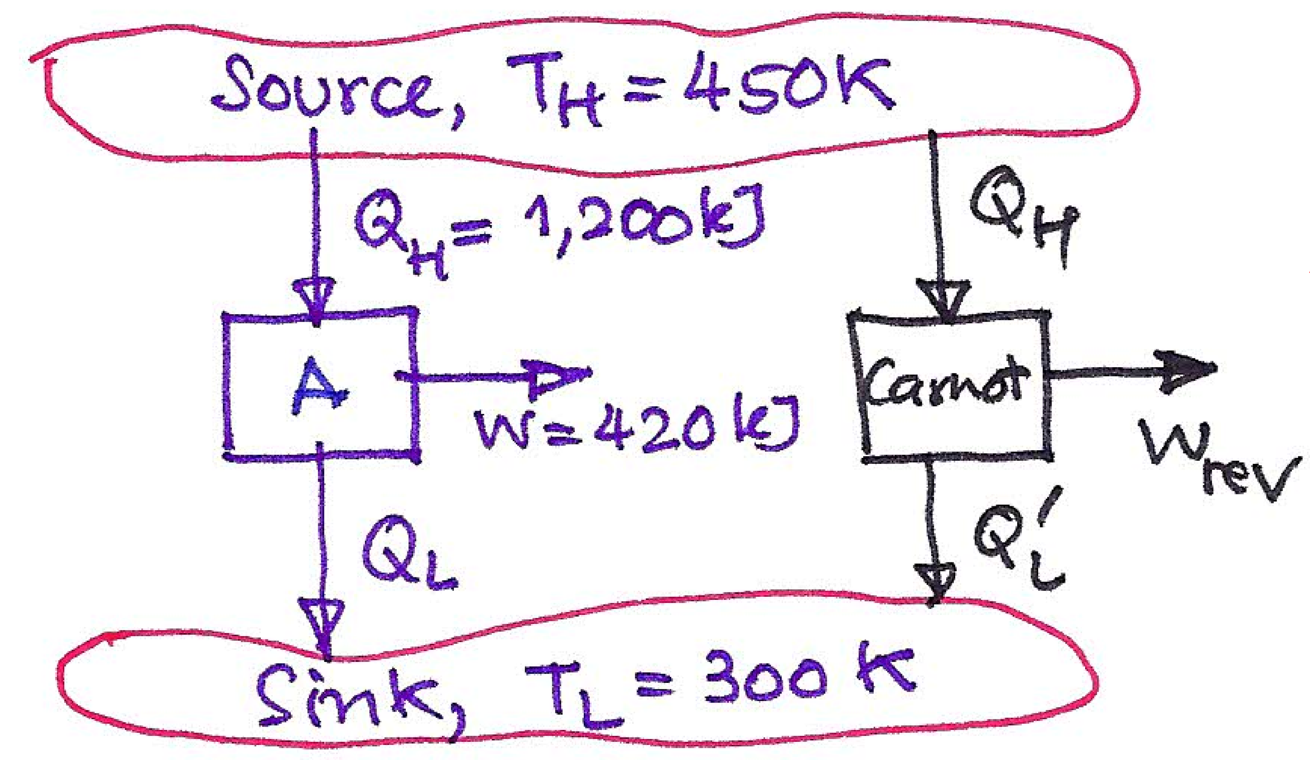
Thermodynamics I Section 1 ***Test #3*** *Saturday 22 August 2009 Time 1 hr 30 min*

เลขที่สอบ……… Name ………………………………………………………

Examiner: *Assoc.Prof.Sommai Priprem, PhD.*

---

1. An inventor claims to have developed a heat engine that receives 1,200 kJ of heat from a source at 450 K and produces 420 kJ of net work while rejecting the waste heat to a sink at 300 K. Is this a reasonable claim? Why (5 Marks)



System : Heat Engine.

