THE PSYCHROMETRIC CHART: Theory and Application

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PSYCHROMETRIC CHART

- Identify parts of the chart
- Determine moist air properties
- Use chart to analyze processes involving moist air

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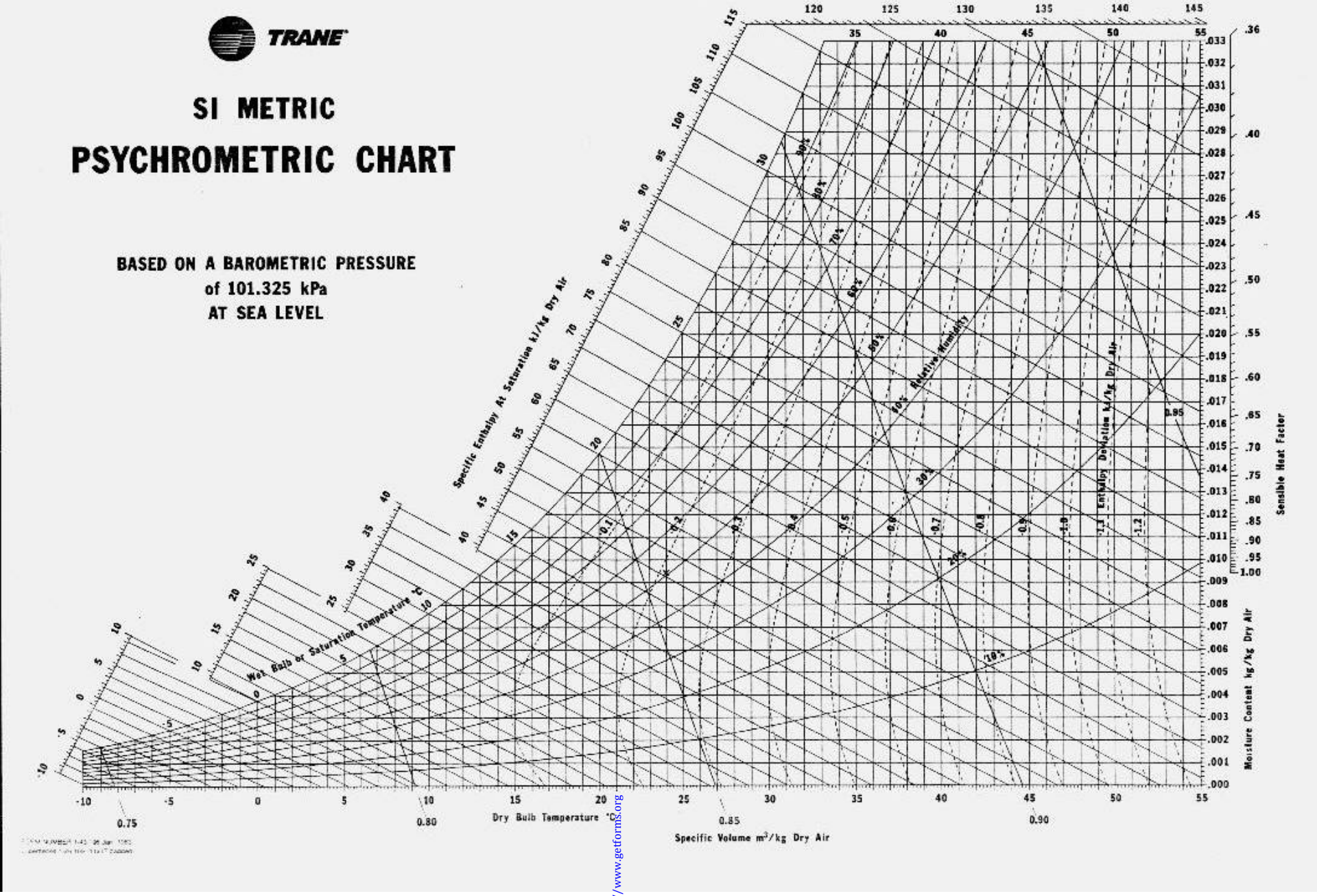
TRANE

