Psychrometrics:

1) Specific humidity / Humidity Ratio:

$$\omega \triangleq \frac{m_v}{m_a} = 0.622 \frac{p_v}{p - p_v}$$

2) Relative humidity : $\phi \triangleq \dfrac{m_v}{m_{v,sat}} = \dfrac{p_v}{p_{sat}}$

(3) Specific Enthalpy. $h = c_{pa} \cancel{T_a} + \omega h_v(T)$

Assume $h_v(T) \approx h_g(T)$ (from the tables)

$[h] = \dfrac{kJ}{kg\ d.a}$

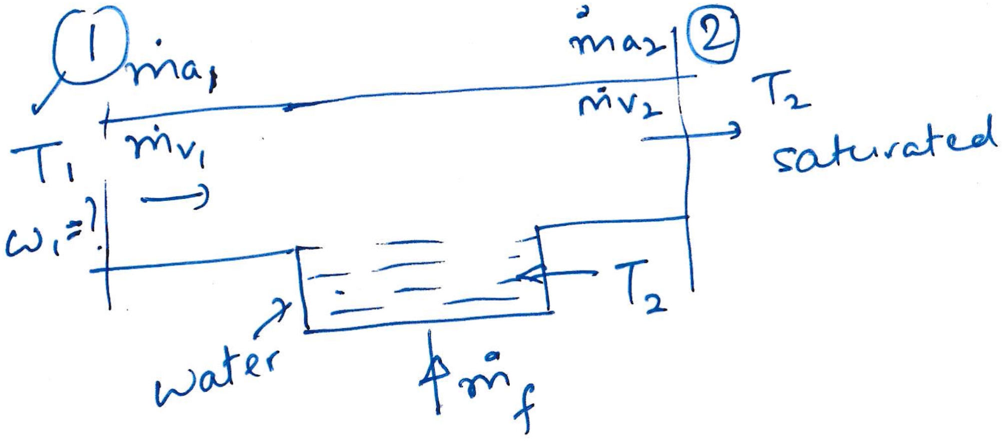
$h = c_{pa} T + \omega h_g(T)$ ← If you're given T

Another approximation: $h = c_{pa} T + \omega(2500 + 1.9T)$

↖ if you need to find T from h.

(4) Specific volume $v \triangleq \dfrac{V}{m_a} = \dfrac{T(1+\omega)}{\frac{P_a}{R_a} + \frac{P_v}{R_v}}$ $\quad R_a = \dfrac{\bar{R}}{MW_{air}} \quad R_v = \dfrac{\bar{R}}{MW_{H_2O}}$

$[v] = m^3/kg\ d.a$



Mass Balance ~~for a~~

1) For air : $\dot m_{a_1} = \dot m_{a_2}$

2) Water : $\dot m_{v_1} + \dot m_f = \dot m_{v_2}$

$$\Rightarrow \dot m_f = \dot m_{v_2} - \dot m_{v_1}$$

Divide by $\dot m_a$

$$\frac{\dot m_f}{\dot m_a} = \frac{\dot m_{v_2}}{\dot m_a} - \frac{\dot m_{v_1}}{\dot m_a} = \omega_2 - \omega_1$$

$$\Rightarrow \dot m_f = \dot m_a(\omega_2 - \omega_1)$$

Energy Balance

~~$H_1 +$~~

$$H_1 + \underline{H_f} = H_2$$

H_1: H_{a_1}, H_{v_1}

H_f: $\dot m_f h_f(T_2)$

H_2: H_{a_2}, H_{v_2}

H_{a_1}: $\dot m_a c_{pa} T_1$

H_{v_1}: $\dot m_{v_1} h_g(T_1) \to \dot m_a \omega_1 h_g(T_1)$

H_{a_2}: $\dot m_a c_{pa} T_2$

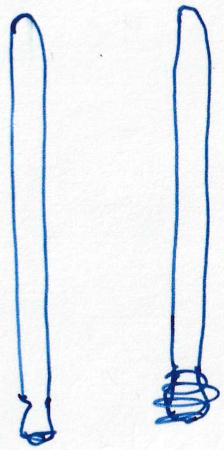
H_{v_2}: $\dot m_{v_2} h_g(T_2) \to \dot m_a \omega_2 h_g(T_2)$

$$\cancel{\dot m_a} c_{pa} T_1 + \cancel{\dot m_a} \omega_1 h_g(T_1) + \cancel{\dot m_a}(\omega_2 - \omega_1) h_f(T_2) = \cancel{\dot m_a} c_{pa} T_2 + \cancel{\dot m_a} \omega_2 h_g(T_2)$$

$$\omega_1 \left(h_g(T_1) - h_f(T_2) \right) = c_{pa}(T_2 - T_1) + \omega_2 \left[h_g(T_2) - h_f(T_2) \right]$$

$$\boxed{\omega_1 = \frac{c_{pa}(T_2 - T_1) + \omega_2 h_{fg}(T_2)}{h_g(T_1) - h_f(T_2)}}$$

$T_2 \rightarrow$ Adiabatic Saturation Temperature.



wet cloth

Dry bulb temperature

T_d

Wet Bulb temperature $\approx$ Adiabatic Saturation Temperature.

