1. Determine the following conditions in our classroom (in English units) from measurements of the dry bulb temperature, the wet bulb temperature, and the dimensions of the room.
   a. Relative humidity. **[1 point]**
   b. Humidity ratio. **[1 point]**
   c. Dew point. **[1 point]**
   d. Volume of the room. **[2 points]**
   e. Mass of air in the room. **[2 points]**
   f. Mass of moisture in the room. **[2 points]**
   g. Mark this state on the attached psychrometric chart. **[1 point]**

- W = 19.5', L = 32.5', H = 7.5'
- Dry temp = 74F
- Wet bulb = 54F

$\cancel{\frac{50}{56} + \frac{5}{5} \rightarrow \boxed{90.89\%}}$

$\frac{55}{56} + \frac{5}{5} \longrightarrow \boxed{98.48\%}$

(a) $\boxed{\phi \approx 24\%}$

(b) $\boxed{\omega = 0.0045 \ \frac{\text{lb moisture}}{\text{lb dry air}}}$

(c) $\boxed{T_{dp} = 36°F}$

(d) $\boxed{V_{room} = 4753 \ ft^3}$ $= (19.5)(32.5)(7.5)$

(e) $\boxed{m_{dry\ air} = 350.8 \ lb}$

$\frac{1}{m} = \frac{v}{V} = \frac{13.55}{4753} \ \frac{\cancel{ft^3}}{lb_{dry}} \ \cancel{ft^3}$

$m = 350.8$

(f) $\boxed{m_{moisture} = 1.58 \ lb}$

$\omega \rightarrow \left(.0045 \ \frac{\text{lb moisture}}{\cancel{\text{lb dry air}}}\right)\left(350.8 \ \cancel{\text{lb dry air}}\right) = 1.58$

(g) $\boxed{\text{On Page 8 (back)}}$

2. In a building's HVAC system, 100 m^3/min of outside air is heated in a duct from 10°C and 60% RH to 40°C. Determine...
   a. The relative humidity of the air at the outlet of the duct? **[2 points]**
   b. The rate of heat transfer to the air (in kW)? **[4 points]**
   c. Determine mass flow rate of moisture (in kg/h) that would need to be added to the air exiting the heater to bring the relative humidity up to 30% at 40°C. **[4 points]**
   d. Draw these two processes on the attached psychrometric chart. **[3 points]**

(a) $\boxed{10\%}$

(b) $\boxed{\dot{Q}_{in} = 61.9 \text{ kW}}$

(c) $\boxed{\dot{m}_w = 70.5 \frac{kg}{hr}}$

(d) $\boxed{\text{on page 9}}$

v_1

$$\frac{100\,m^3}{min} \cdot \frac{1\,min}{60\,sec} \cdot \frac{kg}{.808\,m^3} = 2.06 \frac{kg_{dry}}{s}$$

$$\dot{Q}_{in} = \dot{m}_a(h_2 - h_1) = (2.06 \tfrac{kg_{dry}}{s})(52500 - 22500)$$

$h_1 = 22{,}500$ J/kg dry

$h_2 = 52500$ J/kg dry

$$\dot{Q}_{in} = 61881 \frac{J}{s}$$

State 3 → $\dot{m}_3 = 2.063 \frac{kg_{dry}}{s}$, $w_3 = 14$

$$\dot{m}_2 \omega_2 + \dot{m}_w = \dot{m}_{a3} w_3$$

$$\dot{m}_w = \dot{m}(w_3 - w_2) = 2.063(14 - 4.5)$$

$$\frac{\cancel{kg_{dry}}}{s} \cdot \frac{g_{moisture}}{\cancel{kg_{dry}}}$$

$$\dot{m}_w = 19.6 \frac{g}{\cancel{s}} \cdot \frac{60\,\cancel{s}}{1\,\cancel{min}} \cdot \frac{60\,\cancel{min}}{1\,hr} \cdot \frac{kg}{1000\,\cancel{g}}$$

$$\dot{m} = 70.5 \frac{kg}{hr}$$

3. At an ice rink the air temperature is maintained at 55°F while the surface temperature of the ice may be as low as 17°F. In order to keep moisture in the air from condensing on the ice, or creating a fog above the ice (see figure below), the relative humidity of the air must be kept below what level? Draw on the attached psychrometric chart the method that you used to arrive at this value.
[2 points]

