Answer Key

POWER PLANT ENGINEERING

Refresher 02

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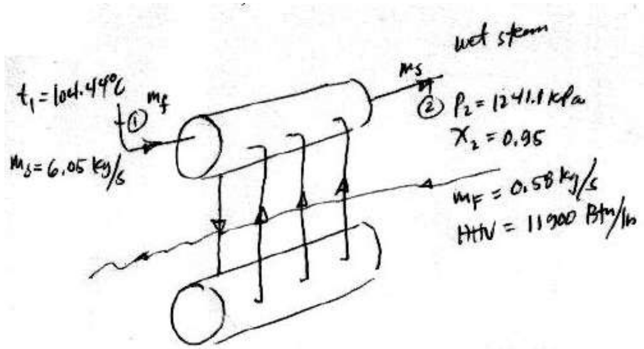
Exponential LEAP
ONLINE REVIEW

1 to 3



Required: The Rate of Heat Absorption, kJ/s

$$Q_A = m_s (h_s - h_f)$$

$$h_s = h_f + X_2 h_{fg}$$

$$= 605.29 \text{ kJ/kg} + (0.95)(1980.6 \text{ kJ/kg})$$

$$h_s = 2686.86 \text{ kJ/kg}$$

Hence;

$$Q_A = (6.05 \text{ kg/s})(2686.86 - 437.78) \text{ kJ/kg}$$

$$\boxed{Q_A = 13{,}606.934 \text{ kJ/s}}$$

Boiler Horsepower

Note: 1 bo Hp = 35322 kJ/hr

$$Q_A = \left(13\,606.934 \text{ kJ/s}\right)\left(\frac{3600 s}{1 hr}\right)\left(\frac{1 bo hp}{35322 \text{ kJ/hr}}\right)$$

$$\boxed{Q_A = 1386.8117 \text{ bo.Hp}}$$

Boiler Efficiency

$$\eta_{BO} = \frac{Q_A}{Q_F} * 100\% = \frac{13606.934 \text{ kJ/s}}{(0.58 \text{ kg/s})(11900 \text{ Btu/lb})\left(\frac{1.055 \text{ kJ}}{1 \text{ Btu}}\right)\left(\frac{2.22 \text{ lb}}{1 \text{ kg}}\right)} * 100\%$$

$$\boxed{\eta_{BO} = 84.94\%}$$

4 to 7

$BP = 680\ bhp$

$fuel = 28°API\ @\ 45°C$

$m_F = 0.78\ \frac{lbs}{bhp\text{-}hr}$

cost of fuel: $₱\ 6.65/L$

Density of fuel:

$$\rho_{F@45°C} = \rho_w\left(SG_{F\,corrected\,@45°C}\right)$$

$$SG_{F\,corrected\,@45°C} = SG_{F@15.6°C}\left[1 - 0.0007\left(t_0 - 15.6\right)\right]$$

$$°API = \frac{141.5}{SG_{F@15.6°C}} - 131.5$$

$$28 = \frac{141.5}{SG_{F@15.6°C}} - 131.5$$

$$SG_{F@15.6°C} = 0.8871$$

Subst;

$$SG_{corrected@45°C} = 0.8871\left[1 - 0.0007\left(45 - 15.6\right)\right]$$

$$SG_{corrected@45°C} = 0.8689$$

Hence;

$$\rho_{F@45°C} = \left(1\ kg/L\right)\left(0.8689\right)$$

$$\boxed{\rho_{F@45°C} = 0.8689\ kg/L}$$

Fuel consumption, in L/hr

$$\text{Fuel consumption} = \left(0.78\ \frac{lbs}{bhp\text{-}hr}\right)\left(680\ bhp\right)\left(\frac{1\ kg}{2.2\ lbs}\right)\left(\frac{1\ L}{0.8689\ kg}\right)$$

$$\boxed{\text{Fuel consumption} = 274.9671\ L/hr}$$

Minimum volume of Required day tank, L/day

$$V_{tank} = \left(274.9671\ L/hr\right)\left(\frac{24\ hrs}{1\ day}\right)$$

$$\boxed{V_{tank} = 6599.2104\ L/day}$$

cost of fuel per day

$$\text{cost of fuel} = \left(6599.2104\ \frac{L}{day}\right)\left(₱6.65/L\right)$$

$$\boxed{\text{cost of fuel} = ₱\ 43884.7492\ /day}$$

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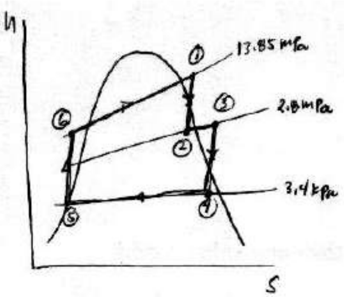
8 to 12



$$\frac{W_T'}{m_s} = (h_1 - h_2)\eta_T + (h_3 - h_4)\eta_T$$

$h_1 = 3434.1$ kJ/kg

$h_2 = 2974.9$ kJ/kg

$h_3 = 3538.5$ kJ/kg

$h_4 = 2204.5$ kJ/kg

$$\frac{W_T'}{m_s} = (3434.1 - 2974.9)\,\text{kJ/kg}\,(0.80) + (3538.5 - 2204.5)\,\text{kJ/kg}\,(0.80)$$

$$\boxed{\frac{W_T'}{m_s} = 1674.56\ \text{kJ/kg}}$$

The enthalpy at the entrance to the boiler

$$W_{P(s=c)} = W_{P(v=c)}$$

$$\cancel{m_s}(h_6 - h_5) = \cancel{m_s}\, v_f\, (P_1 - P_4)$$

$$h_6 - 109.84\ \text{kJ/kg} = 0.0010032\ \text{m}^3/\text{kg}\,(13850 - 3.4)\ \text{kN/m}^2$$

