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ideal vapor compression cycle w/R-134a
refrigerator
given:
evaporator ambient → -10°C
condenser ambient → 25°C

evaporator is 10°C cooler than ambient → $\boxed{-20°C}$

condenser Ambient is around 10°C hotter than the
condenser itself, choosing $\boxed{35°C}$
condenser is hotter than ambient to release heat
evaporator is cooler than ambient
the pressure of the evaporator must be higher
than ambient b/c if $P_{evaporator}$ < ambient it will bring air into
the system.

$$\boxed{P_{evaporator} = 132.82 \text{ kPa} \ @ \ T_e = -20°C}$$

$$\boxed{P_{condenser} = 887.73 \text{ kPa} \ @ \ T_c = 35°C}$$

interpolated
btwn 34°C & 36°C

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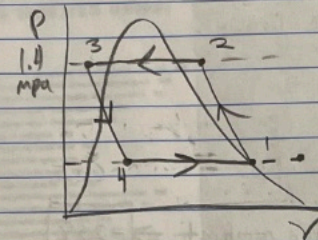
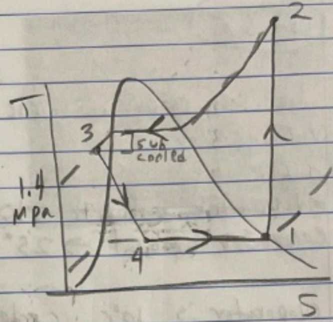
1)





① $\xrightarrow[\text{Win - s const}]{\text{compressor}}$ ② $\xrightarrow[\text{P const}]{\text{condenser}}$ ③ $\xrightarrow[\text{h - const}]{\text{expansion}}$ ④ $\xrightarrow[\text{P - const}]{\text{evaporator}}$

$X_1 = 1$	$P_2 = 1.4\ \text{mpa}$	$P_3 = 1.4\ \text{Mpa}$	$X_4 = 0.23$
$T_1 = 20°C$	$h_2 = 280.075\ \frac{kJ}{kg}$	$h_3 = 121.256\ \frac{kJ}{kg}$	$T_4 = 20°C$
$h_1 = 261.64\ \frac{kJ}{kg}$			$h_4 = 121.256\ \frac{kJ}{kg}$

R-134a $\quad h_{1 @ \text{sat. vapor tables} @ T_1} = h_1 = 261.64\ \frac{kJ}{kg} \quad S_1 = 0.92254\ \frac{kJ}{kg \cdot K}$

hg

$S_2 = S_1 \rightarrow$ superheated tables @ 1.4 mpa

interpolate $\rightarrow h_2 = 280.075\ \frac{kJ}{kg}$

$h_3 = h_4 \qquad h_4 = h_f + X_4 \cdot h_{fg}$

$@T_4 \qquad = 79.32\ \frac{kJ}{kg} + 0.23(182.33\ \frac{kJ}{kg})$

$h_4 = 121.256\ \frac{kJ}{kg}$

$h_3 = h_4$

ⓐ $T_{subcooling} = T_{sat.\ liquid @ P_2} - T_3 \qquad T_3 \Rightarrow$ Sat. liquid $\rightarrow$ Temp @ h_3

T_3 interpolated table $= 48.54°C$

$= 52.4°C - 48.54°C$

$\boxed{T_{subcooled} = 3.86°C}$

(b)

$\dot{Q}_W = \dot{Q}_R$

$\dot{Q}_W = \dot{m}_w cp \cdot \Delta T$

$\dot{Q}_R = \dot{m}_R (h_1 - h_4)$

$\dot{m} = 0.065 \frac{kg}{s}$

$cp = 4.18 \frac{kJ}{kg \cdot K}$

ΔT water $= 50°C - 40°C$

$$\dot{m}_R = \frac{\dot{m}_w \cdot cp \cdot \Delta T}{h_1 - h_4} \rightarrow \frac{0.065 \frac{kg}{s} \cdot 4.18 \frac{kJ}{kg \cdot K} \cdot 10°C}{261.64 \frac{kJ}{kg} - 121.256 \frac{kJ}{kg}}$$

$$\boxed{\dot{m}_R = 0.0194 \frac{kg}{s}}$$

(c)

