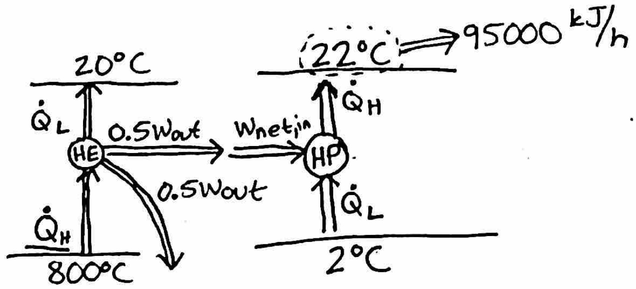
ASEN 3113
Group Exercise 1
31 August

"minimum" $\Rightarrow$ reversible $\Rightarrow \left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$

1. A heat engine operates between two reservoirs at 800 and 20°C. One-half of the work output of the heat engine is used to drive a Carnot heat pump that removes heat from the cold surroundings at 2°C and transfers it to a house maintained at 22°C. If the house is losing heat at a rate of 95,000kJ/h, determine the minimum rate of heat supply to the heat engine required to keep the house at 22°C.



heat pump

$$COP_{HP,rev} = \frac{1}{1 - T_L/T_H} = \frac{1}{1 - \frac{273+2}{273+22}} = 14.75$$

$\dot{Q}_H = 95000 \text{ kJ/hr} \cdot \frac{1\text{hr}}{3600\text{s}} = 26.39 \text{ kW} \longrightarrow$ to maintain 22°C

$$COP_{HP} = \frac{\dot{Q}_H}{\dot{W}_{net,in}} \longrightarrow \dot{W}_{net,in} = \frac{\dot{Q}_H}{COP_{HP}} = \frac{26.39 \text{ kW}}{14.75} = 1.789 \text{ kW}$$

heat engine

half of the work output of the heat engine drives the heat pump $\Rightarrow \dot{W}_{net,out,HE} = 2 \cdot \dot{W}_{net,in,HP} = 3.578$ kW

$$\dot{Q}_H = \frac{\dot{W}_{net,out}}{\eta_{th}} \ ; \ \eta_{th} = 1 - \left(\frac{Q_L}{Q_H}\right)_{rev} = 1 - \frac{T_L}{T_H}$$

$\eta_{th} = 1 - \frac{273+20}{273+800} = 0.727 \rightarrow$ highest possible thermal efficiency of heat engine

$$\dot{Q}_H = \frac{3.578 \text{ kW}}{0.727} = \boxed{4.922 \text{ kW}}$$

ASEN 3113
Group Exercise 2
16 Sept

Name (LAST, First): ______________________

1. An insulated piston-cylinder device initially contains 300 Liter of air at 120 kPa and 17°C. Air is now heated for 15 min by a 200 W resistance heater placed inside the cylinder. The pressure of air is maintained constant during this process (assuming no friction). Determine the entropy change of the air in terms of kJ/K (you can assume constant specific heats for air at room temperature, 25°C).

$V_1 = 300\,L \quad P_1 = 120\,kPa \quad T_1 = 17°C = 290\,K$

Air is heated for 15 min by a 200 W heater. T_2?

constant pressure:

$m c_p \Delta T = Q = (200\,W)(15\,min \cdot \frac{60\,sec}{min})$

$c_p = 1.005\,kJ/kgK$

need m:

Ideal gas: $m = \frac{P_1 V_1}{R T_1} = \frac{(120\,kPa)(0.3\,m^3)}{(0.287\,kJ/kgK)(290\,K)}$

$\therefore m = 0.4325\,kg$

$m c_p (T_2 - T_1) = Q$

$T_2 = \frac{Q}{m c_p} + T_1 = \frac{180\,kJ}{(0.4325\,kg)(1.005\,kJ/kgK)} + 290\,K$

$\therefore T_2 = 704.11\,K$

[OR $h_2 - h_1 = c_p(T_2 - T_1)$ to find T_2]

$s_2 - s_1 = c_{p,avg} \ln\left(\frac{T_2}{T_1}\right) - \cancel{R \ln\left(\frac{P_2}{P_1}\right)}$

0, constant pressure

$s_2 - s_1 = \Delta s = (1.005\,kJ/kgK) \ln\left(\frac{704.11\,K}{290\,K}\right)$

$\Delta s = 0.8915\,kJ/kgK$

$\Delta S = m \Delta s = (0.4325\,kg)(0.8915\,kJ/kgK)$

$\boxed{\Delta S = 0.386\,kJ/K}$

[OR

$s^\circ = \int_0^T c_p(T) \frac{dT}{T} \rightarrow \Delta s = s_2^\circ - s_1^\circ - \cancel{R \ln\left(\frac{P_2}{P_1}\right)}^{\,0}$

using table A-21

*still need to find T_2]

ASEN 3113
Group Exercise 3
16 Sept

Names (LAST, First): ____________________

During an experiment conducted in a room at 25°C, a laboratory assistant measures that a refrigerator that draws 10 kW of power has removed 30,000 kJ of heat from the refrigerated space, which is maintained at –30°C. The running time of the refrigerator during the experiment was 20 min. Determine if these measurements can be valid.

$$COP_R = \frac{Q_L}{W_{net,in}} = \frac{1}{Q_H/Q_L - 1}$$

$$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$$

$$COP_{R,rev} = COP_{R,max} = \frac{1}{T_H/T_L - 1}$$

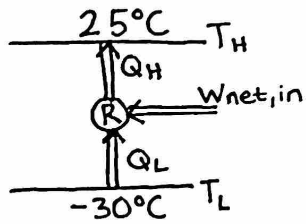
$$COP_{R,rev} = \frac{1}{\frac{273+25}{273-30} - 1} = 4.418$$

maximum possible

$$W_{net,in} = \dot{W}_{in} \cdot \Delta t = (10\ kW)\left(20\,min \cdot \frac{60s}{min}\right)$$
$$= 12000\,kJ$$

Claimed:

$$COP_R = \frac{Q_L}{W_{net,in}} = \frac{30{,}000\ kJ}{12{,}000\ kJ} = 2.5$$



Claimed COP_R is less than $COP_{R,rev}$ → $\boxed{\text{these measurements can be valid!}}$

if the refrigerator draws <u>2 kW</u>, like in lecture:
Claimed $COP_R = 12.5$ and these measurements <u>cannot be valid</u>