Answer Key

POWER PLANT ENGINEERING
Refresher 01

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exponential LEAP
ONLINE REVIEW

1

Zero

2

Greater than zero

3

Increases

4

Adiabatic

5

Energy can be neither created nor destroyed

6

Temperature

7

$V = 90\,ft^3$

$P_1 = 350$ psi $\quad P_2 = 230$ psi

$t_2 = 60\,°F$

$$m = \frac{P_2 V}{R T_2} = \frac{(230 + 14.7)\,psi\left(144\,\frac{in^2}{ft^2}\right)(90\,ft^3)}{(53.3\,lb\text{-}ft/lb\text{-}m\text{-}°R)(60 + 460)\,°R} = 114.4217\,lbs$$

for constant volume process

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{(350 + 14.7)\,psi}{T_1} = \frac{(230 + 14.7)\,psi}{(60 + 460)\,°R}$$

$$T_1 = 775.0\,°R$$

Then;

$$Q = mC_v\Delta T = (114.4217\,lbs)(0.171\,Btu/lb\text{-}°R)(520 - 775)\,°R$$

$$\boxed{Q = -4989.3582\,Btu}$$

exponential LEAP ONLINE REVIEW

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$$\rho = \frac{m}{V}$$

$$62.4\ lb/ft^3 = \frac{12\ lbs}{V}$$

$$V_1 = 0.1923\ ft^3$$

Hence;

$$W = P(V_2 - V_1)$$

$$= \left(14.7 \frac{lb}{in^2}\right)\left(144 \frac{in^2}{ft^2}\right)(300 - 0.1923)\ ft^3$$

$$\boxed{W = 634632.9394\ lb\text{-}ft}$$

9

W=0 for constant volume process

10

$$r_k = \frac{1+c}{c} = \frac{1+0.15}{0.15} = 7.6667$$

$$e_o = 1 - \frac{1}{r_k^{k-1}} = 1 - \frac{1}{7.667^{1.4-1}}$$

$$\boxed{e_o = 55.72\%}$$

11

Is the ratio of the partial pressure of the water vapor to the saturation pressure at the mixture temperature

Exponential LEAP ONLINE REVIEW

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$$W = (3.5\ hp)\left(\frac{2544.5\ Btu/hr}{1hp}\right)\left(\frac{1hr}{60\ min}\right)$$

$$W = 148.4292\ Btu/min$$

$$T_2 = 72°F + 460 = 532°R$$

$$Q_R = 2000\ Btu/min$$

$$\frac{Q_A}{Q_A - Q_R} = \frac{T_1}{T_2 - T_1} ; \quad W = Q_A - Q_R$$

$$148.4292\ \frac{Btu}{min} = Q_A - 2000\ \frac{Btu}{min}$$

$$Q_A = 2148.4292\ \frac{Btu}{min}$$

Then;

$$\frac{2148.4292\ Btu/min}{(2148.4292 - 2000)\ Btu/min} = \frac{T_1}{532°R - T_1}$$

$$T_1 = 497.6335\ °R$$

$$\boxed{t_1 = 37.63\ °F}$$

13

$$\Delta T = 20°F\left(\frac{5}{9}\right)$$

$$\boxed{\Delta T = 11.11°C}$$

14

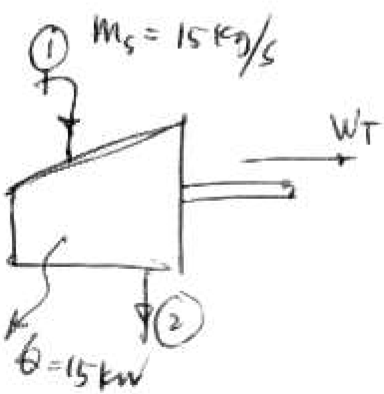
Critical point

15

Compressed liquid

exponential LEAP ONLINE REVIEW

16



$$[E_{IN} = E_{OUT}]$$

$$h_1 = W_T + Q + h_2$$

$$W_T = (h_1 - h_2) - Q$$

$$W_T = (15\ kg/s)(2739 - 2300.5)\ kJ/kg - 15\ kJ/s$$

$$\boxed{W_T = 6562.5\ kW}$$

17

$$\frac{V_1}{V_2} = 6$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^K$$

$$\frac{P_2}{100\ kPa} = (6)^{1.4}$$

$$\boxed{P_2 = 1228.6\ kPa}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{K-1}$$

$$\frac{T_2}{(23+273)K} = 6^{1.4-1}$$

$$\boxed{T_2 = 606.1111\ K}$$

18

$$P = \gamma h = (1.20\ m)(9.81\ kN/m^3)$$

$$\boxed{P = 11.772\ kPa}$$

19

$$Q_A = m(h_1 - h_4) = (0.15\ kg/s)(178 - 55)\ kJ/s$$

$$Q_A = 18.45\ kW$$

$$COP = \frac{Q_A}{W_c} = \frac{18.45\ kW}{3\ kW}$$

$$\boxed{COP = 6.15}$$

20

Rankine

21

Expansion valve

22

1000 dynes/sq cm

23

$$[E_{in} = E_{out}]$$

$$h_1 + W = h_2 + Q$$

$$Q = -(h_2 - h_1) + W$$

$$= -\left(140.543\ \mathrm{kJ/kg}\right)\left(\frac{17.52}{60}\ \mathrm{kg/s}\right) + 48.\dot{5}\ \mathrm{kW}$$