$\dot{Q}_L = \dot{m}_R (h_1 - h_4)$

$= 0.019 (140.3841)$

$\dot{Q}_L = 2.717 \text{ KW}$

$\dot{W}_{in} = \dot{m}_R (h_2 - h_1)$

$= 0.0194 (280.075 \frac{kJ}{kg} - 261.64 \frac{kJ}{kg})$

$\dot{W}_{in} = 0.358 \text{ KW}$

$W_{comp} = W_{in} + q_{out}$

$0.358 \text{ KW} + 0.3 \text{ KW}$

$= 0.658 \text{ KW}$

$\dot{Q}_H = \dot{m}_R (h_2 - h_3)$

$\boxed{\dot{Q}_H = 3.081 \text{ KW}}$

$$COP_{HP} = \frac{\dot{Q}_H}{W_{in\,comp}}$$

$$4.68 = \frac{3.081 \text{ KW}}{0.658 \text{ KW}}$$

(d) Carnot cycle

$$\frac{1}{1 - T_L/T_H}$$

$T_L = T_1 = 20°C$

$T_H = T_2 = 55.59°C \rightarrow$ interpolate

$$\frac{1}{1 - \frac{T_L}{T_H}} = \frac{1}{1 - \frac{20°C}{55.59°C}} = 1.56 \text{ carnot}$$

$$\frac{W_{in}(KW)}{\text{Carnot}} = W_{in(min)} \text{ iop}$$

$$\frac{0.358 \text{ KW}}{1.56} = \boxed{0.229 \text{ KW}}$$

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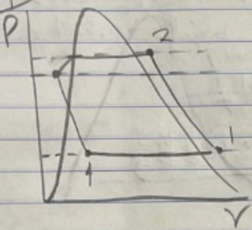

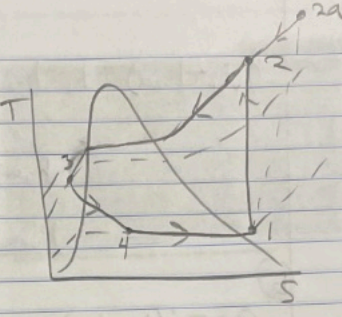

$① \xrightarrow[\text{isentropic}]{\text{compresser}} ② \xrightarrow{\text{condenser}} ③ \xrightarrow[\text{h const}]{\text{expansion}} ④ \xrightarrow[\text{p const}]{\text{evaporator}}$

s const

$P_1 = 200kpa$
$x_1 = 1$
$h_1 = 255.96 \frac{kJ}{kg}$ ✓

$P_2 = 800kpa$
$T_2 = 50°C$
$h_2 = 296.71 \frac{kJ}{kg}$
$s_2 = s_1$ ✓

$P_3 = 750kpa$
$T_3 = 28.31°C$
$h_3 = 91.146 \frac{kJ}{kg}$ ✓

$h_4 = 91.146$
$T_4 = -0.61°C$ ✓

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h_2 @ superheated tables 800kpa & $50°C = 296.71 \frac{kJ}{kg}$
$s_2 = s_1$ $\quad s_2 = 0.9803 \frac{kJ}{kg \cdot K}$
h_1 superheated tables 200kpa & $0.9803 = 255.969 \frac{kJ}{kg}$
interpolated

800kpa @ sat. liquid state $T = 31.31°C$
$T_3 = T_{@800kpa} - 3°C$
$T_3 = 28.31°C$

Sat. liquid tables R-134a $= T_3 =$ interpolate for $h_3 = 91.146 \frac{kJ}{kg}$
$h_3 = h_4$
$T_1 - 4°C = T_4$
$T_1 =$ interpolate w/ s_1 & $s_2 = 3.39°C$
$T_4 = -0.61°C$

ⓐ $\dot{W}_{in} = \dot{m} \cdot cp_{r\text{-}134a} \cdot \Delta T$
$cp_{r\text{-}134} = 1.23 \frac{kJ}{kg \cdot K}$
$\dot{m} = 0.022 \, kg/s$
$\dot{W}_{in} = 0.022 \cdot 1.23 \cdot (50°C - 3.39°C)$
$\dot{W}_{in\,a} = 1.26 \, KW$

ⓐ $\dot{W}_{in} = \dot{m} \cdot \Delta h_{1\text{-}2}$
$\dot{m} \cdot (h_2 - h_1)$
$= 0.6765 \, kW$

ⓢ $\eta = \frac{\dot{W}_{in\,s}}{\dot{W}_{in\,a}} = \boxed{0.537}$

$\eta = \frac{h_1 - h_{2s}}{h_1 - h_{2a}}$ ⟶

$\eta(h_1 - h_{2a}) = h_1 - h_{2s} \rightarrow 0.537h_1 - 0.537h_{2a} =$

$137.43 - 0.537h_{2a} = -30.741$

$-137.43 \qquad\qquad -137.43$

$h_{2a} = \frac{168.171}{0.537}$

$\underline{h_{2a} = 313.168 \frac{kJ}{kg}}$

(b)

