Refrigeration and Air conditioning HomeWork 1

Answers table :

Question 1	a	5.022
	b	2.987 KW
	c	6.022
	d	17.99 KW
Question 2	a	0.0793 m^3/s
	b	20.21 KW
	c	0.356
		0.966
Question 3	a	5.45
	b	5.29
	c	30.25 KW
	d	29.47 KW

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Date : 9/3/2021
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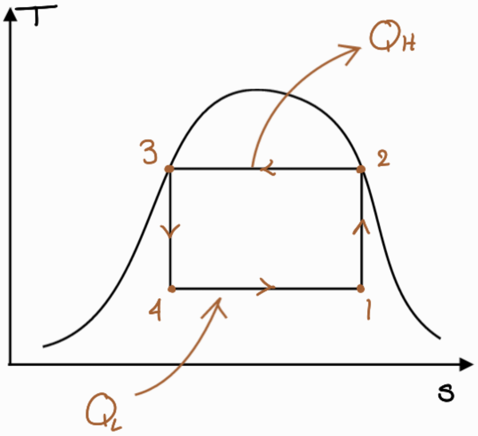
Question 10.1

- Carnot cycle

$T_L = -12°C$

$T_H = 40°C$



a) $COP = \frac{T_L}{T_H - T_L} = \frac{-12 + 273.15}{40 - -12} = 5.022$

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b) $\dot{Q}_L = 15\,kW$ at $T_L = -12°C$

$\dot{W}_{1-2} = ?$

$\dot{Q}_L = h_1 - h_4 = T_L(S_1 - S_4) = (-12 + 273.15)(S_1 - S_4)$

$15 \times 1000 = 261.5\,(S_1 - S_4)$

$(S_1 - S_4) = 57.438\ W/K = \Delta S$

Notice that from the above figure that:

Work done = Area under curve $= (T_H - T_L)\,\Delta S$

$= (40 - -12)(57.438) = 2.987\ KW$

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c) $PF = COP + 1 = 5.022 + 1 = 6.022$

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d) $\dot{Q}_H = h_3 - h_2 = T_H(S_3 - S_2) = (40 + 273.15)(S_3 - S_2)$

But and as shown in the figuree above

$S_1 - S_4 = S_2 - S_3 = 57.438$

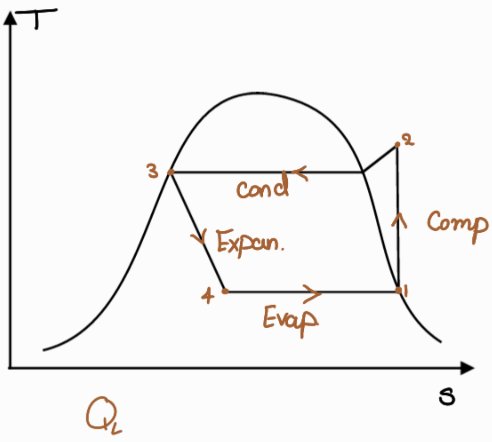
So $\dot{Q}_H = (40 + 273.15)(57.438) = 17986.71\ W = 17.99\ KW$

Question 10.3

Refrigeration capacity $= 80\ kW = \dot{Q}_L$

$T_3 = -8°C$

$T_4 = T_1 = -8$



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

$80 \times 1000 = \dot{m}(h_1 - h_4)$

To find h_1:

We need to make an interpolation between −5°C and −10 since $T_L = -8°C$ (Referring to R410a Tables)

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$y = -8$	$x = ?$
$y_1 = -5$	$x_1 = 275.78$
$y_2 = -10$	$x_2 = 277.53$

$$\frac{-8 - -5}{x - 277.53} = \frac{-10 - -5}{275.78 - 277.53}$$

$x = 276.48 = h_1$

To find h_4:

We need to find h_3 since $h_3 = h_4$.

At point 3, the refrigerant is in the form of saturated liquid and the temperature is $T = 42°C$

We need to interpolate between $T = 40$ and $T = 45$

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$y = 42$	$x = ?$
$y_1 = 40$	$x_1 = 124.09$
$y_2 = 45$	$x_2 = 133.61$

$$\frac{42 - 40}{x - 124.09} = \frac{45 - 40}{133.61 - 124.09}$$

$x = 127.9 = h_3 = h_4$

$\dot{Q}_L = \dot{m}\,(276.48 - 127.9)$

$80 \times 1000 = \dot{m}\,(148.58) \times 1000$

$\dot{m} = 0.5384 \quad Kg/s$

But we need v_1 to find $\dot{V}$

$v_1 = v_g = ?$ at $T = -8°C$

Interpolation:

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$y = -8$	$x = ?$
$y_1 = -10$	$x_1 = 0.04553$
$y_2 = -5$	$x_2 = 0.03848$

$$\frac{-8 - -10}{x - 0.04553} = \frac{-5 - -10}{0.03848 - 0.04553}$$

$x = 0.04271 = v_1$

So: $\dot{V} = \frac{v}{\dot{m}} = \frac{0.04271}{0.5384} = 0.0793 \quad m^3/s$

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b) to calculate the compressor work, we need h_2

we Know that $S_1 = S_2$.