Analysis:

Carnot Principle: $\eta_{irr} < \eta_{rev}$

Solution:

Consider the claimed engine. (Engine A)

$$\eta_{th} = \frac{W_{net}}{Q_H} \times 100\% = \frac{420 kJ}{1{,}200 kJ} \times 100\% = 35.0\%.$$

Consider a Carnot Heat Engine operate between the same heat source and heat sink, also recieves the same amount of Q_H.

$$\eta_{rev} = 1 - \frac{T_L}{T_H} = 1 - \frac{300K}{450K} = 0.333$$

$$= 33.3\%.$$

$\therefore$ $\eta_{irr} > \eta_{rev}$; this violate the carnot principle.

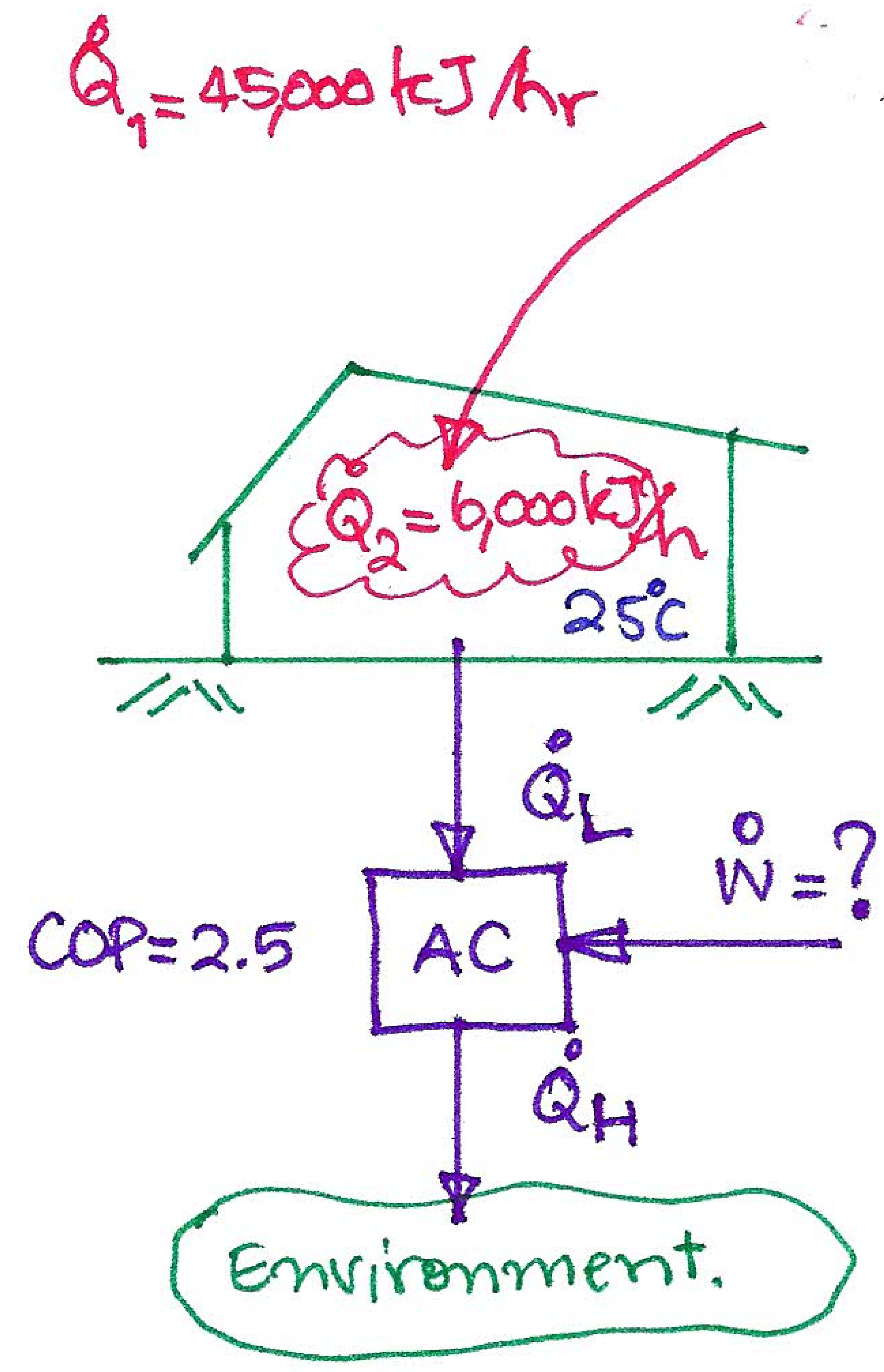
Therefore, this claim is UNRESONABLE (impossible) Ans.