$$\boxed{Q = 7.4614\ \mathrm{kW}}$$

24

T, deg C	P, kPa	hf	hfg	hg
2	462.49	190.4	1255.2	1445.6
26	1033.97	303.6	1162	1465.6

$$h_3 = h_4$$

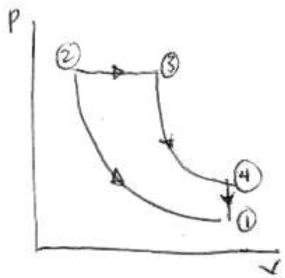
$$h_3 = h_f + x\, h_{fg}$$

$$303.6\ \text{kJ/kg} = 190.4\ \text{kJ/kg} + x(1255.2\ \text{kJ/kg})$$

$$\boxed{x = 9.02\%}$$

25

$$e_{oc} = 1 - \frac{Q_R}{Q_A} = 1 - \frac{T_4 - T_1}{k(T_3 - T_2)}$$



$P_1 = 90\text{ kPa}$ $\quad T_1 = 300\text{ K}$

$r_k = \frac{V_1}{V_2} = 15$

$T_3 = 2050\text{ K}$

Process 1-2: Isentropic Process

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\frac{T_2}{300\text{ K}} = (15)^{1.4-1}$$

$$T_2 = 886.2531\text{ K}$$

Process 2-3: Isobaric Process

$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$

$$\frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{2050\text{ K}}{886.2531\text{ K}} = 2.3131$$

$$V_3 = 2.3131 V_2 = 2.3131\left(\frac{V_1}{15}\right)$$

$$\frac{V_1}{V_3} = 6.4848$$

Process 3-4; isentropic process

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\frac{k-1}{k}} = \left(\frac{V_1}{V_3}\right)^{k-1}$$

$$\frac{2050\text{ K}}{T_4} = (6.4848)^{1.4-1}$$

$$T_4 = 970.4993\text{ K}$$

subst;

$$e_{oc} = 1 - \frac{(970.4993 - 300)\text{ K}}{(1.4)(2050 - 886.2531)\text{ K}}$$

$$\boxed{e_{oc} = 58.85\%}$$

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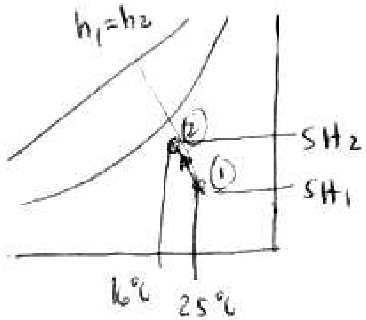

assuming $h_1 = h_2$

$$(h = c_p t + SH\,h_g)$$

$$C_p t_1 + SH_1 h_g = C_p t_2 + SH_2 h_g$$

$$SH_2 = 0.622\left[\frac{P_v}{P_B - P_v}\right] = 0.622\left[\frac{1.8181\ \text{kPa}}{(100 - 1.8181)\ \text{kPa}}\right]$$

$$SH_2 = 0.01151$$

$$\left(1.0062\ \tfrac{kJ}{kg\text{-}K}\right)(25) + SH_1\left(2547.7\ \tfrac{kJ}{kg}\right) = \left(1.0062\ \tfrac{kJ}{kg\text{-}K}\right)(16) + \left(0.01151\ \tfrac{kg_v}{kg_a}\right)\left(2531.0\ \tfrac{kJ}{kg}\right)$$

$$SH_1 = 0.00789\ kg_v/kg_a$$

and; $PV = mRT$

$$(100\ kPa)\left(28.3\ m^3/s\right)\left(\frac{60\ s}{1\ min}\right) = m_a\left(0.287\ \tfrac{kJ}{kg\text{-}K}\right)(25+273)K$$

$$m_a = 1985.3612\ kg/min$$

then;

$$SH_1 = \frac{m_v}{m_a}$$

$$0.00789\ \frac{kg_v}{kg_a} = \frac{m_v}{1985.3612\ kg/min}$$

$$\boxed{m_v = 15.6645\ kg_v/min}$$

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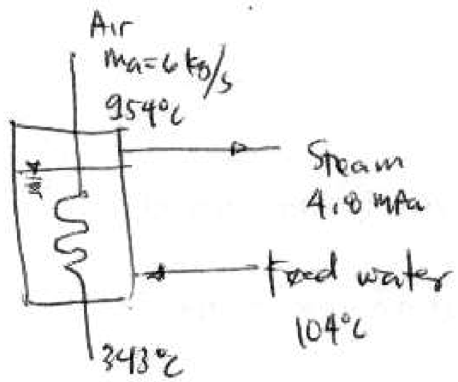

h_f = enthalpy of feedwater $= C_p t = (4.187 \text{ KJ/kg-K})(104°C)$

$h_f = 435.448$ KJ/kg

Heat loss = Heat Gain

$m_g C_{pg}(t_1 - t_2) = m_s(h_s - h_f)$

$(6 \text{ kg/s})(1.0062 \text{ KJ/kg-K})(954 - 343)°C = m_s(2796 - 435.45) \text{ KJ/kg}$