$Q_H = \dot{m}(h_2 - h_3)$

$Q_H = 0.022\frac{kg}{s}\left(313.168\frac{kJ}{kg} - 91.146\frac{kJ}{kg}\right)$

$\boxed{Q_H = 4.88\ KW}$

(c) $COP_{HP} = \frac{Q_H}{W_{net\ in}} = \frac{4.88\ KW}{1.26\ KW} = \boxed{3.88 = COP_{HP}}$

(D)

$COP_R = \frac{Q_L}{W_{net\ in}}$

$\dot{Q}_L = \dot{m}(h_1 - h_4)$

$0.022\frac{kg}{s}\left(255.969\frac{kJ}{kg} - 91.146\frac{kJ}{kg}\right) \rightarrow \boxed{3.626 = \dot{Q}_L}$ KW

$COP_R = \frac{3.626\ KW}{1.26\ KW} = \boxed{2.88 = COP_R}$

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$1 \xrightarrow{\text{Isent}} 2 \xrightarrow{P\text{ const.}} 3 \xrightarrow{\text{Isenthalpic}} 4 \xrightarrow{P\text{ const.}}$ $\dot{m}_B = .11\ kg/s$, $h_3 = h_4$

$5 \xrightarrow{\text{Isentropic}} 6 \xrightarrow{P\text{ const}} 7 \xrightarrow{\text{Isenthalpic}} 8 \xrightarrow{P\text{ const}}$ $h_7 = h_8$

State 1: $P_1 = 160\ kPa$, $x_1 = 1$, $s_1 = s_2$, $s_1 = 0.94202\ kJ/kg\cdot K$, $h_1 = 241.14\ kJ/kg$

State 2: $P_2 = 0.5\ MPa$, $s_2 = 0.94202\ kJ/kg\cdot K$

$h_2 @ P_2 \& s_2 = 264.55\ \frac{kJ}{kg}$ (A-13) Interp.

State 3: $P_3 = P_2$, $P_3 = 0.5\ MPa$, $x_3 = 0$, $h_3 = 73.32\ kJ/kg$

State 4: $P_4 = 160\ kPa$, $h_4 = 73.32\ kJ/kg$

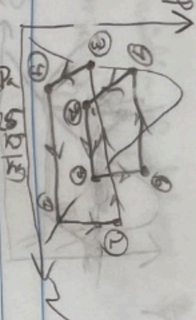
State 5: $P_5 = .4\ MPa$, $x_5 = 1$, $x_5 = 1$, $s_5 = s_6$, $s_5 = 0.92711\ \frac{kJ}{kg\cdot K}$, $h_{5g} = 255.61\ \frac{kJ}{kg}$

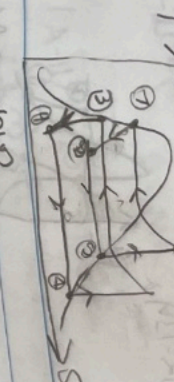
State 6: $P_6 = 1.4\ MPa$, $S_6 = 0.92711\ \frac{kJ}{kg\cdot K}$

$h_6 @ P_6 \& s_6 = 281.58\ \frac{kJ}{kg}$ (A-13) Interp.

State 7: $P_7 = 1.4\ MPa$, $x_7 = 0$, $h_7 @ P_7 = 127.25\ \frac{kJ}{kg}$, $T_7 = 52.4°C$

State 8: $P_8 = P_5$, $P_8 = .4\ MPa$, $h_8 = 127.25\ \frac{kJ}{kg}$





$\eta_{is} = \frac{h_5 - h_{6s}}{h_5 - h_{6a}} \Rightarrow h_{6a} = 223.1475\ \frac{kJ}{kg}$

a.) mass flow rate upper cycle: $(\dot{m}_A)$ -

$\dot{m}_A(h_5 - h_8) = \dot{m}_B(h_2 - h_3) \Rightarrow \dot{m}_A = \frac{\dot{m}_B(h_2 - h_3)}{(h_5 - h_8)} \Rightarrow \boxed{\dot{m}_A = .169\ kg/s}$

b.) Rate of ~~heat~~ removal from refrigerated space: $(\dot{Q}_H)$

$\dot{Q}_H = \dot{m}_A(h_{6a} - h_7) \Rightarrow \boxed{\dot{Q}_H = 16.2\ kW}$

c.) COP of refrigerator: $\frac{\dot{Q}_L}{\dot{W}_{net,in}} \Rightarrow \frac{\dot{m}_B(h_1 - h_4)}{\dot{m}_A(h_5 - h_{6a}) + \dot{m}_B(h_2 - h_1)} \Rightarrow \boxed{2.2}$

11-60 Nathan Cherays
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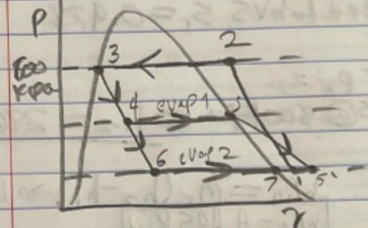