เลขที่สอบ........ Name ....

Examiner: *Assoc.Prof.Sommai Priprem, PhD.*

---

2. An air conditioning system is used to maintain a house at a constant temperature of 25 °C . The house is gaining heat from outdoors at a rate of 45,000 kJ/h, and the heat generated in the house from the people, lights, and appliances amounts to 6,000 kJ/h. For a COP of 2.5, determine the required power input to this air conditioning system (5 Marks)



System: Air Conditioner

Analysis: $\dot{W} = \dfrac{\dot{Q}_L}{COP}$

Solution:

Consider the house,

to maintain constant temp.

$$\sum \dot{Q}_{in} = \sum \dot{Q}_{out}.$$

$$\sum \dot{Q}_{in} = \dot{Q}_1 + \dot{Q}_2$$

$$= (45,000 + 6,000)\ kJ/h$$

$$= 51,000\ kJ/h \times \frac{1}{3,600\ s/h} = 14.17\ kW.$$

and $\dot{Q}_L = \sum \dot{Q}_{out} = 14.17\ kW.$

$$\therefore \quad \dot{W} = \frac{\dot{Q}_L}{COP} = \frac{14.17\ kW}{2.5} = 5.67\ kW$$

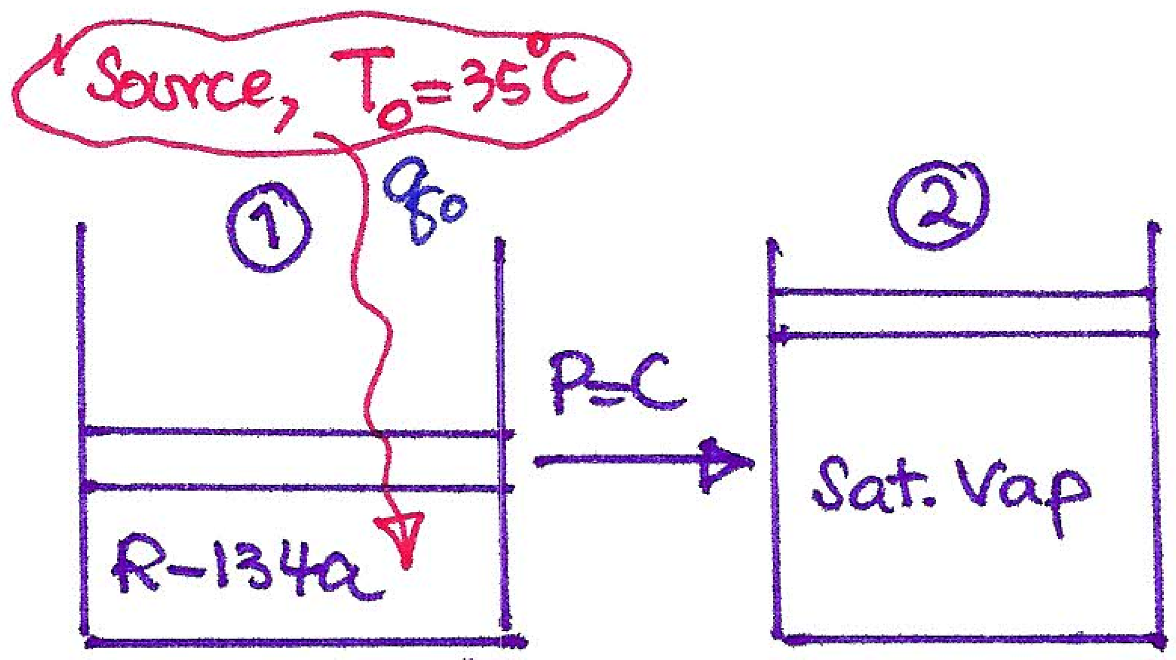
The power required is 5.67 kW Answer

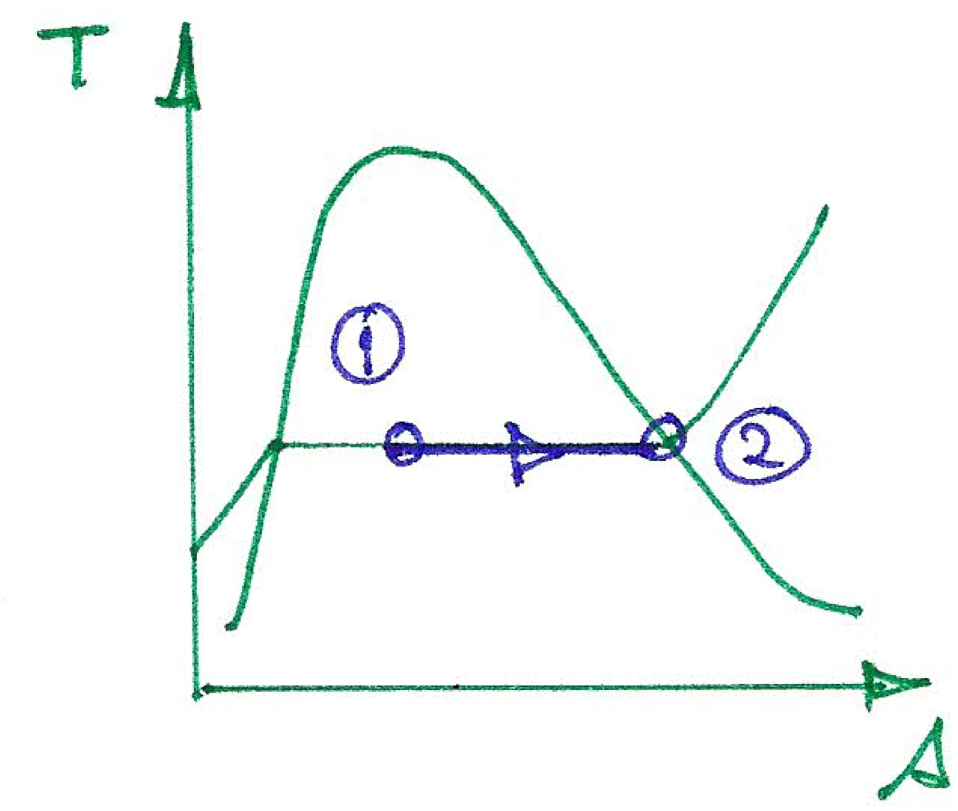
เลขที่สอบ......... Name ....

Examiner: *Assoc.Prof.Sommai Priprem, PhD.*

---

3. A piston-cylinder device contains refrigerant-R-134a initially at 0.5-m³ 400 kPa and 40 percent quality. Heat is transferred to the refrigerant from a source at 35°C until the refrigerant becomes saturated vapour. If the process occurred at constant pressure determine (a) the entropy change of the refrigerant, (b) the entropy change of the heat source, and (c) the total entropy change for this process. (d) does this process violates the principle of increase of entropy, why. (10 marks)





$V_1 = 0.5\,m^3$ a) $\Delta S_{ref} = ?$

$P_1 = 400\,kPa$ b) $\Delta S_{source} = ?$

$x_1 = 40\%$ c) $\Delta S_{Total} = ?$

System: R-134a, Closed system.