$$\boxed{h_6 = 123.7309\ \text{kJ/kg}}$$

Work pump

$$\frac{W_P}{m_s} = (h_6 - h_5) = (123.7309 - 109.84)\ \text{kJ/kg}$$

$$\boxed{\frac{W_P}{m_s} = 13.8903\ \text{kJ/kg}}$$

Heat added to the boiler

$$\frac{Q_A}{m_s} = (h_1 - h_6) + (h_3 - h_2)$$

$$\frac{Q_A}{m_s} = (3434.1 - 123.7309)\ \text{kJ/kg} + (3538.5 - 2974.9)\ \text{kJ/kg}$$

$$\boxed{\frac{Q_A}{m_s} = 3873.9691\ \text{kJ/kg}}$$

Reheat thermal efficiency

$$e_R = \frac{W_{NET}}{Q_A} * 100\% = \frac{W_T' - W_P}{Q_A} * 100\%$$

$$= \frac{(1674.56 - 13.8903)\ \text{kJ/kg}}{3873.9691\ \text{kJ/kg}} * 100\%$$

$$\boxed{e_R = 42.87\%}$$

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Diversity factor

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Utilization factor

15

Load versus time

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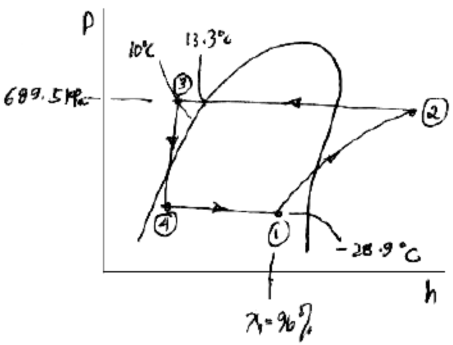
Load factor

17 to 21



Heat absorbed by Evaporator

$$Q_A = m_R(h_1 - h_4)$$

$$h_1 = h_f + x_1 h_{fg}$$

$$= 68.5\ KJ/kg + (0.96)(1424.5 - 68.5)\ KJ/kg$$

$$h_1 = 1370.26\ KJ/kg$$

$$h_4 = 246.531\ KJ/kg = h_3$$

$$\frac{Q_A}{m_R} = (1370.26 - 246.531)\ KJ/kg$$

$$\boxed{\frac{Q_A}{m_R} = 1123.729\ KJ/kg}$$

Heat rejected at condenser

$$Q_R = m_R(h_2 - h_3)$$

$$\frac{Q_R}{m_R} = (1568 - 246.531)\ KJ/kg$$

$$\boxed{\frac{Q_R}{m_R} = 1321.469\ KJ/kg}$$

$$COP = \frac{Q_A}{Q_R - Q_A} = \frac{1123.729\ KJ/kg}{(1321.469 - 1123.729)\ KJ/kg}$$

$$\boxed{COP = 5.6829}$$

17 to 21

Horse power per ton of Refrigeration

$$W_c = m_R (h_2 - h_1)$$

Solving for m_R; for 1 ton of Refrigeration

$$Q_A = m_R (h_1 - h_4)$$

$$(1\,\text{ton})\left(\frac{3.517\text{ kW}}{1\text{ ton}}\right) = m_R \left(1123.729 \text{ kJ/kg}\right)$$

$$m_R = 3.1297 \times 10^{-3} \text{ kg/s}$$

Then;

$$W_c = \left(3.1297 \times 10^{-3} \text{ kg/s}\right)(1560 - 1370.26) \text{ kJ/kg}$$

$$W_c = (0.6189 \text{ kW})\left(\frac{1 \text{ hp}}{0.746 \text{ kW}}\right)$$

$$W_c = 0.8296 \text{ hp}$$

Hence;

$$\boxed{\frac{W_{net}}{Q_A} = 0.8296 \text{ hp/ton}}$$

Quality of Refrigerant upon Entering evaporator

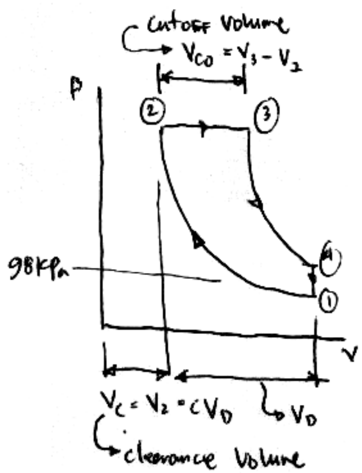
$$h_4 = h_f + x_4 h_{fg}$$

$$246.531 \text{ kJ/kg} = 68.5 \text{ kJ/kg} + x_4 (1424.5 - 68.5) \text{ kJ/kg}$$

$$\boxed{x_4 = 13.13\%}$$

22 to 25

Diesel Cycle



Fuel is injected 5% of the stroke

$C = 0.07$

$V_c = V_3 - V_2 = 0.07 V_D$

$K = 1.4$

Air-Standard Efficiency

$$e_{oc} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^{k} - 1}{k(r_c - 1)}\right] * 100\%$$

compression ratio:

$$r_k = \frac{V_1}{V_2} = \frac{c+1}{c} = \frac{0.07+1}{0.07}$$

$$\boxed{r_k = 15.2857}$$

cut-off ratio:

$$r_c = \frac{V_4}{V_3} = \frac{c + c_o}{c} = \frac{0.07 + 0.05}{0.07}$$

$$\boxed{r_c = 1.7143}$$

hence;

$$e_{oc} = 1 - \frac{1}{15.2857^{1.4-1}}\left[\frac{1.7143^{1.4} - 1}{1.4(1.7143 - 1)}\right] * 100\%$$

$$\boxed{e_{oc} = 62.15\%}$$

clearance ratio as percentage of the piston volume displacement

$$V_2 = c V_D$$

$$\frac{V_2}{V_D} = c$$

$$\boxed{\frac{V_2}{V_D} = 7\%}$$

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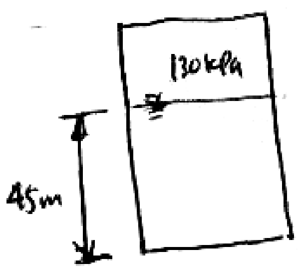

$$P_2 - P_1 = \gamma h$$

$$P_2 = 130\ kPa + (9.81\ kN/m^3)(45m)$$

$$\boxed{P_2 = 571.45\ kPa}$$

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$$P_{abs} = P_{atm} + P_{gage}$$

