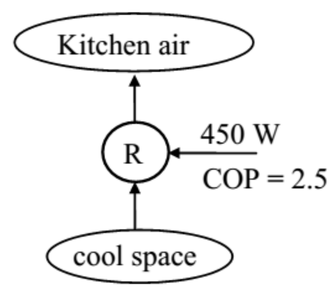
Q 6-46

Assumptions 1 The refrigerator operates steadily. **2** The heat gain of the refrigerator through its walls, door, etc. is negligible. **3** The watermelons are the only items in the refrigerator to be cooled.

Properties The specific heat of watermelons is given to be c = 4.2 kJ/kg.°C.

Analysis The total amount of heat that needs to be removed from the watermelons is

$$Q_L = (mc\Delta T)_\text{watermelons} = 5\times(10\text{ kg})(4.2\text{ kJ/kg}\cdot°\text{C})(20-8)°\text{C} = 2520\text{ kJ}$$



The rate at which this refrigerator removes heat is

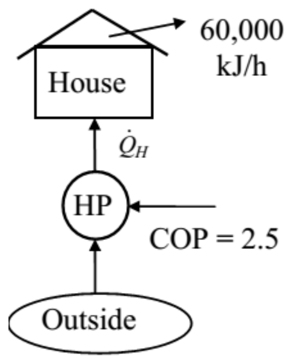
$$\dot{Q}_L = (\text{COP}_\text{R})(\dot{W}_\text{net,in}) = (2.5)(0.45\text{ kW}) = 1.125\text{ kW}$$

That is, this refrigerator can remove 1.125 kJ of heat per second. Thus the time required to remove 2520 kJ of heat is

$$\Delta t = \frac{Q_L}{\dot{Q}_L} = \frac{2520\text{ kJ}}{1.125\text{ kJ/s}} = \mathbf{2240\ s = 37.3\ min}$$

This answer is optimistic since the refrigerated space will gain some heat during this process from the surrounding air, which will increase the work load. Thus, in reality, it will take longer to cool the watermelons.

Q 6-51



Assumptions The heat pump operates steadily.

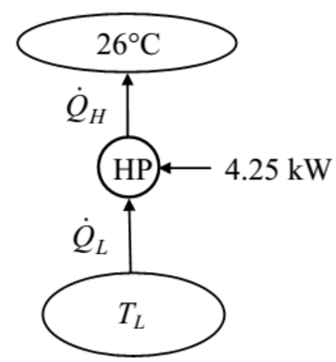
Analysis The heating load of this heat pump system is the difference between the heat lost to the outdoors and the heat generated in the house from the people, lights, and appliances,

$$\dot{Q}_H = 60{,}000 - 4{,}000 = 56{,}000 \text{ kJ / h}$$

Using the definition of COP, the power input to the heat pump is determined to be

$$\dot{W}_{\text{net,in}} = \frac{\dot{Q}_H}{\text{COP}_{\text{HP}}} = \frac{56{,}000 \text{ kJ/h}}{2.5}\left(\frac{1 \text{ kW}}{3600 \text{ kJ/h}}\right) = \mathbf{6.22\ kW}$$

Q 6-95 The power input and the COP of a Carnot heat pump are given. The temperature of the low-temperature reservoir and the heating load are to be determined.



Assumptions The heat pump operates steadily.

Analysis The temperature of the low-temperature reservoir is

$$COP_{\text{HP,max}} = \frac{T_H}{T_H - T_L} \longrightarrow 8.7 = \frac{299 \text{ K}}{(299 - T_L) \text{ K}} \longrightarrow T_L = \mathbf{264.6\ K}$$

The heating load is

$$COP_{\text{HP,max}} = \frac{\dot{Q}_H}{\dot{W}_{in}} \longrightarrow 8.7 = \frac{\dot{Q}_H}{4.25 \text{ kW}} \longrightarrow \dot{Q}_H = \mathbf{37.0\ kW}$$

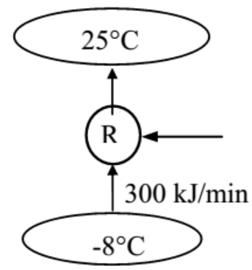
Q 6-96

The refrigerated space and the environment temperatures for a refrigerator and the rate of heat removal from the refrigerated space are given. The minimum power input required is to be determined.

Assumptions The refrigerator operates steadily.

Analysis The power input to a refrigerator will be a minimum when the refrigerator operates in a reversible manner. The coefficient of performance of a reversible refrigerator depends on the temperature limits in the cycle only, and is determined from

$$COP_{\mathrm{R,rev}} = \frac{1}{(T_H/T_L)-1} = \frac{1}{(25+273\ \mathrm{K})/(-8+273\ \mathrm{K})-1} = 8.03$$



The power input to this refrigerator is determined from the definition of the coefficient of performance of a refrigerator,

$$\dot{W}_{\mathrm{net,in,min}} = \frac{\dot{Q}_L}{COP_{\mathrm{R,max}}} = \frac{300\ \mathrm{kJ/min}}{8.03} = 37.36\ \mathrm{kJ/min} = \mathbf{0.623\ kW}$$