SI METRIC
PSYCHROMETRIC CHART

BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL



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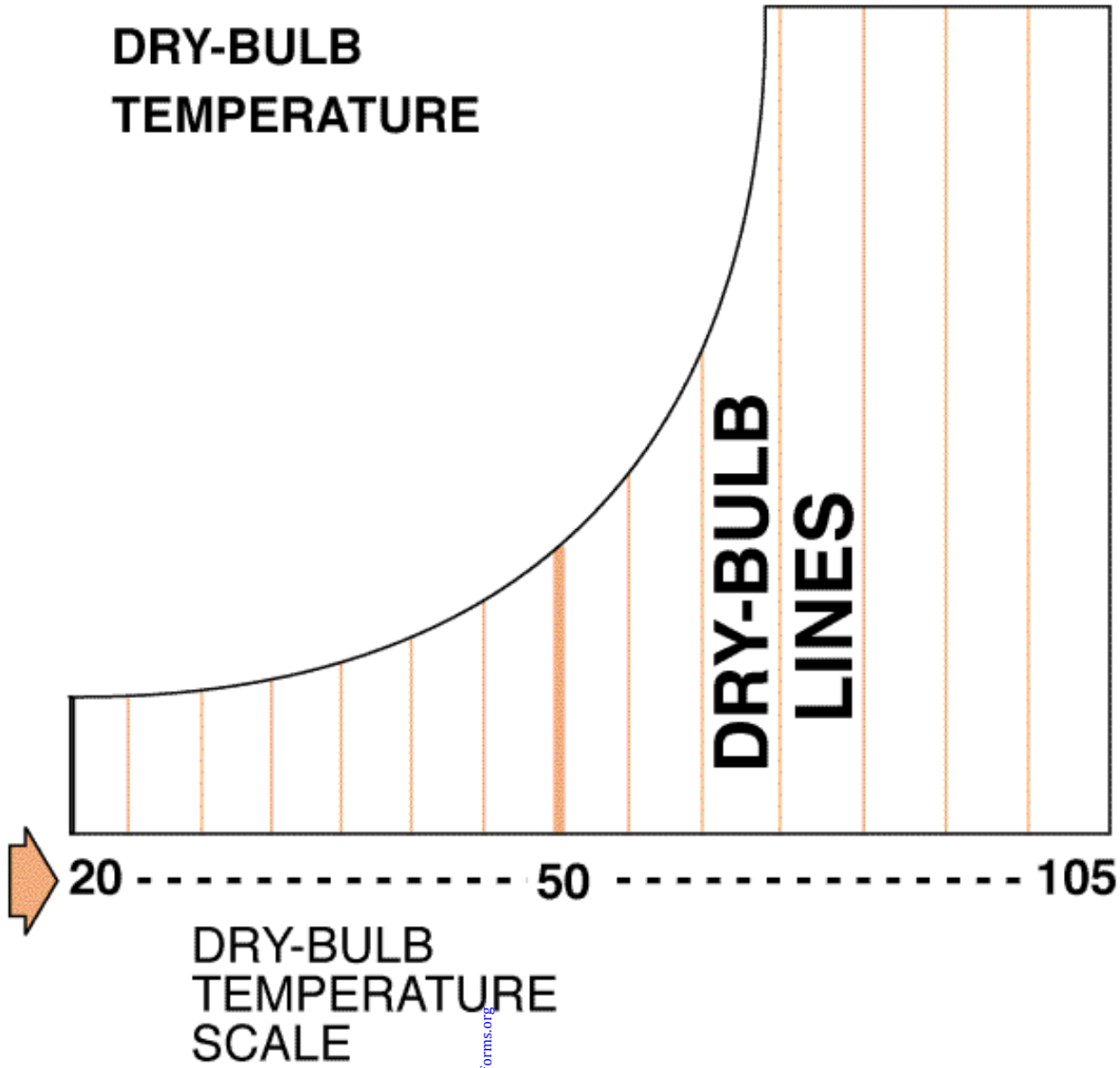