$\boxed{\phi = 20\%}$

see page 8

4. An ice rink uses a two-stage dehumidification system to remove moisture from the arena enclosing the ice sheet. The first stage is a dehumidification process that takes in air at 55°F and 30% RH and the second stage is a reheating process that delivers air back to the room at 55°F and 15% RH. If the system must dehumidify 1,000 cfm of moist air, determine…
   a. The dry-bulb temperature required at the end of the dehumidification process. **[1 point]**
   b. The rate of moisture removal (in lbm/h)? (7,000 grains = 1 lbm) **[4 points]**
   c. The rate of heat removal (in Btu/h) required in the dehumidification process? **[2 points]**
   d. The rate of heat addition (in Btu/h) required in the reheating process? **[2 points]**
   e. Draw these two processes on the attached psychrometric chart. **[3 points]**

Take h_w @ 55°F =

(a) $\boxed{T_{DB} = 11°F}$

(b) $\boxed{\dot{m}_w = 6.58 \frac{lbm_w}{hr}}$

(c) $\boxed{\dot{Q}_{out} = 55144 \frac{Btu}{hr}}$

(d) $\boxed{\dot{Q}_{in} = 48845 \frac{Btu}{hr}}$

(e) on page 8

① 55°F @ $\phi = 30\%$

follow sat. line

②

③ 55°F @ $\phi = 15\%$

moist air,

$\dot{m}_{1a} = \dot{m}_{2a} = \dot{m}_{3a}$

$1000 \frac{ft^3}{min} \cdot \frac{1 \ lb_{dry}}{13.02 \ ft^3} = 76.8 \frac{lb_{dry}}{min}$

$\dot{m}_{1a}\omega_1 = \dot{m}_{2a}\omega_2 + \dot{m}_w$

$\dot{m}_w = \dot{m}(\omega_1 - \omega_2) = 76.8 \frac{\cancel{lb_a}}{min} \left(\frac{19-9}{7000}\right) \frac{lbm}{\cancel{lb_a}}$

$\omega_1 = 19 \frac{grains}{lb_a}$ $\quad \omega_2 = 9 \frac{grains}{lb_a}$

$\dot{m}_w = .1097 \frac{lbm}{min} = 6.58 \frac{lbm_w}{hr}$

$\dot{Q}_{out} = \dot{m}_a(h_1 - h_2) - \dot{m}_w h_w$

$h_1 = 16.2 \frac{Btu}{lb_a}$

$h_2 = 4.2 \frac{Btu}{lb_a}$

$\dot{Q}_{out} = 76.8(60)(16.2 - 4.2) - 6.58(23.07)$

$\frac{\cancel{lb_a}}{hr \ \cancel{min}} \quad \frac{Btu}{\cancel{lb_a}} \quad \frac{lbw}{hr}$

h_w @ ~~11°F~~ 55°F = 23.07

$\dot{Q}_{out} = 55144 \ Btu/hr$

$h_3 = 14.8 \frac{Btu}{lb_a}$

$\dot{Q}_{in} = \dot{m}_a(h_3 - h_2) = 76.8 \frac{\cancel{lb_a}}{\cancel{min}}\left(60 \frac{\cancel{min}}{hr}\right)(14.8 - 4.2)\frac{Btu}{\cancel{lb_a}}$

$\dot{Q}_{in} = 48845$

5. Air enters an evaporative cooler at 110°F and 20% RH at a rate of 1,000 cfm. Determine...
   a. The lowest exit temperature that could be achieved with this cooler? **[2 points]**
   b. The required rate of water supply to the evaporative cooler (in gph @ 60°F) to reach the temperature in part a. **[6 points]**
   c. Draw this process on the attached psychrometric chart. **[2 points]**

