Answer Key

Psychrometrics and Air Conditioning System

1

Exponential LEAP ONLINE REVIEW

Using psychrometric chart

$t_w = 28°C$

$t_a = 33°C$

$h = 90\ kJ/kg$

Using psychrometric chart

$t_w = 25°C$

$RH = 80\%$

$h = 66\ kJ/kg$

Using psychrometric chart

$t_d = 27°C$

$RH = 60\%$

$t_{dp} = 18°C$

Using psychrometric chart

$h = 51\ kJ/kg$

$RH = 80\%$

$SH = 0.012\ kg/kg$

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

$$\%RH = \frac{P_v}{P_{sat@32°C}}$$

$$0.70 = \frac{P_v}{4.759\ kPa}$$

$$P_v = 3.3313\ kPa$$

Then;

$$SH = 0.622\left[\frac{3.3313\ kPa}{(101 - 3.3313)\ kPa}\right]$$

$$SH = 0.02122\ kg/kg$$

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

$$0.06 = 0.622\left[\frac{P_v}{98\,kPa - P_v}\right]$$

$$P_v = 8.6217\ kPa$$

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

$$P_v = P_B - P_a$$

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

$$P_a V_a = m R T_a$$

$$P_a = \rho_a R T_a = \left(1.10\ \frac{kg}{m^3}\right)\left(0.287\ \frac{kJ}{kg\text{-}K}\right)(301K)$$

$$P_a = 95.0257\ kPa$$

Hence;

$$SH = 0.622\left[\frac{100kPa - 95.0257kPa}{95.0257kPa}\right]$$

$$SH = 0.03256\ \frac{kg}{kg}$$

$$h = c_p t_d + SH\, h_g$$

$$75\ \text{kJ/kg} = \left(1.0062\ \text{kJ/kg-K}\right)(30\ ^\circ\text{C}) + SH\,(2556.3\ \text{kJ/kg})$$

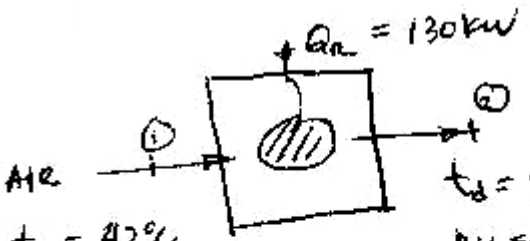
$$SH = 0.01753\ \text{kg/kg}$$

Then;

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

$$0.01753\ \text{kg/kg} = 0.622\left[\frac{P_v}{(101.325\ \text{kPa} - P_v)}\right]$$

$$P_v = 2.7735\ \text{kPa}$$



$t_d = 42°C$

$RH = 63\%$

$h_1 = 113$ kJ/kg

$SH_1 = 0.0125$ kg/kg

$t_d = 23°C$

$RH = 25\%$

$h_2 = 28$ kJ/kg

$$Q_R = m_a(h_2 - h_1)$$

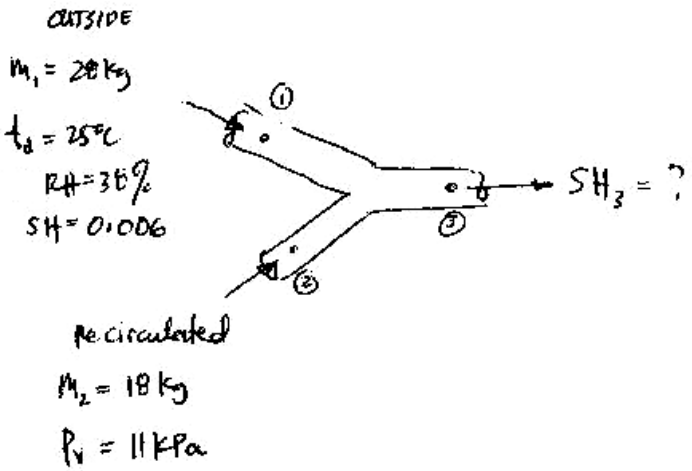
$$-130\text{kW} = m_a(28 - 113)\ \text{kJ/kg}$$

$$m_a = 1.5294\ \text{kg/s}$$

and;

$$\rho = \frac{m_a}{V_a} = \frac{1.5294\ \text{kg/s}}{V_a} = 1.20\ \text{kg/m}^3$$