$\boxed{m_s = 1.5627 \text{ kg/s}}$

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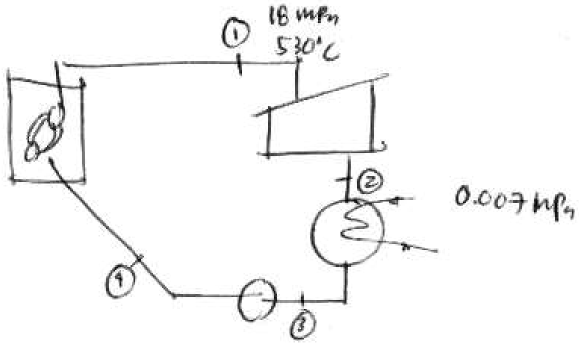


$$W_p = \frac{\bar{v}_3 (P_4 - P_3)}{\eta_p}$$

where; $\bar{v}_3 = \dfrac{1}{1000\ kg/m^3} = 0.001\ m^3/kg$

Bec. of the pressure loss at the inlet

$P_4 = 18\ MPa + 1.5\ MPa = 19.5\ MPa$

$P_4 = 19500\ kPa$

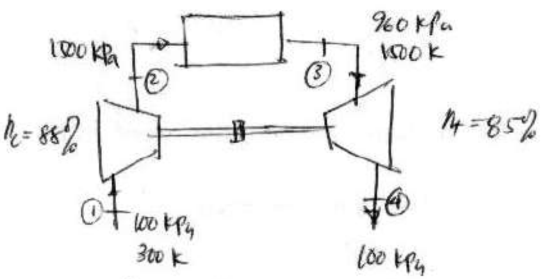
$P_3 = 0.007\ MPa = 7\ kPa$

Hence;

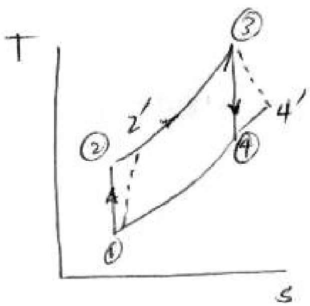
$$W_p = \frac{(0.001\ m^3/kg)(19500 - 7)\ kPa}{0.65}$$

$$\boxed{W_P = 30\ kJ/kg}$$

29



$\dot{V} = 8\ m^3/s$



$$\eta_0 = \frac{W'_{NET}}{Q_A}$$

$$W_{NET} = W_T' - W_C'$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$\frac{T_2}{300\ K} = (11)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 595.1988\ K$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}}$$

$$\frac{1500\ K}{T_4} = \left(\frac{960\ kPa}{100\ kPa}\right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 786.0358\ K$$

Solving for mass of air

$$PV = mRT$$

$$(100\ kPa)(8\ m^3/s) = m(0.287\ kJ/kg\text{-}K)(300\ K)$$

$$m_a = 9.2915\ kg/s$$

Subst;

$$W_T = (9.2915\ kg/s)(1.0062\ kJ/kg\text{-}K)(1500 - 786.0358)\ K$$

$$W_T = 6674.9434\ kW$$

$$W_T' = (6674.934\ kW)(0.85) = 5673.7018\ kW$$

29 cont…

$$W_c = m C_p (T_2 - T_1)$$

$$W_c = (9.2915\ kg/s)(1.0062\ KJ/kg\text{-}K)(595.1988 - 300)K$$

$$W_c = 2759.8452\ kW$$

$$W_c' = \frac{2759.8452\ kW}{0.88} = 3136.1878\ kW$$

$$W_{NET} = (5673.7018 - 3136.1878)\ kW$$

$$W_{NET} = 2537.5140\ kW$$

$$Q_A = m C_p (T_3 - T_2)$$

$$= (9.2915\ kg/s)(1.0062\ KJ/kg\text{-}K)(1500 - 595.1988)K$$

$$Q_A = 8459.0835\ kW$$

Hence;

$$\eta_B = \frac{2537.5140\ kW}{8459.0835\ kW}$$

$$\boxed{\eta_B = 30\%}$$

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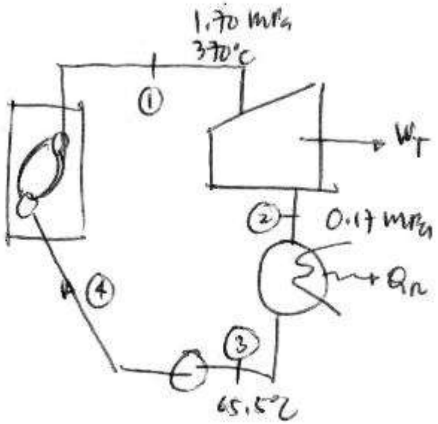
Air cooler

31



$h_1 = 3187.1\ \text{kJ/kg}$

Solving for h_2;

$s_1 = s_2$

$s_1 = s_f + x s_{fg}$

$7.1081\ \text{kJ/kg-K} = 1.4752\ \text{kJ/kg-K} + x_2 (5.7062\ \text{kJ/kg-K})$

$x_2 = 0.9871$

$h_2 = h_f + x_2 h_{fg} = 483.20\ \text{kJ/kg} + 0.9871(2216.0\ \text{kJ/kg})$

$h_2 = 2670.6$

$h_3 = h_4 = 274.14\ \text{kJ/kg}$

31 cont…

$$W_T = \eta_T (h_1 - h_2) = (0.75)(3187.1 - 2670.6)\ \text{KJ/kg}$$

$$W_T = 387.375\ \text{KJ/kg}$$

$$Q_R = \eta_{cond} (h_2 - h_3) = (0.85)(2670.6 - 274.14)\ \text{KJ/kg}$$

$$Q_R = 2036.991\ \text{KJ/kg}$$

$$Q_A = \frac{h_1 - h_4}{\eta_{boiler}} = \frac{(3187.1 - 274.14)\ \text{KJ/kg}}{0.80}$$

$$Q_A = 3641.2\ \text{KJ/kg}$$

Hence;

