engr 292 – Entropy and the 2nd Law Example

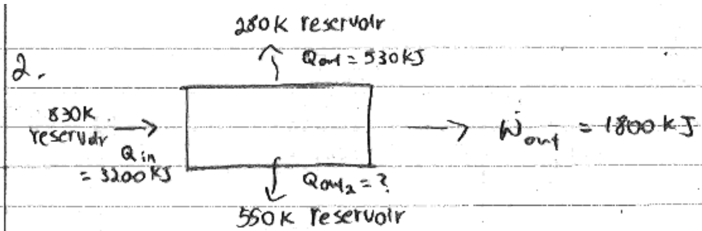
Question 2

A new device claims to be able to produce 1800 kJ of work while transferring heat in the following complex way:

- 3200 kJ of heat enters the system from a 830 K reservoir;
- 530 kJ of heat leaves the system to a 280 K reservoir; and,
- An unknown amount of heat leaves the system to a 550 K reservoir.

a. What is the claimed system efficiency (want “work”, pay for “heat in”)?
b. Will the system operate as claimed? What’s wrong?
c. What is the most amount of work the system can produce in real life?
d. What will be the best system efficiency?

2.



a) $\eta = \frac{W_{ant}}{Cost} = \frac{1800 kJ}{3200 kJ} = 0.5625 = 56.25\%$ ✓

b) $E_{out} - E_{IN} = 0 \Rightarrow \dot{E}_{out} = \dot{E}_{IN}$

$530 kJ + Q_{out_2} + 1800 kJ = 3200 kJ$

$Q_{out_2} = \boxed{870 kJ}$ ✓

$\Delta S = \int \left(\frac{d\dot{Q}}{T}\right)_b + \rho$

$0 = \frac{\dot{Q}_{IN}}{T_{IN}} - \left(\frac{\dot{Q}_{out}}{T_{out}} + \frac{\dot{Q}_{out_2}}{T_{out_2}}\right) + \rho$

$0 = \frac{3200 kJ}{830 k} - \left(\frac{530 kJ}{280 k} + \frac{870 kJ}{550 k}\right) + \rho$

$\rho = -0.3807 \Rightarrow$ will not operate ✓

c) $\Delta S = \frac{\dot{Q}_{IN}}{T_{IN}} - \left(\frac{\dot{Q}_{out}}{T_{out}} + \frac{\dot{Q}_{out_2}}{T_{out_2}}\right) + \rho$

$0 = \frac{3200 kJ}{830 k} - \left(\frac{530 kJ}{280 K} + \frac{\dot{Q}_{out_2}}{550 K}\right) + 0$

$\dot{Q}_{out_2} = 1079.41 kJ$ ✓

$W_{actual} = Q_{IN} - Q_{out} - Q_{out_2}$

$= 3200 kJ - 530 kJ - 1079.41 kJ$

$= 1590.589$

$= 1590.6 kJ$ ✓

d) $\eta = \frac{W_{ant}}{Cost} = \frac{1590.6 kJ}{3200 kJ} = 0.4970$

$= \boxed{49.71\%}$ ✓