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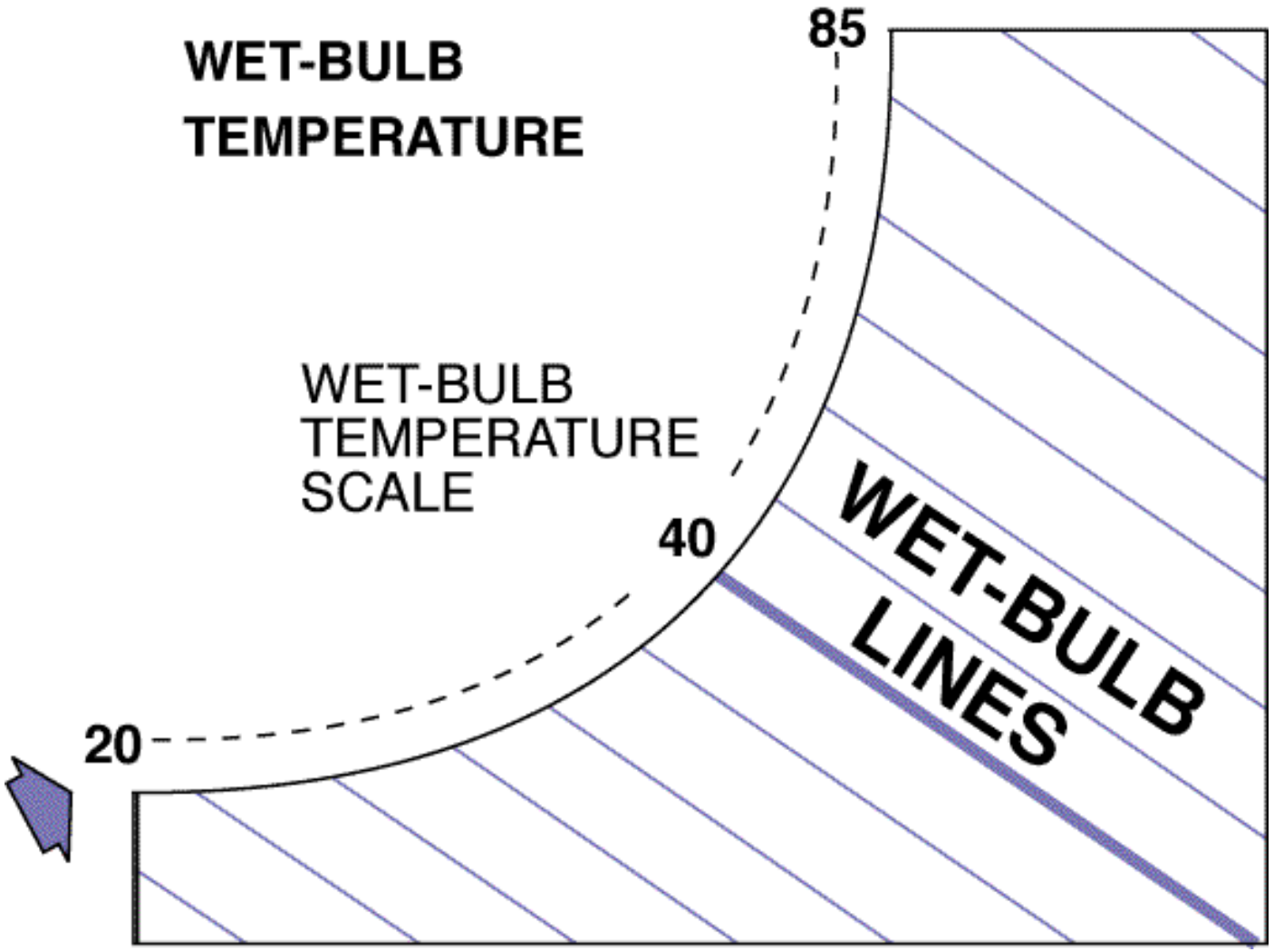