(a) $\boxed{T_{lowest} \cong 75\,°F}$

(b) $\boxed{\dot{V} = 3.943 \text{ gph}}$

(c) See back of pg. 8

$$1000 \frac{\cancel{ft^3}}{min} \Big| \frac{lb_a}{14.6\ \cancel{ft^3}} = 68.49 \frac{lb_a}{min} = \dot{m}_a$$

$$= 4109.5\ lb_a/hr$$

$$\omega_1 = .011 \qquad \omega_2 = .019$$

$$\dot{m}_w = \dot{m}_{a_1}(\omega_1 - \omega_2) = 4109.5(.019 - .011)$$

$$\frac{\cancel{lb_a}}{hr} \quad \frac{lb_w}{\cancel{lb_a}}$$

$$\dot{m}_w = 32.877 \frac{lb_w}{hr}$$

water @ 60°F

$$8.3378 \frac{lb}{gal}$$

$$32.877 \frac{\cancel{lb_w}}{hr} \Big| \frac{gal}{8.3378\ \cancel{lb}}$$

$$\dot{V} = 3.943 \text{ gph}$$

6. Two air streams are mixed steadily and adiabatically. The first stream enters at 40°C and 10% RH at a rate of 200 m^3/min, while the second stream enters at 10°C and 60% RH at a rate of 400 m^3/min. Assuming that the mixing process occurs at a pressure 1 atm, determine the...
   a. Relative humidity of the air mixture. **[2 points]**
   b. Dry-bulb temperature of the air mixture. **[2 points]**
   c. Volumetric flow rate of the air mixture. Recall that there is no conservation of volume! **[2 points]**
   d. Draw this process on the attached psychrometric chart. **[3 points]**

$\omega_1 = \omega_2 = 4.5 \frac{g}{kg_a}$

$.0045 \frac{kg_w}{kg_a}$

(a) $\boxed{\phi = 30\%}$

(b) $\boxed{T_{db} = 19.5°C}$

(c) $\boxed{\dot{V}_3 = 600.4 \frac{m^3}{min}}$

(d) $\boxed{\text{on page 9}}$

Stream 1

$200 \frac{m^3}{min} \left| \frac{1\ kg_a}{.893\ m^3} \right. = 223.964 \frac{kg_a}{min}$

$h_1 = 52000 \frac{J}{kg_a}$

$\dot{m}_{a3} = 719.01 \frac{kg_a}{min}$

$h_2 = 21500\ J/kg_a$

Stream 2

$400 \frac{m^3}{min} \left| \frac{1\ kg_a}{.808\ m^3} \right. = 495.05 \frac{kg_a}{min}$

$\dot{m}_{a1}\omega_1 + \dot{m}_{a2}\omega_2 = \dot{m}_{a3}\omega_3$

$\downarrow$

$\omega_3 = .0045$

$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{h_2 - h_3}{h_3 - h_1} \rightarrow \frac{223.96}{495.05} = \frac{21500 - h_3}{h_3 - 52000}$