$$V_a = 1.2745\ \text{m}^3/\text{s}$$



$$m_{a_1} SH_1 + m_{a_2} SH_2 = (m_{a_1} + m_{a_2}) SH_3$$

$$SH_2 = 0.622 \left[\frac{P_v}{P_B - P_v} \right]$$

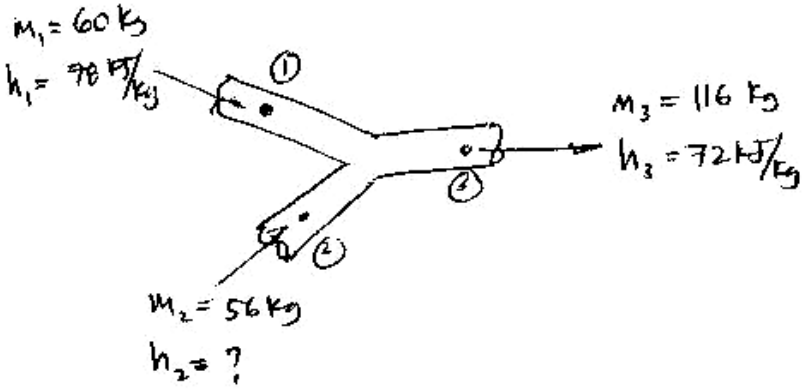
$$SH_2 = 0.622 \left[\frac{11 \text{ kPa}}{(101.325 \text{ kPa} - 11 \text{ kPa})} \right]$$

$$SH_2 = 0.07575 \text{ kg/kg}$$

Then;

$$(20 \text{ kg})\left(0.006 \frac{\text{kg}}{\text{kg}}\right) + (18 \text{ kg})\left(0.07575 \frac{\text{kg}}{\text{kg}}\right) = (46 \text{ kg}) SH_3$$

$$SH_3 = 0.0333 \text{ kg/kg}$$



$$m_1 h_1 + m_2 h_2 = m_3 h_3$$

$$(60\ kg)(78\ kJ/kg) + (56\ kg)\,h_2 = (116\ kg)(72\ kJ/kg)$$

$$h_2 = 65.5714\ kJ/kg$$

$V_R = (5 * 6 * 5)\,m^3 = 150\,m^3$

$P = 100\,kPa$

$t = 32°C$

$P_{sat} = 5.6\,kPa$

$RH = 68\%$

mass of vapor $= m_v = ?$

$P_v V_r = m R_v T_v$

$RH = \frac{P_v}{P_{sd}} * 100\%$

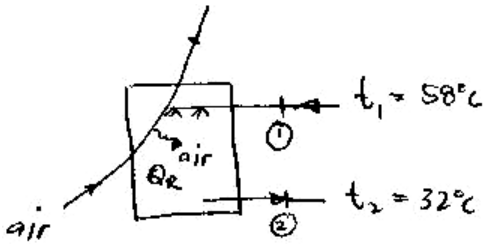
$0.68 = \frac{P_v}{5.6\,kPa}$

$P_v = 3.808\,kPa$

subst;

$(3.808\,kPa)(150\,m^3) = m_v\left(0.422\,\frac{kJ}{kg-K}\right)(305\,K)$

$m_v = 4.4379\,kg_v$



Q_R = Heat rejected to air = 125 kW

reqd! pump capacity

$$Q = m_w C_p (T_2 - T_1)$$

$$125\ kW = m_w \left(4.187\ \frac{kJ}{kg\text{-}K}\right)(58 - 32)\ K$$

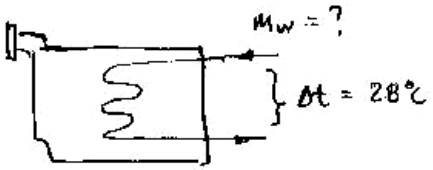
$$m_w = 1.1482\ kg/s$$

then;

$$\rho = \frac{m_w}{\dot{V}_w}$$

$$1\ kg/L = \frac{1.1482\ kg/s}{\dot{V}_w}$$

$$\dot{V}_w = 1.1482\ L/s$$



$BP = 120\ hp$

$\eta_B = 32\%$

$Q_j = 33\%$

$$\eta_B = \frac{BP}{E_c} * 100\%$$

$$0.32 = \frac{(120\ hp)\left(\frac{0.746\ kw}{1\ hp}\right)}{E_c}$$

$$E_c = 279.75\ kw$$

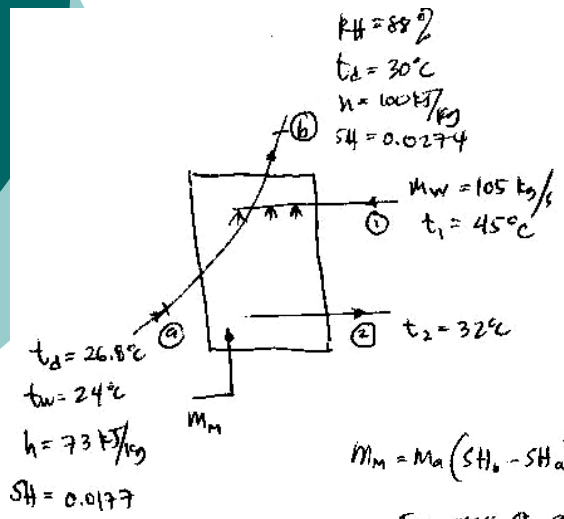
Then;