$$P = \frac{F}{A} = \frac{m}{A}\left(\frac{g_0}{g_c}\right) = \frac{35\,kg}{(0.030\,m^2)}\left(\frac{9.80\,m/s^2}{1000\,\frac{kg-m}{kN-s^2}}\right)$$

$$P = 11.445\ kPa.$$

Hence;

$$P_{abs} = 98\,kPa + 11.445\,kPa$$

$$\boxed{P_{abs} = 109.445\ kPaa}$$

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Adequately greater

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Charge with new refrigerant

30

Abrupt drop in steam load

31

21% and 79%

32

Higher heating value

33

$$\Delta P = \gamma \Delta h$$

$$= \left(13600\ kg/m^3\right)\left(\frac{9.71\ m/s^2}{1000\ \frac{kg\cdot m}{kN\cdot s^2}}\right)\left(0.290\ m\right)$$

$$\boxed{\Delta P = 38.2962\ kPa}$$

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$$P_{abs} = P_{atm} - P_{vac}$$

$$= 98\,\text{kPa} - (710\,\text{mm Hg})\left(\frac{101.325\,\text{kPa}}{760\,\text{mm Hg}}\right)$$

$$\boxed{P_{abs} = 3.3411\,\text{kPa}}$$

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$$P = \gamma h = \rho\left(\frac{g_o}{g_c}\right)h = \left(810\ \text{kg/m}^3\right)\left(\frac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)\left(0.305\text{m}\right)$$

$$\boxed{P = 2.4236\ \text{kPa}}$$

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$$P_{abs} = P_{atm} + P_{gauge}$$

$$= 98\ kPa + 2500\ kPa$$

$$\boxed{P_{abs} = 2598\ kPaa}$$

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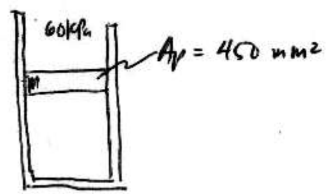

$$P = \frac{F}{A}$$

$$60\ kPa = \frac{F}{(450\ mm^2)\left(\frac{1\ m}{1000\ mm}\right)^2}$$

$$F = 0.027\ kN = 27\ N$$

Then;

$$F = m\left(\frac{g_o}{g_c}\right)$$

$$27\ N = m\left(\frac{9.81\ m/s^2}{1\ \frac{kg\text{-}m}{N\text{-}s^2}}\right)$$

$$\boxed{m = 2.7523\ kg}$$

38 to 40

$PV^k = c$

$P_1 = 98 kPa$

$V_1 = 0.43 m^3$

$T_2 = 200 + 273 = 473 K$

$W_{NF} = -65 kJ/kg$

The initial temperature

$W_{NF} = -m C_v (T_2 - T_1)$

$-65 kJ/kg = -(0.7186 kJ/kg\text{-}K)(473 - T_1)$

$T_1 = 382.5463 K$

$\boxed{t_1 = 109.5463 °C}$

The air mass

$P_1 V_1 = m R T_1$

$(98 kPa)(0.43 m^3) = m(0.287 kJ/kg\text{-}K)(382.5463 K)$

$\boxed{m = 0.3838 kg}$

$\Delta u = m C_v \Delta T$

$= (0.3838 kg)(0.7186 kJ/kg\text{-}K)(473 - 382.5463) K$

$\boxed{\Delta u = 24.9484 kJ}$

41 to 42

$PV^n = C$

$P_1 = 100\ kPa \qquad t_1 = (24 + 273)K = 297\ K$

$P_2 = 1400\ kPa \qquad t_2 = (180 + 273)K = 453\ K$

Heat removed during compression

$$Q = mC_n(T_2 - T_1) \quad , \quad C_n = C_v\left[\frac{k-n}{1-n}\right]$$

Solving for the polytropic exponent, n

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

$$\frac{453\ K}{297\ K} = \left(\frac{1400\ kPa}{100\ kPa}\right)^{\frac{n-1}{n}}$$

$$1.5253 = 14^{\frac{n-1}{n}}$$

$$\log 1.5253 = \log 14^{\frac{n-1}{n}}$$

$$\frac{n-1}{n} = \frac{\log 1.5253}{\log 14}$$

$$n = 1.1904$$

Solving for C_n;

$$C_n = 0.7186\ kJ/kg\text{-}K\left[\frac{1.4 - 1.1904}{1 - 1.1904}\right]$$

$$C_n = -0.7911\ kJ/kg\text{-}K$$

Hence;

$$\frac{Q}{m} = (-0.7911\ kJ/kg\text{-}K)(453 - 297)K$$

$$\boxed{Q = -123.4116\ kJ/kg}$$

The reversible work

$$W_{NF} = \left[\frac{P_2V_2 - P_1V_1}{1-n}\right] = mR\left[\frac{T_2 - T_1}{1-n}\right]$$

$$\frac{W_{NF}}{m} = (0.287\ kJ/kg\text{-}K)\left[\frac{(453 - 297)K}{1 - 1.1904}\right]$$

$$\boxed{W_{NF} = -235.1471\ kJ/kg}$$

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$T = C$; $T_1 = 400\,K$

$P_1 = 210\,kPa$

$V_1 = 0.018\,m^3$

$V_2 = 0.088\,m^3$

$$W_{NF} = Q = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= (210\,kPa)(0.018\,m^3)\ln\left(\frac{0.088\,m^3}{0.018\,m^3}\right)$$

$$\boxed{W_{NF} = 5.9987\,kJ}$$

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$V = C = 1\,m^3$

$P_1 = 355.6\ kPa$

$T_1 = 273\ K$

$T_2 = 610\ K$

For the heat added; Q

$Q = mC_v(T_2 - T_2)$

$P_1V_1 = mRT_1$

$(355.6\ kPa)(1\,m^3) = m(0.287\ KJ/kg\text{-}K)(273\ K)$

$m = 4.5386\ kg$

$Q = (4.5386\ kg)(0.7186\ KJ/kg\text{-}K)(610 - 273)K$

$\boxed{Q = 1099.1046\ KJ}$

For the final pressure; P_2

$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_1 \cancel{V_1}}{T_1}$

$\frac{P_2}{610\ K} = \frac{355.6\ KPa}{273\ K}$

$\boxed{P_2 = 794.5641\ KPa}$

45

$P = C$

$V_1 = 0.55 m^3$

$T_1 = 350 k$

$T_2 = 280 k$

$W_{NF} = 130 kPa$

For the final volume

$$\frac{\cancel{P_1} V_1}{T_1} = \frac{\cancel{P_2} V_2}{T_2}$$

$$\frac{0.55\ m^3}{350\ k} = \frac{V_2}{280 K}$$

$$\boxed{V_2 = 0.44 m^3}$$

for Work Non Flow;