$$\text{Cogeneration Efficiency} = \frac{W_T + Q_R}{Q_A} = \frac{(387.375 + 2036.991)\ \text{KJ/kg}}{3641.2\ \text{KJ/kg}}$$

$$\boxed{\text{Cogeneration Efficiency} = 66.58\ \%}$$

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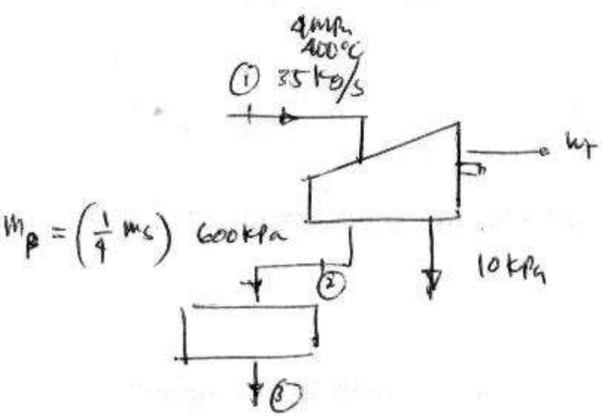


$s_1 = s_2 = s_f + x_2 s_{fg}$

$6.7690\ kJ/kg\text{-}K = 1.9312\ kJ/kg\text{-}K + x_2 (4.8288\ kJ/kg\text{-}K)$

$x_2 = 1.00$ (sat'd vapor)

$h_2 = h_f + x_2 h_{fg}$

$h_2 = 670.56 + (1.00)(2086.3\ kJ/kg)$

$= 2756.9\ kJ/kg$

$h_3 = h_f = 670.56\ kJ/kg$

Hence;

$Q = m_p (h_2 - h_3) = \frac{1}{4}(35\ kg/s)(2756.9 - 670.56)\ kJ/kg$

$\boxed{Q = 18\,255.475\ kW}$

33

138.5 kPa	415.3 kPa
28°C	188°C
0.03 m³	0.03 m³
m_1	m_2

Volume of each part $= \frac{0.060\ m^3}{2} = 0.03\ m^3$

Solving for m_1 & m_2

$P_1V_1 = m_1RT_1$

$(138.5\ kPa)(0.03 m^3) = m_1(0.287\ kJ/kg\text{-}K)(28+273)K$

$m_1 = 0.04810\ kg$

$P_2V_2 = m_2RT_2$

$(415.3\ kPa)(0.03 m^3) = m_2(0.287\ kJ/kg\text{-}K)(188+273)K$

$m_2 = 0.09417\ kg$

Solving for final temperature t_f of the system:

$Q_{loss} = Q_{gain}$

$m_2\cancel{C_v}(t_2 - t_f) = m_1\cancel{C_v}(t_f - t_1)$

$(0.09417 kg)(461 - t_f) = (0.04810 kg)(t_f - 301)$

$t_f = 406.9057\ K$

33 cont…

then;

$$\Delta S = mC_v \ln\left(\frac{T_f}{T_1}\right)$$

$$\Delta S_1 = m_1 C_v \ln\left(\frac{T_f}{T_1}\right) = (0.04810\ kg)(0.7186\ kJ/kg\text{-}K)\ln\left(\frac{406.9057\ K}{301\ K}\right)$$

$$\Delta S_1 = 0.01042\ kJ/K$$

$$\Delta S_2 = M_2 C_v \ln\left(\frac{T_f}{T_1}\right) = (0.09417\ kg)(0.7186\ kJ/kg\text{-}K)\ln\left(\frac{406.9057\ K}{461\ K}\right)$$

$$\Delta S_2 = -8.4464 \times 10^{-3}\ kJ/K$$

Hence; ΔS of the system;

$$\Delta S = \Delta S_2 - \Delta S_1$$

$$= (-8.4464 \times 10^{-3}\ kJ/K) - (0.01042\ kJ/K)$$

$$\boxed{\Delta S = -0.01887\ kJ/K}$$

34

$$W = m(h_2 - h_1)$$

$$75.5\,kW = m(382 - 338.14)\,KJ/kg$$

$$m = 1.7317\,kg/s$$

And;

$$Q = m(h_1 - h_4)$$

$$= (1.7317\,kg/s)(338.4 - 248.15)\,KJ/kg$$

$$Q = 156.2815\,KW$$

Hence,

$$COP = \frac{Q_A}{W_c} = \frac{156.2815\,KW}{75.5\,KW}$$

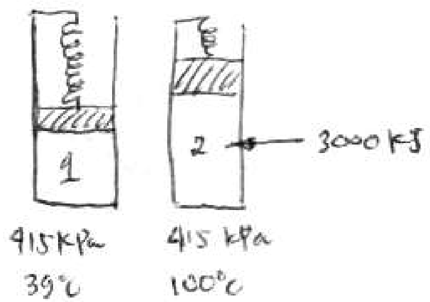
$$\boxed{COP = 2.0699}$$

35

$$Q - 0.30Q = 1200 \text{ kW-h}$$

$$\boxed{Q = 1714.2857 \text{ kW-h}}$$

36



M = Molecular weight of NH_3

$$M = (14)(1) + (1)(3) = 17 \text{ kg/kg}$$

and;

$$R = \frac{\bar{R}}{M} = \frac{8.314 \text{ kJ/kg-K}}{17 \text{ kg/kg}} = 0.4891 \text{ kJ/kg-K}$$