$$\%Q_j = \frac{Q_j}{E_c} * 100\% = \frac{m_w C_{pw} \Delta T}{E_c} * 100\%$$

$$0.33 = \frac{m_w\left(4.187\ kJ/kg\text{-}K\right)(28°C)}{279.75\ kw}$$

$$\dot{m}_w = \left(0.7875\ kg/s\right)\left(\frac{3600\ s}{1\ hr}\right)$$

$$\dot{m}_w = 2834.8204\ kg/hr$$



$$m_M = m_a(SH_b - SH_a)$$

For mass of air

$$Q_{air} = Q_{water}$$

$$m_a(h_2 - h_1) = m_w C_p \Delta T$$

$$m_a(100 - 73)\,kJ/kg = (105\ kg/s)(4.187\ kJ/kg)(45-32)\,k$$

$$m_a = 211.6761\ kg/s$$

subst;

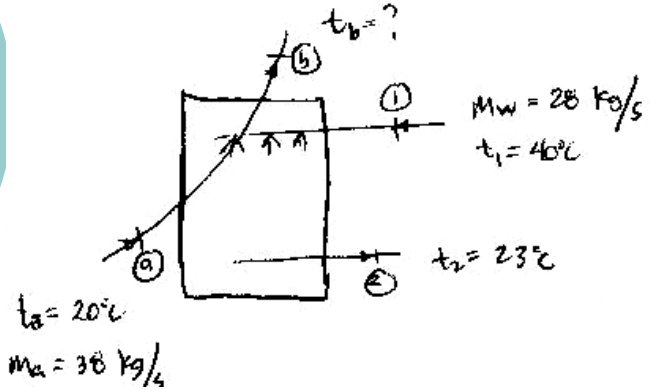
$$m_M = (211.6761\ kg/s)(0.0274 - 0.0177)\,kg/kg$$

$$m_M = 2.0533\ kg/s$$

Hence;

$$\%\ m_M = \frac{2.0533\ kg/s}{105\ kg/s} * 100\%$$

$$\%\ m_M = 1.955\%$$



$$Q_{AIR} = Q_{WATER}$$

$$m_a C_p (t_b - t_a) = m_w C_{pw} (t_2 - t_1)$$

$$\left(38 \frac{kg}{s}\right)\left(1.0062 \frac{kJ}{kg\text{-}K}\right)(t_b - 293K) = \left(28 \frac{kg}{s}\right)\left(4.184 \frac{kJ}{kg\text{-}K}\right)(40 - 23)K$$

$$t_b = 345.1245\ K$$

$$\boxed{t_b = 72.1245\ °C}$$

$$SHF = \frac{Q_s}{Q_T} = \frac{\text{sensible heat}}{\text{Total heat}}$$

$$SHF = \frac{123\ kW}{(123 + 23)\ kW}$$

$$SHF = 84.25\%$$

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

$$0.0153\ kg/kg = 0.622\left[\frac{P_v}{101.325\ kPa - P_v}\right]$$

$$P_v = 2.4326\ kPa$$

Using Steam tables, $t_{dp} = t_{sat}$ @ $P_v = 2.4326\ kPa$

$$t_{dp} = 21°C$$

$V_a = 36\ m^3/s$

$t_1 = 15°C$

$Q_T = 330\ kW$

$SHF = 0.80$

Det. the temp inside the auditorium

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

$$0.80 = \frac{Q_s}{330\ kW}$$

$$Q_s = 264\ kW$$

Hence;

$$Q_s = m_a C_{pa} (t_2 - t_1) \quad ; \quad \rho_a = \frac{m_a}{V_a}$$

$$Q_s = \rho_a \dot{V}_a C_{pa} (t_2 - t_1)$$

$$264\ kJ/s = (1.20\ kg/m^3)(36\ m^3/s)(1.0062\ kJ/kg\text{-}K)(t_2 - 288K)$$

$$t_2 = 293.7538\ K$$

$$t_2 = 20.7538°C$$

$$BF = 1 - CF$$

$$CF = \frac{t_i - t_o}{t_i - a\,t_{up}} = \frac{(52 - 88)^\circ F}{(52 - 112)^\circ F}$$

$$CF = 0.60$$

therefore;

$$BF = 1 - 0.60$$

$$\boxed{BF = 0.40}$$

$$SHR = \frac{Q_s}{Q_T} = \frac{Q_s}{Q_s + Q_L} = \frac{55\ kW}{(58 + 18)\ kW}$$

$$SHR = 76.32\%$$