$$W_{NF} = P(V_2 - V_1) = 130 KPa(0.44 - 0.55) m3$$

$$\boxed{W_{NF} = -14.3 kJ}$$

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$P = C = 360 \text{ kPa}$

$m = 1.5 \text{ kg}$

$\Delta U = 180 \text{ kJ}$

$\Delta T = 60 \text{ K}$

$W_{NF} = 130 \text{ kJ}$

For the specific heat;

$$W_{NF} = mR\Delta T$$

$$130 \text{ kJ} = (1.5 \text{ kg}) R (60 \text{ K})$$

$$R = 1.4444 \text{ kJ/kg-K}$$

and;

$$\Delta U = mC_v \Delta T$$

$$180 \text{ kJ} = (1.5 \text{ kg}) C_v (60 \text{ K})$$

$$C_v = 2 \text{ kJ/kg-K}$$

Hence;

$$R = C_p - C_v$$

$$1.4444 \text{ kJ/kg-K} = C_p - 2 \text{ kJ/kg-K}$$

$$\boxed{C_p = 3.4444 \text{ kJ/kg-K}}$$

For the change in volume;

$$W_{NF} = P\Delta V$$

$$130 \text{ kJ} = (360 \text{ kPa}) \Delta V$$

$$\boxed{\Delta V = 0.3611 \text{ m}^3}$$

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$$PV^k = C$$

$$W_{nf} = -m C_v (T_2 - T_1)$$

$$-55\ \text{kJ} = -(1.43\ \text{kg})(0.7186\ \text{kJ/kg-K})(T_2 - 301\ \text{K})$$

$$\boxed{T_2 = 354.5229\ \text{K}}$$

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$V = 6\,m^3$

$R = 0.1152\ kJ/kg\text{-}K$

$P_2 = 300\,kPa$

$T_2 = 310\,K$

$m_2 = m_1 - 2.8\,kg$

$T_1 = 320\,K$

For the original mass, m_1

$$P_2 V_2 = m R T_2$$

$$(300\,kPa)(6\,m^3) = (m_1 - 2.8\,kg)(0.1152\ kJ/kg\text{-}K)(310\,K)$$

$$\boxed{m_1 = 53.2032\,kg}$$

and;

$$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_1 \cancel{V_1}}{T_1}$$

$$\frac{300\,kPa}{310\,K} = \frac{P_1}{320\,K}$$

$$\boxed{P_1 = 309.6774\,kPa}$$

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$$h = h_f + x h_{fg}$$

$$2676.2 \text{ kJ/kg} = 486.99 \text{ kJ/kg} + x(2213.6 \text{ kJ/kg})$$

$$\boxed{x = 0.9889}$$

50

$$P_{abs} = P_{atm} - P_{vac}$$

$$= (30\,in\,Hg)\left(\frac{25.4\,mm}{1\,in}\right)\left(\frac{14.7\,psi}{760\,mm\,Hg}\right) - 9.8\,psi$$

$$\boxed{P_{abs} = 4.9387\,psia}$$

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$r_k = 9.0$

$P_1 = 98\,kPa$

$T_1 = (24 + 273)\,K = 297\,K$

$Q_A = 1400\,kJ/kg$

for the work done;

$$e_{oc} = \frac{W_{NET}}{Q_A} = 1 - \frac{1}{r_k^{\,k-1}}$$

$$\frac{W_{NET}}{1400\,kJ/kg} = 1 - \frac{1}{9.0^{1.4-1}}$$

$$\boxed{W_{NET} = 818.6589\,kJ/kg}$$

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$$e_{DC} = 1 - \frac{1}{r_k^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] * 100\%$$

$$\frac{T_3}{T_2} = r_c \quad ; \quad r_k = \left(\frac{T_2}{T_1}\right)^{1/k-1}$$

$$13 = \left(\frac{T_2}{301\,K}\right)^{1/1.4-1}$$

$$T_2 = 839.7381\,K$$

subst;

$$\frac{2000\,K}{839.7381\,K} = r_c$$

$$r_c = 2.3817$$

Substituting

$$e_{DC} = 1 - \frac{1}{13^{1.4-1}}\left[\frac{2.3817^{1.4} - 1}{1.4(2.3817 - 1)}\right] * 100\%$$

$$\boxed{e_{DC} = 56.08\%}$$

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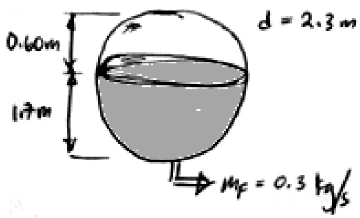

For spherical segment;

$$V_{sphere} = \frac{\pi h^2}{3}(3r - h)$$

$$= \frac{\pi (1.5m)^2}{3}\left[3(1.15m) - 1.5\,m\right]$$

$$V_{sphere} = 4.5946\ m^3$$

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

$$(0.85)(1000\ kg/m^3) = \frac{m_F}{4.5946\ m^3}$$

$$m_F = 3905.41\ kg$$

$$\text{Time to consume} = \frac{3905.41\ kg}{(0.3\ kg/s)\left(\frac{3600\ s}{1\ hr}\right)}$$

$$\boxed{\text{Time to consume} = 3.6161\ hrs}$$

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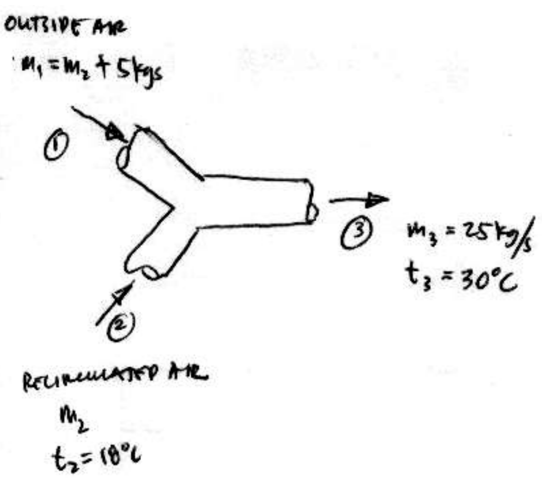