solve for h_3 on calc

$\downarrow$

$h_3 = 31000 \frac{J}{kg_a}$

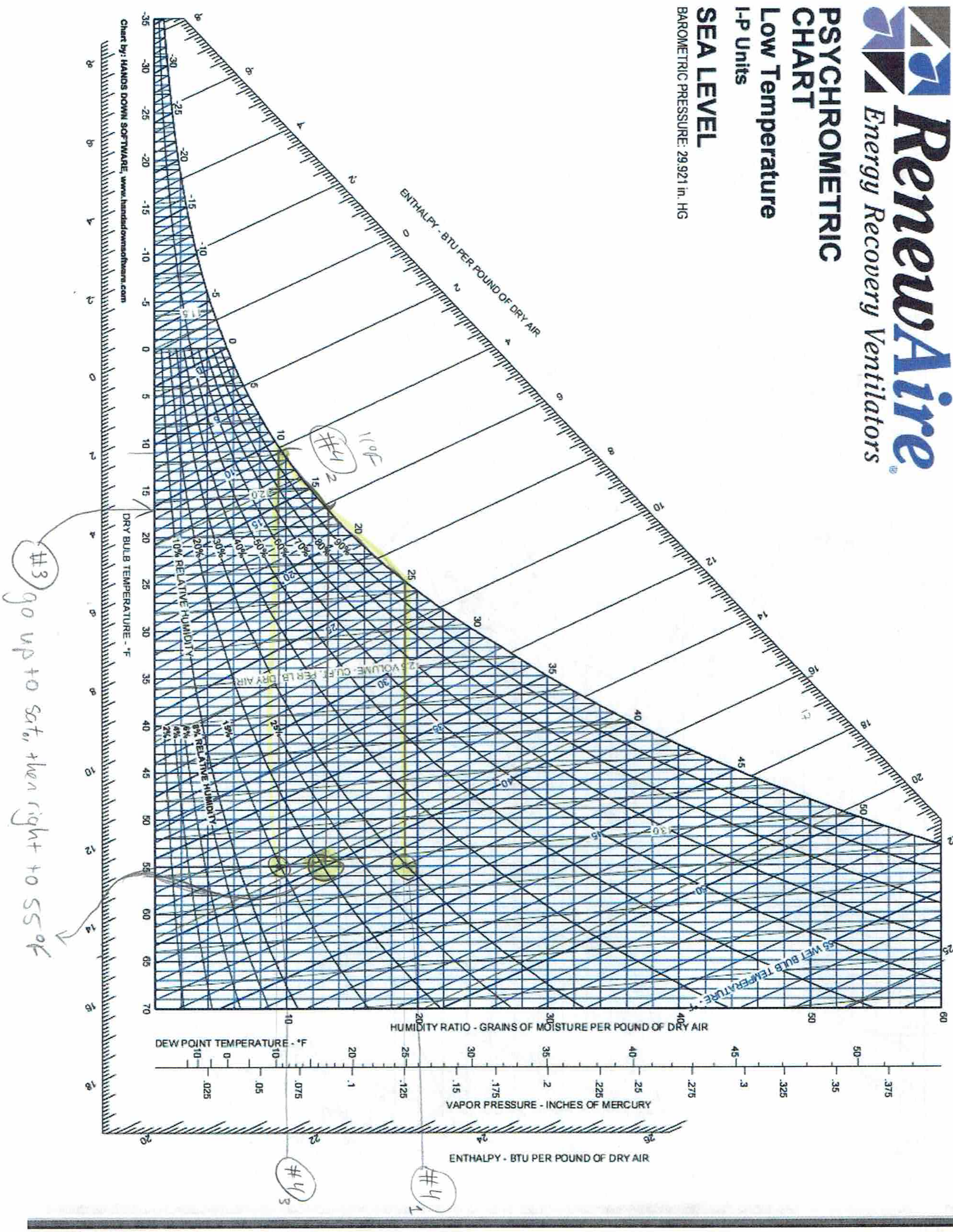
chart $\downarrow$

$v_3 = .835 \frac{m^3}{kg_a}$ / $T_{mix,dry} = 