Solving for V_1 and V_2

$$V_1 = \frac{mRT_1}{P_1} = \frac{(25 \text{ kg})(0.4891 \text{ kJ/kg-K})(312 \text{ K})}{415 \text{ KPa}} = 9.1927 \text{ m}^3$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{(25 \text{ kg})(0.4891 \text{ kJ/kg-K})(373 \text{ K})}{415 \text{ KPa}} = 10.99 \text{ m}^3$$

Hence;

$$W_{nf} = P(V_2 - V_1) = (415 \text{ KPa})(10.99 - 9.1927) \text{m}^3$$

$$\boxed{W_{nf} = 745.8795 \text{ kJ}}$$

37

Degree of saturation

38

Carnot

39

A valve designed to allow a fluid to pass in one direction only

40

$$\eta_{cc} = \frac{W}{Q_A} = \frac{Q_A - Q_R}{Q_A} = \frac{T_H - T_c}{T_H}$$

$$\frac{(150 - 50)\,Btu}{150\,Btu} = \frac{1260\,°R - T_c}{1260\,°R}$$

$$T_c = 420\,°R$$

$$\boxed{t_c = -40\,°F}$$

41

$$\eta_{c} = \frac{T_H - T_c}{T_H} = \frac{(1760 - 690)°R}{1760°R} * 100\%$$

$$\boxed{\eta_{c} = 60.79\%}$$

42

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{(48 + 14.7)\,\text{psia}}{(82 + 460)\,^{\circ}R} = \frac{P_2}{(140 + 460)\,^{\circ}R}$$

$$\boxed{P_2 = 69.4096 \text{ psia}}$$

43

$$\eta_{cc} = \frac{W}{Q_A} = \frac{T_H - T_C}{T_H}$$

$$\frac{18\ kW}{38\ kJ/s} = \frac{T_H - 303\ K}{T_H}$$

$$T_H = 575.7\ K$$

$$\boxed{t_H = 115.7°C}$$

44

$$\dot{Q} = \frac{1\,kW}{m^2}(1\,m^2) = 1\,kW = 1000\,W$$

$$m = \left(\frac{3.5\,L}{min}\right)\left(1000\,\frac{kg}{m^3}\right)\left(\frac{1\,m^3}{1000\,L}\right)\left(\frac{1\,min}{60\,s}\right) = 0.05833\,kg/s$$

and; $Q = m\,C_p\,\Delta T$

$$1000\,\frac{J}{s} = (0.05833\,kg/s)(4187\,J/kg\text{-}K)\,\Delta T$$

$$\boxed{\Delta T = 4.0945\,°C}$$

45

$$Q = mC_p \Delta T$$

$$540\text{ kJ} = (1\text{ kg})\,C_p\,(800 - 320)\text{ k}$$

$$\boxed{C_p = 1.125\ \text{kJ}/\text{kg-k}}$$

46

$$W = 1300 \text{ W-hr}$$
$$= 1.3 \text{ kW-hr}$$
$$= \left(1.3 \frac{\text{kJ}}{\cancel{s}} - \cancel{\text{hr}}\right)\left(\frac{3600 \cancel{s}}{1 \cancel{\text{hr}}}\right) = 4680 \text{ kJ}$$

$$\eta_o = \frac{W}{Q_A}$$

$$0.4 = \frac{4680 \text{ kJ}}{Q_A}$$

$$\boxed{Q_A = 11700 \text{ kJ}}$$

47

Solving for the mass of air 710 kPa

$$P_1V_1 = mRT_1$$

$$(710\ kPa)(3\ m^3) = m_1(0.287\ KJ/kg\text{-}K)(30+273)\ K$$

$$m_1 = 24.4937\ kg$$

Solving for the mass of air 190 kPa

$$P_2V_2 = mRT_2$$

$$(190\ kPa)(3\ m^3) = m_2(0.287\ KJ/kg\text{-}K)(30+273)\ K$$

$$M_2 = 6.5547\ kg$$

Percentage mass reduced:

$$\%\ reduced = \frac{(24.4937 - 6.5547)\ kg}{24.4937\ kg}$$

$$\boxed{\%\ reduced = 73.24\ \%}$$

48

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^k$$

$$\frac{P_2}{98\ kPa} = \left(\frac{0.30\ m^3}{0.01\ m^3}\right)^{1.4}$$

$$P_2 = 11460.2959\ kPa$$

Hence;

$$W_{NF} = \frac{P_2V_2 - P_1V_1}{k-1} = \frac{(11460.2959\ kPa)(0.01\ m^3) - (98\ kPa)(0.30\ m^3)}{1.4-1}$$

$$\boxed{W_{NF} = 213\ kJ/kg}$$

49

$$r_k = \frac{1+c}{c} = \frac{1+0.08}{0.08} = 13.5$$

$$\eta_o = \frac{W}{Q_A} = 1 - \frac{1}{r_k^{k-1}}$$

$$\frac{320\,kW}{Q_A} = 1 - \frac{1}{13.5^{1.4-1}}$$

$$Q_A = 494.6475\ kW$$

Here;

$$W = Q_A - Q_R$$

$$320\,kW = 494.6475\,kW - Q_R$$

$$\boxed{Q_R = 174.6475\ kW}$$

50

For Throttling process:

$$h_3 = h_4 = h_f + x_4 h_{fg}$$

$$249.686 \text{ KJ/kg} = 188.426 \text{ KJ/kg} + x_4 (401.60 - 188.426) \text{ KJ/kg}$$

$$\boxed{x_4 = 0.2874}$$

51

Equals the increase in enthalpy

Exponential LEAP ONLINE REVIEW

52

$T_1 = (25 + 273)\,K = 298\,K$

pressure ratio $= r_p = \frac{P_2}{P_1} = \frac{P_3}{P_4} = 9$

$T_3 = (1200 + 273)\,K = 1473\,K$

$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$

$\frac{T_2}{298\,K} = (9)^{\frac{1.4-1}{1.4}} = 558.2863\,K$

for compressor work

$W_c = m C_p (T_2 - T_1)$

$\frac{W_c}{m} = (1.0062\,KJ/kg\text{-}K)(558.2863 - 298)\,K = 261.9\,KJ/kg$

and;