For the mass flow rate of recirculated air

$$25\ kg/s = m_1 + m_2$$

$$25\,kg/s = (m_2 + 5\,kgs) + m_2$$

$$m_2 = 10\ kg/s$$

$$m_3 t_3 = m_1 t_1 + m_2 t_2$$

$$(25\,kg/s)(30°C) = (15\,kg/s)t_1 + (10\,kg/s)(18°C)$$

$$\boxed{t_1 = 38°C}$$

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$$Q_{COND} = Q_{cooling\ water}$$

$$m_R (h_3 - h_4) = m_c C_p \Delta T$$

From; $Q_{EVAP} = Q_{WATER\ COND}$

$$m_R (h_2 - h_1) = m C_p \Delta T$$

$$m_R (1471.6 - 410.4)\ \mathrm{KJ/kg} = \left(\frac{45000\ \mathrm{kg}}{5\ \mathrm{hrs}}\right)\left(\frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}\right)\left(4.187\ \mathrm{KJ/kg\text{-}K}\right)(30-15)^{\circ}C$$

$$m_R = 0.1479\ \mathrm{kg/s}$$

Hence;

$$(0.1479\ \mathrm{kg/s})(1650 - 410.4)\ \mathrm{KJ/kg} = m_c (4.187\ \mathrm{KJ/kg\text{-}K})(8^{\circ}C)$$

$$\boxed{m_c = 5.4755\ \mathrm{kg/s}}$$

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Turbulent flow

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Photovoltaic-energy conversion

58

Viscosity

59

No, Wp is only 75 kPa at FS of 8

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Heat

61

$$COP = \frac{Q_A}{W_c} = \frac{h_2 - h_1}{h_3 - h_2} = \frac{(1462 - 350.2)\ kJ/kg}{(1720 - 1462)\ kJ/kg}$$

$$\boxed{COP = 4.3093}$$

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$$\Delta s = \frac{Q}{T} = \frac{780\ \text{Btu}}{(160+460)\,°R}$$

$$\boxed{\Delta s = 1.2581\ \text{Btu}/°R}$$

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$$h = u + PV$$

$$9000\ \text{kJ/kg} = u + (1000\ \text{kPa})(0.653\ \text{m}^3/\text{kg})$$

$$\boxed{u = 8347\ \text{kJ/kg}}$$

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$$h = u + PV$$

$$= 2590\ kJ/kg + (480\ kPa)(1.010\ m^3/kg)$$

$$\boxed{h = 3074.8\ kJ/kg}$$

65

$$Q_A = (12 \text{ tons})\left(\frac{200 \text{ Btu/min}}{1 \text{ ton}}\right)\left(\frac{0.252 \text{ kcal}}{1 \text{ Btu}}\right)$$

$$\boxed{Q_A = 604.8 \ \frac{\text{kcal}}{\text{min}}}$$

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66

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

$$(100\text{ kPa})(0.55\text{ m}^3) = (500\text{ kPa})V_2$$

$$\boxed{V_2 = 0.11\text{ m}^3}$$

67

$$W_{NET} = mR\left(T_1 - T_4\right)\ln\frac{P_1}{P_2}$$

$$\Delta S = mR\ln\frac{P_1}{P_2}$$

subst;

$$W_{NET} = \Delta S\left(T_1 - T_4\right) = \left(2.4\ \mathrm{kJ/K}\right)\left(900 - 250\right)\mathrm{K}$$

$$\boxed{W_{NET} = 1560\ \mathrm{kJ}}$$

68

$$P_{abs} = P_{atm} - P_{vac}$$

$$P = \gamma_{Hg} h_{Hg} = \gamma_w h_w$$

$$-(13.6)(9.81\ kN/m^3)(0.11\ m\ Hg) = (9.81\ kN/m^3)h_w$$

$$h_w = -1.496\ m \text{ of water}$$

Hence;

$$P_{abs} = 12.22\ m - 1.496\ m$$

$$\boxed{P_{abs} = 10.724\ m \text{ of water}}$$

69

Directly proportional to the refrigerating effect

70

Hydraulic mean depth

71

"Extra standard" weight

72

Increase COP

73

Zero

74

$$W = m(h_2 - h_1) = \left(12\ \text{lb/sec}\right)\left(439 - 134\right)\ \text{Btu/lb}$$

$$W = \left(3660\ \frac{\text{Btu}}{\text{sec}}\right)\left(\frac{1.0551\ \text{kW}}{1\ \text{Btu/sec}}\right)\left(\frac{1\ \text{hp}}{0.746\ \text{kW}}\right)$$

$$\boxed{W = 5176.4959\ \text{hp}}$$

75

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \quad ; \quad V_2 = \frac{1}{10} V_1$$

$$\frac{T_2}{580°R} = (10)^{1.4-1}$$

$$\boxed{T_2 = 1456.8941\ °R}$$

76

$$Q_{metal} = Q_{water}$$

$$m C_p \Delta T \big|_{metal} = m C_p \Delta T \big|_{water}$$

$$(0.30\,kg)\,C_p\,(120-50)^\circ C = (0.05\,kg)(4.187\,kJ/kg\text{-}K)(50-23)^\circ C$$

$$\boxed{C_{p\,metal} = 0.2692\ kJ/kg\text{-}K}$$

77

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

$$u_1 + 15500 \text{ lb-ft} = (45 \text{ Btu})\left(\frac{778 \text{ lb-ft}}{1 \text{ Btu}}\right) + u_2$$