19.5°C$ / $\phi = 30\%$

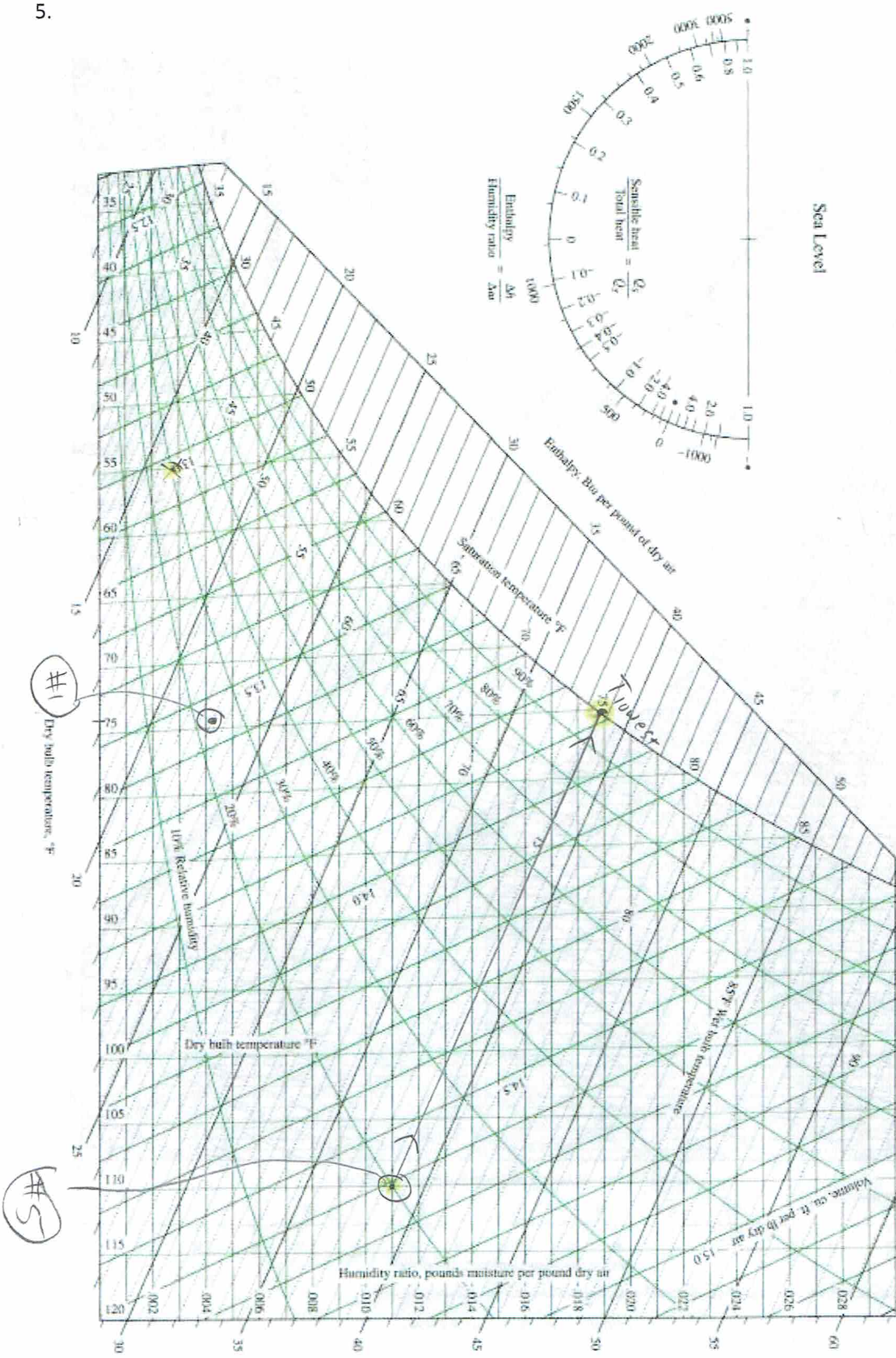
$\dot{V}_3 = 719.01 \frac{kg_a}{min} \left| \frac{.835\ m^3}{kg_a} \right. = 600.4\ m^3/min$