$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}}$

$\frac{T_4}{1473\,K} = \left(\frac{1}{9}\right)^{\frac{1.4-1}{1.4}}$

$T_4 = 786.2525\,K$

for heat added

$Q_A = m C_p (T_3 - T_2)$

$\frac{Q_A}{m} = (1.0062\,KJ/kg\text{-}K)(1473 - 558.2863)\,K = 920.3849\,KJ/kg$

for turbine work;

$W_T = m C_p (T_3 - T_4)$

$\frac{W_T}{m} = (1.0062\,KJ/kg\text{-}K)(1473 - 786.2525)\,K = 691\,KJ/kg$

for the cycle efficiency;

$\eta_B = \frac{W_T - W_c}{Q_A} = \frac{(691 - 261.9)\,KJ/kg}{920.3849\,KJ/kg} \times 100\%$

$\boxed{\eta_B = 46.62\%}$

53

refrigeration system;

$$1 \text{ ton} = \left(3.516 \text{ KJ/sec}\right)\left(\frac{3600 \text{ sec}}{1 \text{ hr}}\right) = 12660 \text{ KJ/hr}$$

54

Carnot cycle efficiency

$$\eta_c = 1 - \frac{T_2}{T_1} = 1 - \frac{(250+273)K}{(1380+273)K} * 100\%$$

$$\boxed{\eta_c = 68{,}36\%}$$

55

$$SHF = \frac{Q_s}{Q_T}$$

$$0.78 = \frac{Q_s}{110}$$

$$\boxed{Q_s = 85.8}$$

56

$$h_1 = h_f + x\,h_{fg}$$

$$h_1 = 962.11\ \text{kJ/kg} + (0.98)(1841.0\ \text{kJ/kg}) = 2766.3\ \text{kJ/kg}$$

$$Q = h_2 - h_1 = (3171.8 - 2766.3)\ \text{kJ/kg}$$

$$\boxed{Q = 405.5\ \text{kJ/kg}}$$

57

$$P_{atm} = (758\ mmHg)\left(\frac{101.325\ kPa}{760\ mmHg}\right) = 101.0584\ kPa$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{(170 + 101.0584)\ kPa}{(32 + 273)\ K} = \frac{P_2}{(65 + 273)\ K}$$

$$P_2 = 300.3860\ kPa_a - 101.0584\ kPa$$

$$\boxed{P_2 = 199.3276\ kPa\ gauge}$$

58

Heat loss = Heat gain

$$m(h_2 - h_1)_w = m(h_2 - h_1)_{air}$$

$$\left(130\ \tfrac{kg}{s}\right)(167.48 - 121.43)\ \tfrac{kJ}{kg} = m_{air}(166 - 72.5)\ \tfrac{kJ}{kg}$$

$$m_{air} = 64.0267\ \tfrac{kg}{s}$$

Amount of make up water = amount of moisture absorbed by air

$$M_w = \left(64.0267\ \tfrac{kg}{s}\right)(0.0488 - 0.013)\ \tfrac{kg}{kg}\left(\frac{3600\ s}{1\ hr}\right)$$

$$\boxed{M_w = 8251.7659\ \tfrac{kg}{hr}}$$

59

$$e_D = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] = 1 - \frac{1}{22^{1.4-1}}\left[\frac{6^{1.4} - 1}{1.4(6-1)}\right]$$

$$e_D = 0.5318$$

and from; $Q = mC_p(T_3 - T_2)$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\frac{T_2}{301K} = (20)^{1.4-1} = 997.6507\ K$$

$$\frac{V_2}{T_2} = \frac{V_3}{T_3}$$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}$$

$$\frac{T_3}{997.6507K} = 6$$

$$T_3 = 5985.9039\ K$$

subst;

$$Q_A = mC_p\,\Delta T = (1.0062\ KJ/kg\text{-}K)(5985.9039 - 997.6507)K$$

$$Q_A = 5019.1804\ KJ/kg$$

Hence;

$$e_D = \frac{W_{NET}}{Q_A} * 100\%$$

$$0.5318 = \frac{W_{NET}}{5019.1804\ KJ/kg}$$

$$\boxed{W_{NET} = 2669.2001\ KJ/kg}$$

60

$$Q = mC_p \Delta T$$

$$(0.480\ \text{kcal})\left(\frac{4.187\ \text{kJ}}{1\ \text{kcal}}\right) = (2L)(1\ \text{kg}/L)(4.187\ \text{kJ}/\text{kg}\cdot{}^\circ\text{C})(t_f - 300\ \text{K})$$

$$t_f = 300.24\ \text{K}$$

$$\boxed{t_f = 27.24\ {}^\circ\text{C}}$$

61

$$\eta_H = \frac{\text{Heat absorbed}}{\text{Heat supplied}}$$

$$0.95 = \frac{m_L\,(697.22 - 105.5)\ \text{KJ/kg}}{(0.870\ \text{kg/s})(2763.5 - 697.22)\ \text{KJ/kg}}$$