$$\Delta u = (u_2 - u_1) = -(19510 \text{ lb-ft})\left(\frac{1 \text{ Btu}}{778 \text{ lb-ft}}\right)$$

$$\boxed{\Delta u = -25.0771 \text{ Btu}}$$

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78

$$P_1V_1 = m_1RT_1$$

$$(101.325\ kPa)(2.6\ m^3) = m_1(0.287\ kJ/kg\text{-}K)(30+273)K$$

$$m_1 = 3.0295\ kg$$

@ State 2

$$P_2V_2 = m_2RT_2$$

$$(1600\ kPa)(2.6\ m^3) = (m_2 + 3.0295\ kg)(0.287\ kJ/kg\text{-}K)(38+273)K$$

$$\boxed{m_2 = 43.5775\ kg}$$

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79

$$Q = mC_p(T_2 - T_1)$$

$$12\ \text{KJ/sec} = m(1.0062\ \text{KJ/kg-K})(15°C)$$

$$\boxed{m = 0.7951\ \text{kg/s}}$$

80

$$W_{NF} = \frac{P_2V_2 - P_1V_1}{1-n}$$

Solving for polytropic exponent n;

$$\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

$$\frac{120\,psi}{12\,psi} = \left(\frac{1.5\,ft^3}{0.156\,ft^3}\right)^n$$

$$10 = 9.6154^n$$

$$\log 10 = n \log 9.6154$$

$$n = 1.0173$$

Subst;

$$W_{NF} = \left[\frac{\left(120 * 144\frac{lb}{ft^2}\right)\left(0.156\,ft^3\right) - \left(12 * 144\frac{lb}{ft^2}\right)\left(1.5\,ft^3\right)}{1 - 1.0173}\right]$$

$$\boxed{W_{NF} = -5993.0636\ lb\text{-}ft}$$

81

$$P_{abs} = P_{atm} - P_{vac}$$

$$= (758\ mmHg)\left(\frac{101.325\ KPa}{760\ mmHg}\right) - (580\ mm\ Hg)\left(\frac{101.325\ KPa}{760\ mmHg}\right)$$

$$\boxed{P_{abs} = 23.7314\ KPa}$$

82

$$e_c = \frac{T_H - T_L}{T_H} = \frac{Q_A - Q_R}{Q_A}$$

$$\frac{1260°R - T_L}{1260°R} = \frac{(110 - 40)\,Btu}{110\,Btu}$$

$$T_L = 458.1818\,°R$$

$$\boxed{t_L = -1.8182\,°F}$$

83 to 85

The weight of air in kg per kg of coal

$$A{:}F = 11.5C + 34.5\left(H_2 - \frac{O_2}{8}\right) + 4.3S$$

$$= 11.5(0.705) + 34.5\left[0.045 - \frac{0.06}{8}\right] + 4.3(0.03)$$

$$A{:}F = 9.5303\ \frac{kg_a}{kg_F}$$

w/ 25% excess air:

$$A{:}F' = A{:}F(1+e) = \left(9.5303\ \frac{kg_a}{kg_F}\right)(1+0.25)$$

$$\boxed{A{:}F' = 11.9129\ \frac{kg_a'}{kg_F}}$$

83 to 85

The volume of air in m³

for air: $PV = m_a RT$

$$V_a = \frac{m_a RT}{P}$$

Solving for the mass of air, m_a

$$FE = \frac{h_s - h_f}{2257} = 1.20$$

$$h_s - h_f = 2708.4 \text{ kJ/kg}$$

and;

$$HHV = 14600C + 62000\left[H_2 - \frac{O_2}{8}\right] + 4050S \; ; \text{ Btu/lb}_F$$

$$HHV = 14600(0.705) + 62000\left[0.045 - \frac{0.06}{8}\right] + 4050(0.03)$$

$$HHV = \left(12739.5 \text{ Btu/lb}\right)\left(2.2 \text{ lb/kg}\right)\left(1.055 \text{ kJ/Btu}\right)$$

$$HHV = 29568.3795 \text{ kJ/kg}$$

Then;

$$\eta_{BO} = \frac{m_s(h_s - h_f)}{m_F \, HHV}$$

$$0.80 = \frac{(180000 \text{ kg/hr})(2708.4 \text{ kJ/kg})}{m_F(29568.3795 \text{ kJ/kg})}$$

$$m_F = 20609.5163 \text{ kg/hr}$$

for mass of air;

$$A{:}F' = \frac{m_a'}{m_F}$$

$$11.9129 \frac{\text{kg}_a'}{\text{kg}_F} = \frac{m_a'}{20609.5163 \text{ kg/hr}}$$

$$m_a = 245\,519.107 \text{ kg}_a\text{/hr}$$

Hence;

$$V_a = \frac{(245519.107 \text{ kg/hr})(0.287 \text{ kJ/kg-K})(15.5556 + 273)\text{K}}{(101.325 \text{ kPa})}$$

$$\boxed{V_a = 200\,668.9079 \text{ m}^3\text{/hr}}$$

83 to 85 cont...

Coal needed for 24 hrs operation

$$\text{for 24 hours operation} = \left(20609.5163\ \frac{kg}{hr}\right)\left(24\ hrs\right)\left(\frac{1\ m\ ton}{1000\ kg}\right)$$

$$\boxed{\text{for 24 hours operation} = 494.6284\ \text{metric Tons}}$$

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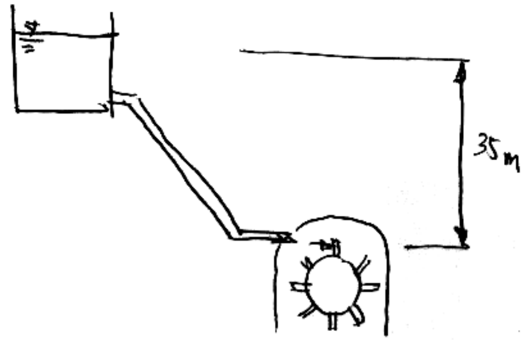
86 to 87