$(\dot{m}_{a3})(v_3)$

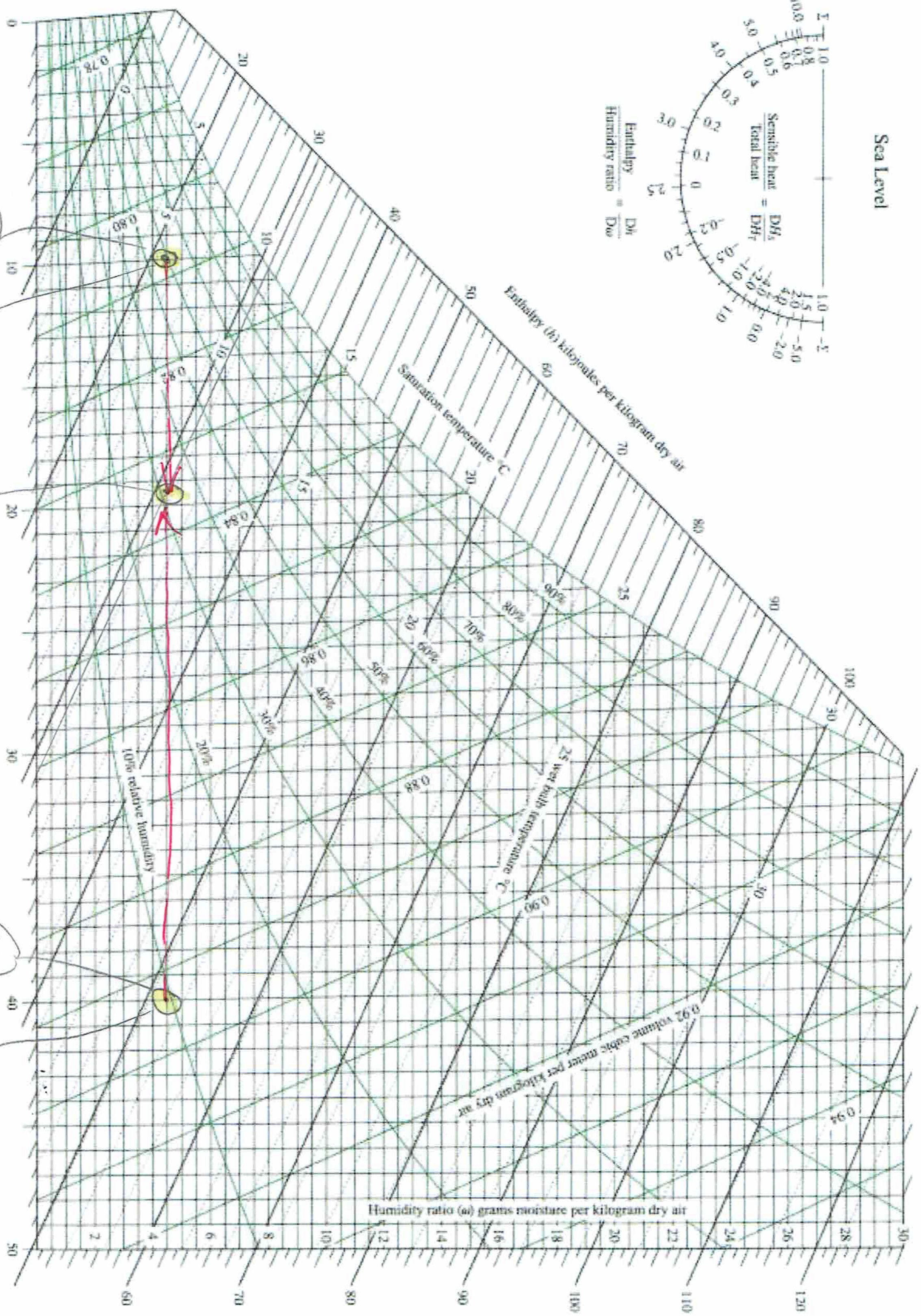
4.


RenewAire
Energy Recovery Ventilators
PSYCHROMETRIC CHART
Low Temperature
I-P Units
SEA LEVEL
BAROMETRIC PRESSURE: 29.921 in. HG
ENTHALPY - BTU PER POUND OF DRY AIR
DRY BULB TEMPERATURE - °F
RELATIVE HUMIDITY
VOLUME - CU.FT. PER LB DRY AIR
WET BULB TEMPERATURE
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DEW POINT TEMPERATURE - °F
VAPOR PRESSURE - INCHES OF MERCURY
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com
#3 go up to sat, then right to 55°F
#4
11°F

5.


Sea Level
Sensible heat / Total heat = Q_s / Q_t
Enthalpy / Humidity ratio = $\Delta h / \Delta \omega$
Enthalpy, Btu per pound of dry air
Saturation temperature °F
Dry bulb temperature °F
10% Relative humidity
85°F Wet bulb temperature
Humidity ratio, pounds moisture per pound dry air
Volume, cu. ft. per lb dry air
#1
#5
Lowest

6.



#6 Stream 2

#2

#6 Stream 3

Processes -1

#2

#6 Stream 1