$$\boxed{m_L = 2.8861\ \text{kg/s}}$$

62

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(743\ mmHg)(460\ cc)}{(25+273)K} = \frac{(760\ mmHg)V_2}{(0+273)K}$$

$$\boxed{V_2 = 411.9831\ cc}$$

63

Saturation temperature for the existing pressure

64

Trapping the steam and letting water through

65

Air pressure

Relative humidity

67

Third law of thermodynamics

68

$$COP = \frac{T_L}{T_H - T_L} = \frac{(-15+273)\,K}{(310\,K) - (-15+273)\,K}$$

$$\boxed{COP = 4.9615}$$

69

Dew point

70

$$\Delta s = mc_p \ln\left(\frac{T_2}{T_1}\right) = (30\,kg)\left(0.42\,kJ/kg\text{-}K\right)\ln\left(\frac{283\,K}{450\,K}\right)$$

$$\boxed{\Delta s = -5.8439\ kJ/K}$$

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By pass factor

$$BPF = \frac{120°F - 95°F}{120°F - 65°F}$$

$$\boxed{BPF = 0.4545}$$

72

Dew point temperature

73

$s_1 = s_2 = s_f + x_2 s_{fg}$

$6.4085\ kJ/kg\text{-}K = 1.0910\ kJ/kg\text{-}K + x_2(6.5029\ kJ/kg\text{-}K)$

$x_2 = 0.8177$

$h_2 = h_f + x_2 h_{fg} = 340.49\ kJ/kg + 0.8177(2645.9 - 340.49)\ kJ/kg$

$h_2 = 2225.6\ kJ/kg$

for h_4;

$h_3 = h_f = 340.49\ kJ/kg$

$W_p = h_4 - h_3 = v_3(P_2 - P_1)$

$h_4 - 340.49\ kJ/kg = 0.00103\ m^3/kg\,(2500 - 50)\ kPa$

$h_4 = 343.01\ kJ/kg$

Thermal eff:

$$\eta_t = \frac{W_T - W_P}{Q_A} * 100\%$$

$$\eta_t = \frac{(2880.1 - 2225.6) - 2.52\ kJ/kg}{(2880.1 - 343.01)\ kJ/kg} * 100\%$$

$$\boxed{\eta_T = 25.7\%}$$

74

$$RH = \frac{P_v}{P_{sat}}$$

$$0.85 = \frac{P_v}{(5.628\ kPa)}$$

$$P_v = 4.7838\ kPa$$

$$SH = 0.622\left[\frac{P_v}{P_B - P_v}\right]$$

$$= 0.622\left[\frac{4.7838\ kPa}{(110 - 4.7838)\ kPa}\right]$$

$$SH = 0.02828\ kg/kg_a$$

Solving for the mass of air

$$V_{room} = (4m)(4m)(4m) = 64\ m^3$$

$$PV = mRT \quad ; \quad P_B = P_a + P_v$$

$$(110\ kPa - 4.7838)\ kPa\,(64\ m^3) = m_a\left(0.287\ kJ/kg\text{-}K\right)(38 + 273)$$

$$m_a = 75.4432\ kg_a$$

Hence;

$$m_v = \left(0.02828\ \frac{kg_v}{kg_a}\right)\left(75.4432\ kg_a\right)$$

$$\boxed{m_v = 2.1335\ kg_v}$$

75

Regeneration

76

cogeneration

77

$$PV = mRT$$

$$\rho = \frac{m}{V} = \frac{P}{RT}$$

$$= \frac{(750\ \text{mm Hg})\left(\frac{101.325\ \text{kPa}}{760\ \text{mm Hg}}\right)}{(0.287\ \text{kJ/kg-K})(23+273)\,\text{K}}$$

$$\boxed{\rho = 1.177\ \text{kN/m}^3}$$

78

Actual horsepower delivered to the engine shaft

79

$h_1 = 3207.2 \ \mathrm{KJ/kg}$

$h_2 = h_f + x h_{fg}$

$= 251.40 \ \mathrm{KJ/kg} + (0.85)(2609.7 - 251.40) \ \mathrm{KJ/kg}$

$h_2 = 2255.955 \ \mathrm{KJ/kg}$

Hence;

$W_T = (3207.2 - 2255.955) \ \mathrm{KJ/kg}$

$\boxed{W_T = 951.245 \ \mathrm{KJ/kg}}$

80

increase efficiency

81

Maximum attainable effective temperature

82

Back work ratio

83

Dual cycle

84

$$Q_A = mC_v(T_3 - T_2)$$

$$\frac{Q_A}{m} = \left(0.7186\ \text{KJ/kg-K}\right)(3273 - 893)\text{K} = 1710.268\ \text{KJ/kg}$$

$$e_0 = \frac{W}{Q_A} = \frac{910\ \text{KJ/kg}}{1710.268\ \text{KJ/kg}} = 53.20\%$$

and;

$$e_0 = 1 - \frac{1}{r_k^{k-1}} \quad ; \quad 0.5320 = 1 - \frac{1}{r_k^{1.4-1}}$$

$$\boxed{r_k = 6.6740}$$

85

Monochlorodiflouromethane

86

$$e_0 = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]$$

$$= 1 - \frac{1}{14^{1.33-1}}\left[\frac{2.5^{1.33} - 1}{1.33(2.5-1)}\right]$$

$$e_0 = 0.50$$

Then; for the brake thermal efficiency

$$e_B = \frac{(1\ \text{kw-hr})(3600)}{11310.1\ \text{kJ}} = 0.3183$$

Hence;