Friction Head loss = $h_L = (0.18)(35m) = 6.3\,m$

net head = $H_E = (35-6.3)\,m = 28.7\,m$

velocity = $v = \sqrt{2gH_E}$

$v = \sqrt{2(9.81\,m/s^2)(28.7\,m)}$

$v = 23.7296\,m/s$

to solve for Diameter of the penstock;

$$h_f = \frac{2fLv^2}{gD}$$

$$6.3\,m = \frac{2(0.00085)(85\,m)(23.7296\,m/s)^2}{(9.81\,m/s^2)D}$$

$$\boxed{D = 1.3166\,m}$$

The Power Output;

$WP = Q\gamma H_E$

$Q = Av = \frac{\pi D^2}{4}v = \frac{\pi(1.3166\,m)^2}{4}(23.7296\,m/s)$

$Q = 32.3047\,m^3/s$

Hence;

$WP = (32.3043\,m^3/s)(9.81\,kN/m^3)(28.7\,m)$

$$\boxed{WP = 9095.7582\,kW}$$

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Steam Engine

$$IP = P_m V_D \; ; \; V_D = 2\left[\frac{\pi}{4}D^2\right]L\left(N/_{60}\right)$$

$$P_m = \left(5\ kg/_{cm^2}\right)\left(\frac{10000\ cm^2}{1\ m^2}\right)\left(\frac{9.81\ m/_{s^2}}{1000\ \frac{kg-m}{kN-s^2}}\right) = 490.5\ kN/_{m^2}$$

$$V_D = 2\left[\frac{\pi}{4}(0.3m)^2\right](0.450\ m)\left(240\ rpm/_{60}\right) = 0.2545\ m^3/_s$$

Hence;

$$IP = (490.5\ kPa)\left(0.2545\ m^3/_s\right)$$

$$IP = (124.8170\ kW)\left(\frac{1\ hp}{0.746\ kW}\right)$$

$$\boxed{IP = 167.3151\ hp}$$

89

Product Load Calculations

$$RE = \frac{m}{T}\left[c_1(t_1 - t_f) + L + c_2(t_f - t_2)\right]$$

$$= \frac{12000\ kg}{12\ hrs}\left[\left(0.8\ kcal/kg\text{-}K\right)(18+2)^\circ C + \left(55.5\ kcal/kg\right) + \left(0.29\ kcal/kg\text{-}K\right)(-2+5)^\circ C\right]$$

$$RE = \left(72370\ kcal/hr\right)\left(\frac{4.187\ kJ}{1\ kcal}\right)\left(\frac{1\ hr}{3600\ s}\right)\left(\frac{1\ ton}{3.516\ kW}\right)$$

$$\boxed{RE = 23.9392\ tons}$$

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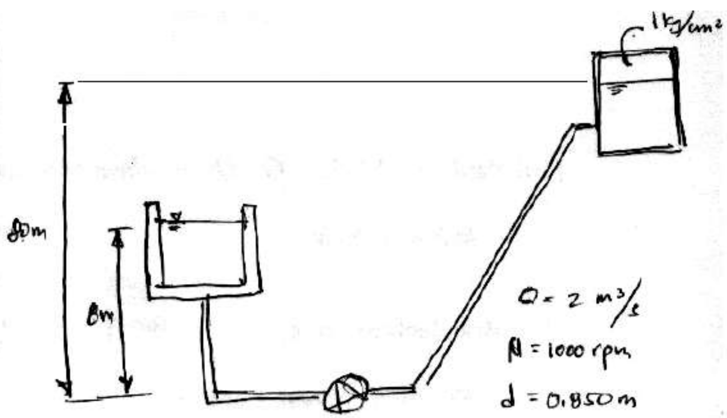
90 to 91



Solving for the water power

$$WP = Q\gamma TDH$$

$$TDH = (z_2 - z_1) + \left(\frac{P_2 - \cancel{P_1}}{\gamma}\right)^0 + \left(\frac{v_2^2 - \cancel{v_1^2}}{2g_0}\right)^0 + h_L$$

$$P_2 = \left(1\ \frac{kg}{cm^2}\right)\left(\frac{9.81\ m/s^2}{1000\ \frac{kg-m}{kN-s^2}}\right)\left(\frac{10\,000\ cm^2}{1\ m^2}\right) = 98.1\ kPa$$

$$Q = Av$$

$$2\ m^3/s = \frac{\pi(0.850\ m)^2}{4}v$$

$$v = 3.5245\ m/s$$

Subst;

$$TDH = 72\ m + \frac{98.1\ kPa}{9.81\ kN/m^3} + \frac{(3.5245\ m/s)^2}{2(9.81\ m/s^2)} + 2\ m$$

$$TDH = 84.6331\ m$$

Hence;

$$WP = (2\ m^3/s)(9.81\ kN/m^3)(84.6331\ m)$$

$$\boxed{WP = 1660.5014\ kW}$$

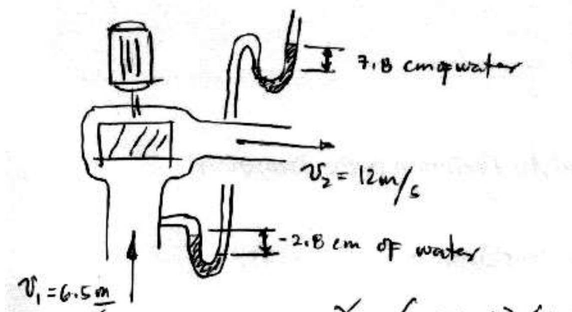
The new value of discharge, Q_2

$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1}$$

$$\frac{Q_2}{2\ m^3/s} = \left(\frac{1300\ rpm}{1000\ rpm}\right)$$

$$\boxed{Q_2 = 2.6\ m^3/s}$$

92 to 93



$\left(\frac{9.81 \, m/s^2}{1000 \, \frac{kg-m}{kN \, s^2}}\right) = 0.01158 \, kN/m^3$