At point 2, the refrigerent is superheated. But we still need to find pressure at this point

$P_2 = P_3 = ? \longrightarrow$ interpolation between 40°, 45°C

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$y = 42$	$x = ?$
$y_1 = 40$	$x_1 = 2420.7$
$y_2 = 45$	$x_2 = 2728.3$

$$\frac{42 - 40}{x - 2420.7} = \frac{45 - 40}{2728.3 - 2420.7}$$

$x = 2543.74 = P_3 = P_2$

we need S_1:

Also by interpolation between $T = -5°C$ and $-10°C$ since $T_L = -8°C$

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

y = -8	x = ?
$y_1 = -5$	$x_1 = 1.0466$
$y_2 = -10$	$x_2 = 1.0567$

$$\frac{-8 - -5}{x - 1.0466} = \frac{-10 - -5}{1.0567 - 1.0466}$$

$x = 1.0526 = S = S_2$

Since we have S and P of the point, we can find h
let $S = 1.0526$, $P = 2500$ (For easier calculations)

First: we interpolate between $S = 1.00998$ and $S = 1.0878$ at $P = 2000$ KPa

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

y = 1.053	x = ?
$y_1 = 1.0099$	$x_1 = 295.49$
$y_2 = 1.0878$	$x_2 = 320.62$

$$\frac{1.053 - 1.00998}{x - 295.49} = \frac{1.0878 - 1.00998}{320.62 - 295.49}$$

$x = 309.39 = h_2'$ at 2000 KPa, 1.053 KJ/kg.K

Do the same for $P = 3000$, $S = 1.053$ between $S = 0.9933$ and $S = 1.0762$

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

y = 1.053	x = ?
$y_1 = 0.9933$	$x_1 = 300.7$
$y_2 = 1.0878$	$x_2 = 329.12$

$$\frac{1.053 - 0.9933}{x - 300.7} = \frac{1.0878 - 0.9933}{329.12 - 300.7}$$

$x = 318.65 = h_2''$ at 3000 KPa, 1.053 KJ/kg

So $h_2 = \frac{h_2' + h_2''}{2} = \frac{309.39 + 318.65}{2} = 314.02$ at $P = 2500$

$$\dot{W} = \dot{m}(h_2 - h_1)$$
$$= 0.5384\,(314.02 - 276.48)$$
$$= 20.21 \text{ KW}$$

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c) fraction of vapor $= \frac{m_{vap}}{m_{total}}$

Using specefic volume and quality (X_m)

$$v_4 = v_f + X_m v_{fg}$$

But v_4 can't be found, so using h_4, h_f, h_{fg} at $T = -8$
We need to interpolate to find h_f, h_{fg}

h_f:

$$\frac{y - y_1}{X - X_1} = \frac{y_2 - y_1}{X_2 - X_1}$$

$y = -8$	$X = ?$
$y_1 = -5$	$X_1 = 50.22$
$y_2 = -10$	$X_2 = 42.8$

$$\frac{-8 - -5}{X - 50.22} = \frac{-10 - -5}{42.8 - 50.22}$$

$$X = 45.77 = h_f$$

h_{fg}:

$$\frac{y - y_1}{X - X_1} = \frac{y_2 - y_1}{X_2 - X_1}$$

$y = -8$	$X = ?$
$y_1 = -5$	$X_1 = 227.13$
$y_2 = -10$	$X_2 = 232.98$

$$\frac{-8 - -5}{X - 227.13} = \frac{-10 - -5}{232.98 - 227.13}$$

$$X = 230.64 = h_{fg}$$

So The vapor fraction: X_m

$$X_m = \frac{h_4 - h_f}{h_{fg}} = \frac{127.898 - 45.77}{230.64} = 0.356$$

To find the fraction in volume basis X_v:

$$V_{total} = V_{liquid} + V_{vapor}$$

But we need $\frac{V_{vapor}}{V_{total}}$

$$1 = \frac{V_{liq}}{V_{tot}} + \underbrace{\frac{V_{vap}}{V_{tot}}}_{X_v}$$

$$1 = \frac{m_{liq}\, v_f}{m_{tot}\, v_4} + X_v$$

$(1 - X_m)$ ← $\frac{m_{liq}}{m_{tot}}$

we need to find v_f by interpolation

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$y = -8$	$x = ?$
$y_1 = -5$	$x_1 = 0.000841$
$y_2 = -10$	$x_2 = 0.000827$

$$\frac{-8 - -5}{x - 0.000841} = \frac{-10 - -5}{0.000827 - 0.000841}$$

$$x = 0.000833 = v_f$$

To find v_4:

$$v_4 = v_f + X_m v_{fg}$$

So we need v_{fg} by interpolation

$$\frac{y-y_1}{x-x_1} = \frac{y_2-y_1}{x_2-x_1}$$

$y = -8$	$x = ?$
$y_1 = -5$	$x_1 = 0.03761$
$y_2 = -10$	$x_2 = 0.0447$

$$\frac{-8 - -5}{x - 0.03761} = \frac{-10 - -5}{0.0447 - 0.03761}$$

$$x = 0.04188 \; v_g$$

Back to v_4

$$v_4 = 0.0008326 + 0.04188\,(0.356)$$

$$v_4 = 0.01574 \; m^3/kg$$

Back to x_v:

$$1 = (1-0.356)\,\frac{x\,0.0008326}{0.01574} + x_v$$

$$x_v = 0.966$$

Question 10.7

a) Without the heat exchanger

$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

h_1 at $T = -10$:

From R22 tables

$h_1 = h_g = 401.2$ KJ/Kg , $s = 1.766$ KJ/Kg.K

$h_2 = ?$ $S_g = S_1 = S_2 = 1.766$ KJ/Kg.K (isentropic compression)

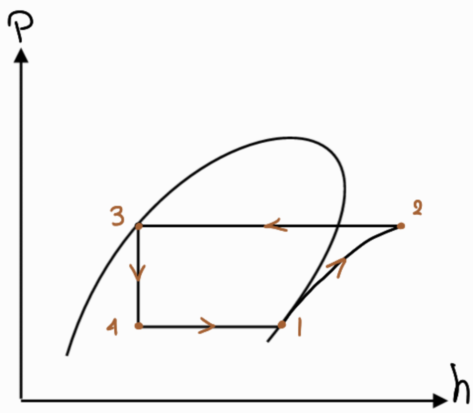
$P_2 = P_3 = 1192$ KPa

Since P = 1192 KPa, I will be assuming that it is 1200 KPa

So S = 1.766 , P = 1200 and Superheated

From Superheated tables:

$h_2 = 431.4$ KJ/Kg



$h_4 = ?$

From the P-h diagram $\rightarrow h_3 = h_4$

At point 3: the refrigerant is saturated liquid

So $h_3 = h_f$ at T = 30°C and P = 1200 KPa ($P_2 = P_3$)

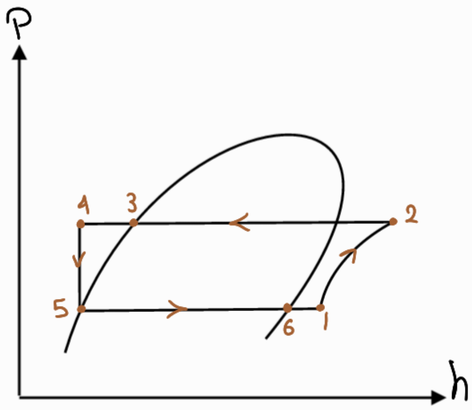
From Saturated tables

$h_3 = 236.6 = h_4$

Back to COP

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{401.2 - 236.6}{431.4 - 401.2} = 5.45$$

b) With a heat exchanger



$$COP = \frac{h_6 - h_5}{h_2 - h_1}$$

To find h_6:

$T = -10$ and saturated vapor

$P_6 = 354.8$ and $h_g = h_6 = 401.2$ KJ/Kg

To find h_1:

$P = 354.8$ KPa ($P_1 = P_6 = P_5$) and superheated (I assumed P tobe 350)

so $h_1 = 411.7$ KJ/Kg and $S_1 = 1.806$ KJ/Kg.K $= S_2$

To find h_2:

$S_1 = 1.806$ KJ/Kg.K and $P = 1200$ KPa (superheated)

$h_2 = 444.825$ KJ/Kg

To find h_5:

h_5 can not be obtained from tables but we know that $h_5 = h_4$

$h_3 - h_4 = h_1 - h_6$

h_3 is from tables where $T = 30°C$ and it is a saturated liquid

$h_3 = h_f = 236.6$ KJ/Kg

So $h_5 = h_3 - h_1 + h_6$

$= 236.6 - 411.7 + 401.2$

$= 226.1$ KJ/Kg

Back to COP:

$$COP = \frac{h_6 - h_5}{h_2 - h_1} = \frac{401.2 - 226.1}{444.825 - 411.7} = 5.286$$

c) $\dot{V} = 12\times10^{-3}$ m^3/s

$\dot{Q}_L = (h_1 - h_4)\dot{m} = (401.2 - 236.6) \times \frac{12\times10^{-3}}{v_1}$

At Point 1, Saturated vapor, $v_1 = v_g = 0.0653$ m^3/Kg

$\dot{Q}_L = (401.2 - 236.6) \times \frac{12\times10^{-3}}{0.0653} = 30.25$ KW

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d) $\dot{V} = 12\times10^{-3}$ m^3/s

$\dot{Q}_L = (h_6 - h_5)\dot{m} = (401.2 - 226.1) \times \frac{12\times10^{-3}}{v_1}$

At Point 1, superheated vapor, $v_1 = 0.0713$ m^3/Kg

$\dot{Q}_L = (401.2 - 226.1) \times \frac{12\times10^{-3}}{0.0713} = 29.47$ KW