$$e_0 = \frac{\text{output}}{\text{input}} = \frac{e_B}{e_e}$$

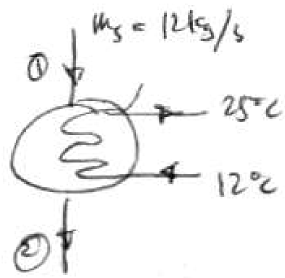
$$0.50 = \frac{0.3183}{e_e}$$

$$\boxed{e_e = 63.66\%}$$

87

Heat of vaporization

88



By heat balance in the condenser

$$m_s (h_1 - h_2) = m_w C_p (t_2 - t_1)$$

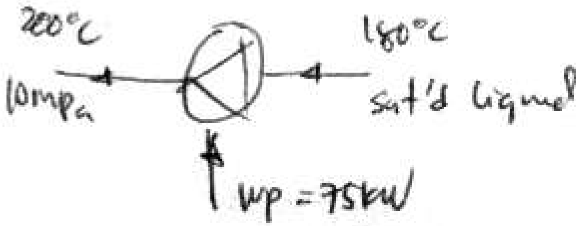
$$(12\ kg/s)(2580 - 180)\ kJ/kg = m_w (4.187\ kJ/kg\text{-}K)(12 - 25)°C$$

$$\boxed{m_w = 529.1102\ kg/s}$$

89

Avogadro’s number

90



$$h_2 - h_1 = v_f \left(P_2 - P_1\right)$$

$$h_2 - 763.22 \ \mathrm{KJ/kg} = 0.0011274 \ \frac{m^3}{kg} \left(10000 - 1002.1\right) \mathrm{KPa}$$

$$h_2 = 773.36 \ \mathrm{KJ/kg}$$

Hence;

$$WP = m_s \left(h_2 - h_1\right)$$

$$80 \ \mathrm{kW} = m_s \left(773.36 - 763.22\right) \mathrm{KJ/kg}$$

$$\boxed{m_s = 7.8895 \ \mathrm{kg/s}}$$

91

Hertz

92

Steel

93

Constant

94

Decreases

95

$$m_o h_o + m_r h_r = m_T h_s$$

$$(3\ \mathrm{kg/s})(92\ \mathrm{kJ/kg}) + (9\ \mathrm{kg/s})(55\ \mathrm{kJ/kg}) = (3+9)\ \mathrm{kg/s}\,(h_s)$$

$$h_s = 64.25\ \mathrm{kJ/kg}$$

Air conditioning capacity:

$$Q = m_s (h_4 - h_1)$$

$$= (3+9)\ \mathrm{kg/s}\,(64.25 - 45)\ \mathrm{kJ/kg}$$

$$\boxed{Q = 231\ \mathrm{kW}}$$

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$$m_o + m_r = m_T$$

$$m_o = 0.30 m_r$$

$$m_r = 3.3333 m_o$$

subst;

$$m_o + 3.3333 m_o = 16 \text{ kg/s}$$

$$\boxed{m_o = 3.6926 \text{ kg/s}}$$

97

$$RH = \frac{P_v}{P_{sat}}$$

$$0.75 = \frac{P_v}{4.245\ kPa}$$

$$P_v = 3.1837\ kPa$$

and;

$$SH = 0.622\left[\frac{P_v}{P_B - P_v}\right] = 0.622\left[\frac{3.1837\ kPa}{(100 - 3.1837)\ kPa}\right]$$

$$\boxed{SH = 0.02045\ kg_v/kg_a}$$

98

$$SH = 0.622\left[\frac{P_v}{P_B - P_v}\right]$$

$$0.048\ kg_v/kg_a = 0.622\left[\frac{P_v}{100\ kPa - P_v}\right]$$

$$\boxed{P_v = 7.1642\ kPa}$$

99

$$\rho = \frac{m}{V} = \frac{P_a}{RT}$$

$$1.10\ \frac{kg}{m^3} = \frac{P_a}{\left(0.287\ \text{kJ}/\text{kg-K}\right)\left(36+273\right)\text{K}}$$

$$P_a = 97.5513\ \text{kPa}$$

and;

$$P_B = P_a + P_v$$

$$100\ \text{kPa} = 97.5513\ \text{kPa} + P_v$$

$$P_v = 2.4487\ \text{kPa}$$

Hence;

$$SH = 0.622\left[\frac{P_v}{P_B - P_v}\right] = 0.622\left[\frac{2.4487\ \text{kPa}}{(100 - 2.4487)\ \text{kPa}}\right]$$

$$\boxed{SH = 0.01561\ \text{kg}_v/\text{kg}_a}$$

100

$$h = C_p t + SH\, h_v$$

$$RH = \frac{P_v}{P_{sat}}$$

$$0.65 = \frac{P_v}{5.628\ \text{kPa}}$$

$$P_v = 3.6582\ \text{kPa}$$

and;

$$SH = 0.622\left[\frac{P_v}{P_B - P_v}\right] = 0.622\left[\frac{3.6582\ \text{kPa}}{102\ \text{kPa} - 3.6582\ \text{kPa}}\right]$$

$$SH = 0.02314\ \text{kg}_v/\text{kg}_{da}$$

$$h_v = h_g = 2565.3\ \text{kJ/kg}$$

Hence;

$$h = \left(1.0062\ \text{kJ/kg-K}\right)\left(35°C\right) + \left(0.02314\ \text{kg/kg}\right)\left(2565.3\ \text{kJ/kg}\right)$$

$$\boxed{h = 94.5721\ \text{kJ/kg}}$$