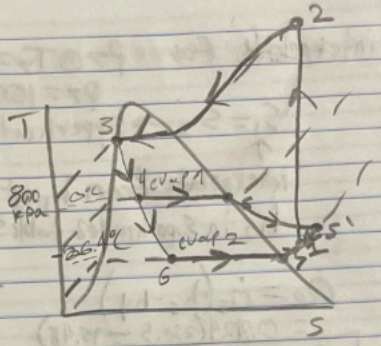

$\dot{Q}_L = 8\,KW \quad \dot{m}_T = 0.1\,kg/s$

7 pconst, 5` pconst $\rightarrow$ ① $\xrightarrow{\text{isentropic compressor}}$ ② $\xrightarrow{\text{pconst}}$ ③ $\xrightarrow{\text{hconst}}$ ④ $\xrightarrow[\text{Tconst}]{\text{pconst}}$ ⑤ $\rightarrow$

① $h_1 = 241.1$, $P_1 = 100\,kPa$

② $P_2 = P_3 = 800\,kPa$, $h_2 = 286.05\,\frac{kJ}{kg}$

③ $X_3 = 0$, $P_3 = 800\,kPa$, $h_3 = 95.48\,\frac{kJ}{kg}$

④ $T_4 = 0°C$, $h_4 = 95.48\,\frac{kJ}{kg}$

⑤ $T_5 = 0°C$, $X_5 = 1$, $h_5 = 250.5\,\frac{kJ}{kg}$

⑤ $\xrightarrow{\text{hconst}}$ ⑤`

$h_5 = h_{5`} = 250.5\,\frac{kJ}{kg}$

③ $\xrightarrow{\text{hconst}}$ ⑥ $\xrightarrow{\text{pconst}}$ ⑦ $\xrightarrow{\text{pconst}}$ ①

⑥ $T_6 = -26.4°C$, $h_6 = 95.48\,\frac{kJ}{kg}$

⑦ $T_7 = -26.4°C$, $h_7 = 234.448\,\frac{kJ}{kg}$, $X_7 = 1$, $P_7 = 100\,kPa$

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③ sat. Liquid → refrigerant 134a @ 800 kPa $= \underline{h_3 = 95.48\,\frac{kJ}{kg}}$

④ $T_4 = 0°C \quad T_5 = T_4 \quad T_6 = T_7$

⑤ $\underline{h_5 @ 0°C = 250.5\,\frac{kJ}{kg}}$

⑦ $h_7 @ -26.4°C \Rightarrow$ interpolate $\rightarrow \underline{h_7 = 234.448\,\frac{kJ}{kg}}$

① 1st law joint

$$\underline{h_1} \cdot \dot{m}_T = \underline{\dot{m}_5} h_5 + \underline{\dot{m}_7} \cdot h_7$$

$$h_1 = \frac{(0.0424 \cdot 250.5) + (0.0575 \cdot 234.448)}{0.1}$$

$$\underline{h_1 = 241.1}$$

$$\dot{Q}_L = \dot{m}_7 \cdot (h_7 - h_6) \rightarrow \frac{8\,KW}{(234.448 - 95.48)} = \dot{m}_7$$

$$\underline{\dot{m}_7 = 0.0575\,\frac{kg}{s}}$$

$$\dot{m}_T = \dot{m}_5 + \dot{m}_7$$

$$0.1\,\frac{kg}{s} - 0.0575 = \dot{m}_5 = \underline{0.0424\,\frac{kg}{s}}$$

interpolate for P_7 @ $T_7 = -26.4°C$ & sat. vapor

$P_7 = 100\ kPa$

$s_1 = s_2 \rightarrow$ superheated tables $s_1 = 0.978$

↑

interpolate from h_1 at P_1

h_2 in superheated tables @ 800 kPa $= \underline{h_2 = 286.05 \frac{kJ}{kg}}$

$\dot{Q}_R = \dot{m}_5 (h_5 - h_4)$

$= 0.0424(250.5 - 95.48)$

$\boxed{\dot{Q}_R = 6.573\ kW}$

$\dot{W}_{in} = \dot{m}_T (h_2 - h_1) \rightarrow 0.1 \frac{kg}{s}(286.05 - 241.1)$

$\boxed{W_{in} = 4.495\ kW}$

$COP_R = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{\dot{m}_5 (h_5 - h_4) + \dot{m}_7 (h_7 - h_6)}{W_{in}}$

$0.0575(234.448 - 95.48)$

$\boxed{COP_R = 3.24} = \frac{6.573\ kW + 7.99\ kW}{4.495\ kW}$