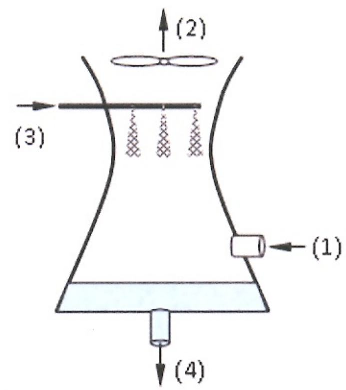
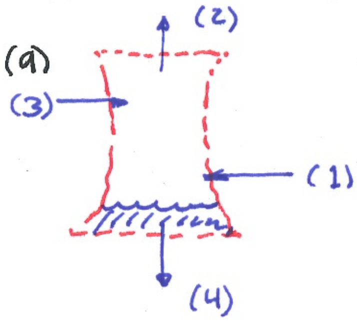
Example

Warm water enters a cooling tower at 45°C at a rate of 130 kg/s to be cooled to 30°C. Atmospheric air at a dry bulb temperature of 25°C and φ = 50% enters the tower to effect the cooling, and leaves the tower at a saturated state at 32°C. Neglecting the power input to the fan, determine

(a) the mass flow rate of dry air into the tower,
(b) the volumetric flow rate of air entering the tower (at 1), and
(c) how much water evaporates in kg/s.



(a)



Cons. of mass

AIR:

$$0 = \dot{m}_{a,1} - \dot{m}_{a,2}$$

$$\dot{m}_{a,1} = \dot{m}_{a,2} = \dot{m}_a$$

WATER:

$$0 = \dot{m}_a \omega_1 + \dot{m}_{w,3} - \dot{m}_a \omega_2 - \dot{m}_{w,4}$$

$$\dot{m}_{w,4} = \dot{m}_{w,3} - \dot{m}_a(\omega_2 - \omega_1) \quad (1)$$

$\dot{m}_a(\omega_2-\omega_1)$ → $\dot{m}_{EVAPORATED\ WATER}$

$\omega_1 = \omega(T_1 = 25°C, \phi_1 = 50\%)$
= ______

$\omega_2 = \omega(T_2 = 32°C, \phi_2 = 100\%)$
-OR-
$\omega(T_2 = 32°C, T_{wb} = 32°C)$
-OR-
$\omega(T_2 = 32°C, T_{DEW} = 32°C)$
= ______

Cons. of energy

$$0 = 0 - 0 + \dot{m}_a h_1 + \dot{m}_w h_{3,w} - \dot{m}_a h_2 - \dot{m}_{w,4} h_{w,4}$$

USING (1)

$$0 = \dot{m}_a h_1 + \dot{m}_w h_{w,3} - \dot{m}_a h_2 - [\dot{m}_{w,3} - \dot{m}_a(\omega_2 - \omega_1)] h_{w,4}$$

SOLVE FOR $\dot{m}_a$:

$$\dot{m}_a = \frac{\dot{m}_{w,3}[h_{w,4} - h_{w,3}]}{h_1 - h_2 + (\omega_2 - \omega_1) h_{w,4}}$$

$h_{w,3} \approx h_f(T_3) =$ ______

$h_{w,4} \approx h_f(T_4) =$ ______

$h_1 = h(T_1 = 25°C, \phi_1 = 50\%)$

$=$ ______

$h_2 = h(T_2 = 32°C, \phi_2 = 100\%)$

$=$ ______

... $\boxed{\dot{m}_a = \qquad \text{kg/s}}$

(b) $\dot{m}_a = \dfrac{\dot{V}_1}{v_{a1}}$

$\dot{V} = v_{a1} \dot{m}_a$

$v_{a1} = v(T_1 = 25°C, \phi_1 = 50\%)$

$=$ ______

$= \boxed{\qquad \dfrac{m^3}{s}}$

(c) $\dot{m}_{evap} = \dot{m}_a(\omega_2 - \omega_1) =$

$= \boxed{\qquad \dfrac{kg}{s}}$