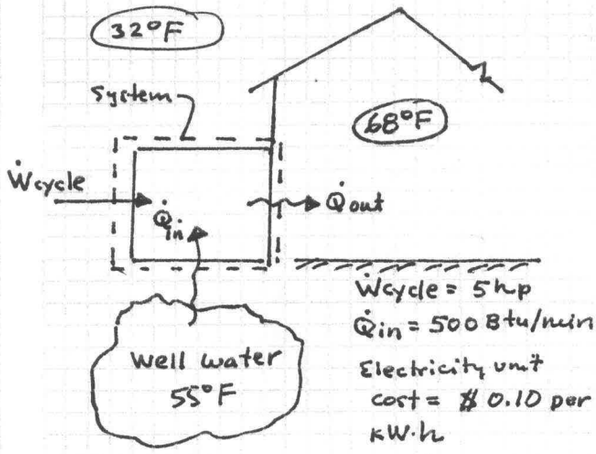
PROBLEM 2.91

KNOWN: Operating and cost data are provided for a heat pump.

FIND: Determine the coefficient of performance for the heat pump and the cost of electricity in a month when the heat pump operates for 300 hours.

SCHEMATIC & GIVEN DATA:



$\dot{W}_{cycle} = 5\,hp$

$\dot{Q}_{in} = 500\,Btu/min$

Electricity unit cost = ¢ 0.10 per kW·h

ENGINEERING MODEL:

1. The system shown in the schematic operates in a heat pump cycle.
2. Energy transfers are positive in the direction of the arrows.
3. The heat pump operates steadily.
4. Electricity is valued at ¢ 0.10 per kW·h.

ANALYSIS:

(a) Using Eq. 2.47 on a time rate basis,

$$\gamma = \frac{\dot{Q}_{out}}{\dot{W}_{cycle}} \qquad (1)$$

together with the cycle energy balance, Eq. 2.44, on a time rate basis: $\dot{W}_{cycle} = \dot{Q}_{out} - \dot{Q}_{in}$, we get:

$$\dot{Q}_{out} = \dot{W}_{cycle} + \dot{Q}_{in} = \underbrace{(5hp)\left|\frac{2545\,Btu/h}{1\,hp}\right|\left|\frac{1\,h}{60\,min}\right|}_{212.1\,Btu/min} + 500\,\frac{Btu}{min}$$

$$\therefore \dot{Q}_{out} = 712.1\,Btu/min$$

Eq. (1) gives,

$$\gamma = \frac{712.1\,Btu/min}{212.1\,Btu/min} = 3.36$$

(b) $$\$ = \left(212.1\,\frac{Btu}{min}\right)\left[\frac{300\,h}{month}\right]\left[\frac{¢\,0.10}{kW\cdot h}\right]\left|\frac{60\,min}{1\,h}\right|\left|\frac{1\,kW}{3413\,Btu/h}\right|$$

unit conversions: 1 W = 3.413 Btu/h

$$= \$\,111.86/month$$