T_w

$T_d = 40°C \quad T_w = 25°C \quad RH = ? \quad \omega = ?$

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$$\omega_1 = \frac{C_{pa}(T_2 - T_1) + \omega_2 h_{fg}(T_2)}{h_g(T_1) - h_f(T_2)}$$

$T_1 = T_d$

$T_2 = T_w$

$h_g(T_1) = h_g(40) = 2574.3$ kJ/kg

$h_{fg}(T_2) = h_{fg}(25) = 2547.2$ kJ/kg ; $h_f(T_2) = h_f(25) = 104.89$ kJ/kg

At 2, $\phi = 1 \Rightarrow p_v = P_{sat}(25)$

$= 0.03169$ bar

$$\omega_2 = 0.622 \frac{p_{v_2}}{P - p_{v_2}}$$

$$= (0.622) \frac{0.03169}{1.013025 - 0.03169}$$

$= 0.0201$ kg / kg d.a.

$$\omega_1 = \frac{(1.005)(25-40) + (0.0201)(2547.2)}{2574.3 - 104.89} = 0.01463 \text{ kg/kg d.a}$$

$$\omega_1 = 0.622 \frac{p_{v_1}}{P - p_{v_1}} \Rightarrow \omega_1 P - \omega_1 p_v = 0.622\, p_v$$

$$\Rightarrow p_v = \frac{\omega_1 P}{0.622 + \omega_1} = \frac{(0.01463)(1.013025)}{0.622 + 0.01463}$$

$= 0.02328$ bar

$$\phi_1 = \frac{p_v}{p_{vsat}}$$

$p_{vsat}(40) = 0.07384$ bar

$$\phi = \frac{0.02328}{0.07384} = 31.5\%$$

$$h = c_{pa} T_d + \omega h_g(T_d)$$

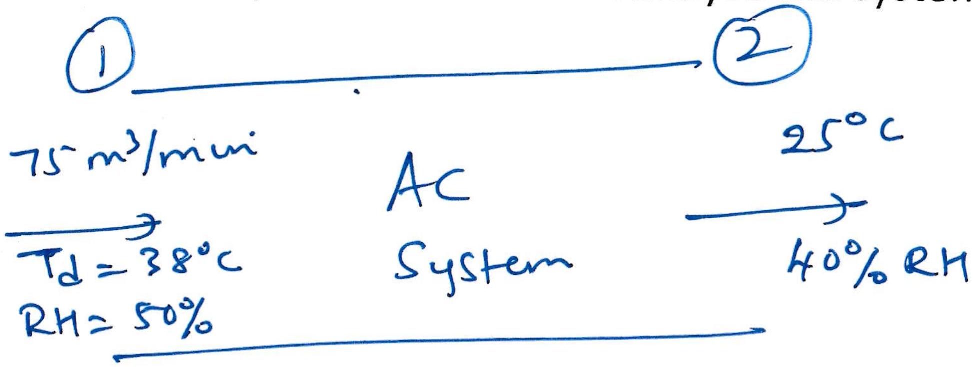
$$= (1.005)\,40 + (0.01463)(2574.3)$$

$$h = 77.86 \text{ kJ/kg d.a.}$$

$$v = \frac{T(1+\omega)}{\dfrac{p_a}{R_a} + \dfrac{p_v}{R_v}} = \frac{(1+0.01463)(273+40)}{\dfrac{(1.010325 - \cancel{0.01463})}{29} + \dfrac{(\cancel{0.01463})}{18}}$$

$$= \frac{(1+0.01463)(273+40)}{\left[\left(\dfrac{1.010325 - 0.0238}{29}\right) + \left(\dfrac{0.0238}{18}\right)\right] 10^2}$$ ← bar to kPa conversion

75 m^3/min of air at 38C and 50% RH is to be conditioned and delivered to a room at 25C and 40% RH. T
coefficient of performance of 3. Analyze the system



$h_1 = C_{pa} T_1 + \omega_1 h_g(T_1)$

At $T_d = 38°C$, $P_{sat} = 0.06632$, Since $\phi = 50\%$, $P_v = 0.03316$ bar

$$\omega_1 = (0.622)\frac{0.03316}{1.013025 - 0.03316} = 0.02105 \text{ kg/kg d.a.}$$

At $T_d = 25°C$ $P_{sat} = 0.03169$ bar $\phi = 40\% \Rightarrow P_v = 0.012676$ bar

$$\omega_2 = (0.622)\frac{0.012676}{1.013025 - 0.012676} = 7.882 \times 10^{-3} \text{ kg/kg d.a.}$$

$$p_v \text{ corresponding to } \omega_2 = \frac{\omega_2 P}{0.622 + \omega_2} = \frac{7.882\times10^{-3} \times 1.013025}{0.622 + 7.882\times10^{-3}}$$

$$= 0.01268 \text{ bar}$$

Cool it down to 10.5°C (corresponding to $P_{sat} = 0.01268$ bar)