The fan power

$$AP = Q \gamma_a h_T$$

$$h_T = \frac{P_2 - P_1}{\gamma_a} + \frac{v_2^2 - v_1^2}{2g_0}$$

$$= \frac{(0.078 \, m + 0.028 \, m)(9.81 \, kN/m^3)}{0.01158 \, kN/m^3} + \frac{(12^2 - 6.5^2) \, m^2/s^2}{2(9.81 \, m/s^2)}$$

$$h_T = 94.9839 \text{ m of air}$$

Hence;

$$AP = (9.56 \, m^3/s)(0.01158 \, kN/m^3)(94.9839 \text{ m of air})$$

$$\boxed{AP = 10.5152 \, kW}$$

Fan efficiency;

$$\eta_F = \frac{AP}{BP} = \frac{10.5152 \, kW}{14 \, kW} * 100\%$$

$$\boxed{\eta_F = 75.11\%}$$

94

Dew point temperature

95

Pour point

96

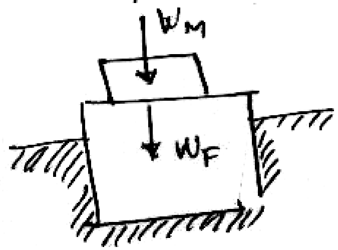
Cd<1

97

Inside diameter of the steam cylinder measured in inches

98

MACHINE FOUNDATION



$$W_F = e W_M \sqrt{N}$$

$$= (0.11)(10000\ kg)\sqrt{1300\ rpm}$$

$$W_F = 39661.0640\ kg$$

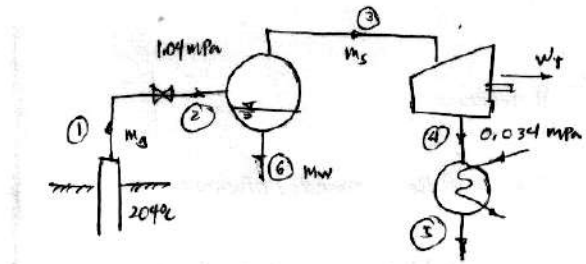
$$S_b = \frac{W_F + W_M}{A}$$

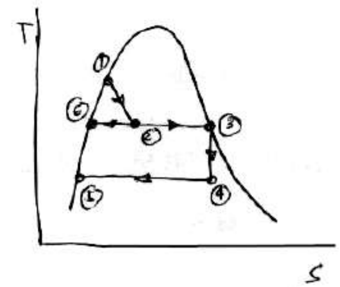
$$48.876\ kPa = \frac{(39661.0640 + 10000)\ kg \left(\dfrac{9.81\ m/s^2}{1000\ \frac{kg\text{-}m}{kN\text{-}s^2}}\right)}{A}$$

$$\boxed{A = 9.9676\ m^2}$$

99

Geothermal power plant





Solving mass flow rate of well water, m_g

$h_3 = h_g @ 1.04\ mPa = 2779.6\ KJ/kg$

Solving for h_4;

$S_3 = S_4$

$S_3 = S_f + x_4 S_{fg}$

$6.5929\ KJ/kg\text{-}K = 0.9793\ KJ/kg\text{-}K + x_4 \left(6.7463\ KJ/kg\text{-}K\right)$

$x_4 = 0.829$

$h_4 = h_f + x_4 h_{fg}$

$= 301.4\ KJ/kg + (0.829)(2328.8\ KJ/kg)$

$h_4 = 2232.3\ KJ/kg$

Solving for the mass flow rate of steam, m_s

$W_T = m_s (h_3 - h_4) \eta_t$

$60000\ kW = m_s (2779.6 - 2232.3)\ KJ/kg\ (0.80)$

$m_s = 137.0364\ kg/s$

Solving for the quality of steam x_2 (after throttling)

$h_1 = h_2 = h_f + x_2 h_{fg}$

$870.51\ KJ/kg = 770.38\ KJ/kg + x_2 (2009.2\ KJ/kg)$

$x_2 = 0.049836$

Hence; for the mass flow rate of well water;

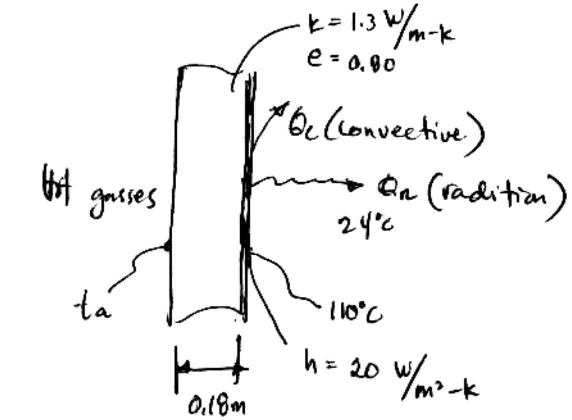
$m_s = x_2 m_g$

$137.0364\ kg/s = (0.049836)\, m_g$

$\boxed{m_g = 2749.7472\ kg/s}$

100

Heat transfer



Solving for the brick inner surface temperature, t_a

Consider per unit area; $A = 1\ m^2$

Q_c = convective Heat transfer

$$Q_c = h_c(t_1 - t_2)$$

$$= \left(20\ \text{W/m}^2\text{-K}\right)(110 - 24)°C$$

$$Q_c = 1720\ \frac{W}{m^2}$$

Q_R = Heat transfer due to radiation

$$Q_R = \left(5.669 \times 10^{-8}\ \frac{W}{m^2\text{-}K^4}\right) F_e \left(T_1^4 - T_2^4\right)$$

$$= \left(5.669 \times 10^{-8}\ \frac{W}{m^2\text{-}K^4}\right)(0.80)\left[(110+273)^4 - (24+273)^4\right] K^4$$

$$Q_R = 622.9929\ \frac{W}{m^2}$$

Then; The total heat transfer, Q, heat transfer due to conduction

$$Q = (1720 + 622.9929)\ \frac{W}{m^2}$$

$$Q = 2342.9929\ \frac{W}{m^2}$$

Hence;

$$\frac{Q}{A} = \frac{k(t_a - t_b)}{x}$$

$$2342.9929\ \frac{W}{m^2} = \frac{\left(1.3\ \text{W/m-K}\right)(t_a - 100)°C}{0.18\ m}$$

$$\boxed{t_a = 424.4144°C}$$