Solution: state ① $P_1 = 400\,kPa$, $x_1 = 40\%$, Table A-15b.

$$v_1 = v_f + x_1 v_{fg} = (0.0008) + 0.4(0.0509 - 0.0008) = 0.0208\ m^3/kg$$

$$m = \frac{V_1}{v_1} = \frac{0.5\,m^3}{0.0208\,m^3/kg} = 24\ kg$$

$$h_1 = h_f + x_1 h_{fg} = 62.0 + 0.4(190.32) = 138.13\ kJ/kg$$

$$s_1 = s_f + x_1 s_{fg} = 0.2399 + 0.4(0.6746) = 0.5097\ kJ/kgK$$

state ② $P_2 = P_1 = 400\,kPa$, sat. vapor.

$$h_2 = h_g = 252.32\ \frac{kJ}{kg}\ ;\quad s_2 = s_g = 0.9145\ kJ/kgK.$$

a) $\Delta S_{ref} = m(s_2 - s_1) = 24kg(0.9145 - 0.5097)\ kJ/kgK$

$= 9.7138\ kJ/K$ Answer

b) $q_0 = -{}_1q_2 \therefore = {}_1w_2 + u_2 - u_1 = P(v_2 - v_1) + u_2 - u_1)$

$= h_2 - h_1$

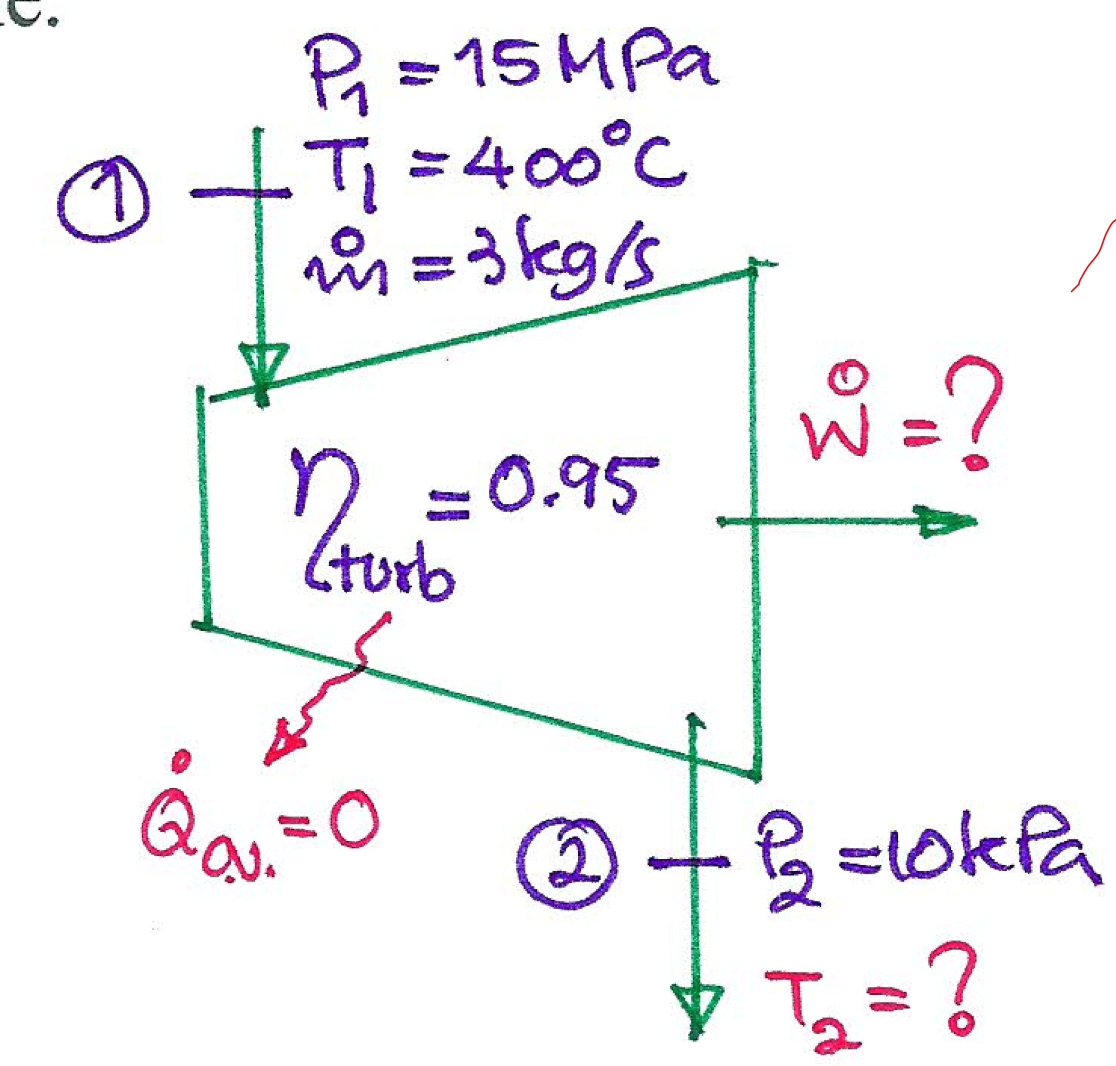
$$\Delta S_{source} = \frac{Q_0}{T_0} = \frac{m\,q_0}{T_0} = \frac{(24\,kg)(138.13 - 252.32)\,kJ/kg}{(35+273)\,K} = -9.196\,\frac{kJ}{K}$$

c) $\Delta S_{Total} = \Delta S_{ref} + \Delta S_{source} = 9.7138 - 9.1963 = 0.51755\ kJ/K.$

Does not violate Princ. of increase of entropy $\because \Delta S_{Total} > 0$ Answer

---

4. Steam enters an adiabatic turbine at 15 MPa and 400°C with a mass flow rate of 3 kg/s and leaves at 10 kPa. The adiabatic efficiency of the turbine is 0.95. Neglecting the kinetic energy change of the steam, determine (a) the temperature at the turbine exit and (b) the power output of the turbine.



System: steam, Turbine

Assumption: SSSF, neglect ΔKE, ΔPE

Analysis: $T_2 \rightarrow$ state 2

$$\dot{W} = \dot{m}\,w$$

$$\eta = \frac{w_a}{w_s}$$

$$w_s = h_1 - h_{2s}$$

Solution state ① 15 MPa, 400°C ⇒ superheated vap.

Table A-6; $h_1 = 2{,}975.5\ kJ/kg$; $s_1 = 5.8811\ kJ/kg\,K$

Consider isentropic process $1 \rightarrow 2s$; $s_{2s} = s_1$, $P_2 = 10\,kPa$.

$\therefore\ s_f < s_{2s} < s_{fg} \Rightarrow$ mixture

$$x_{2s} = \frac{s_{2s} - s_f}{s_{fg}} = \frac{5.8811 - 0.6493}{7.5009} = 0.6975$$

$$h_{2s} = h_f + x_{2s}h_{fg} = (191.8) + (0.6975)(2392.8) = 1{,}860.8\ kJ/kg$$

1st law: $w_s = h_1 - h_{2s} = (2{,}975.5 - 1{,}860.8) = 1{,}114.7\ kJ/kg$

$w_a = \eta\, w_s = (0.95)(1{,}114.7)\,kJ/kg = 1{,}059.0\ kJ/kg$

$\dot{W} = \dot{m}\,w_a = \left(3\,\frac{kg}{s}\right)\left(1059.0\,kJ/kg\right) = 3{,}176.9\ kW$ Answer (b)

1st law: actual process, $w_a = h_1 - h_2 \Rightarrow h_2 = h_1 - w_a$

$h_2 = (2{,}975.5 - 1{,}059.0) = 1{,}916.5\ kJ/kg$

At $P = 10\,kPa$, $h_f < h_2 < h_g \Rightarrow$ ② is mixture

$\therefore\ T_2 = T_{sat}$ at $10\,kPa = 45.81°C$ Answer (a)