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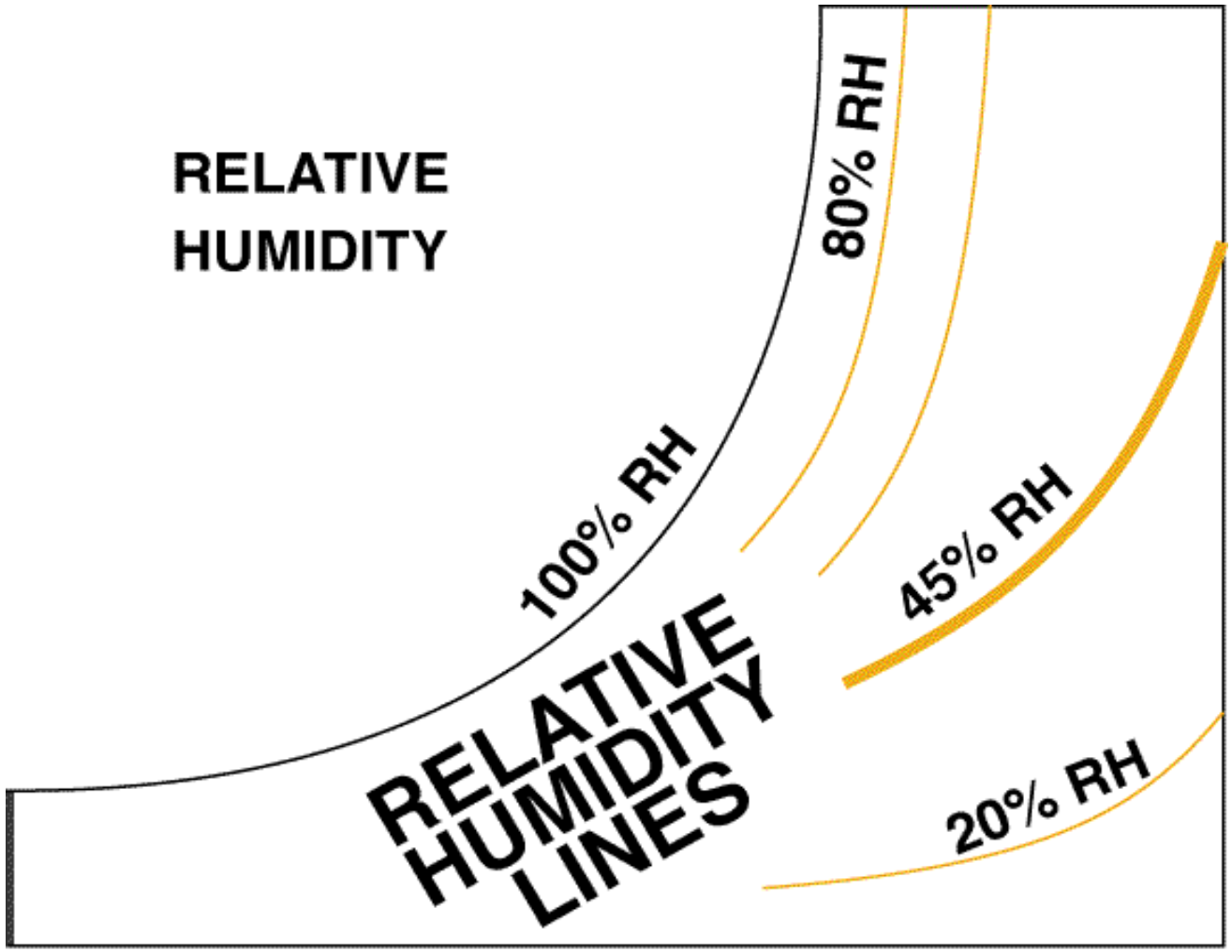

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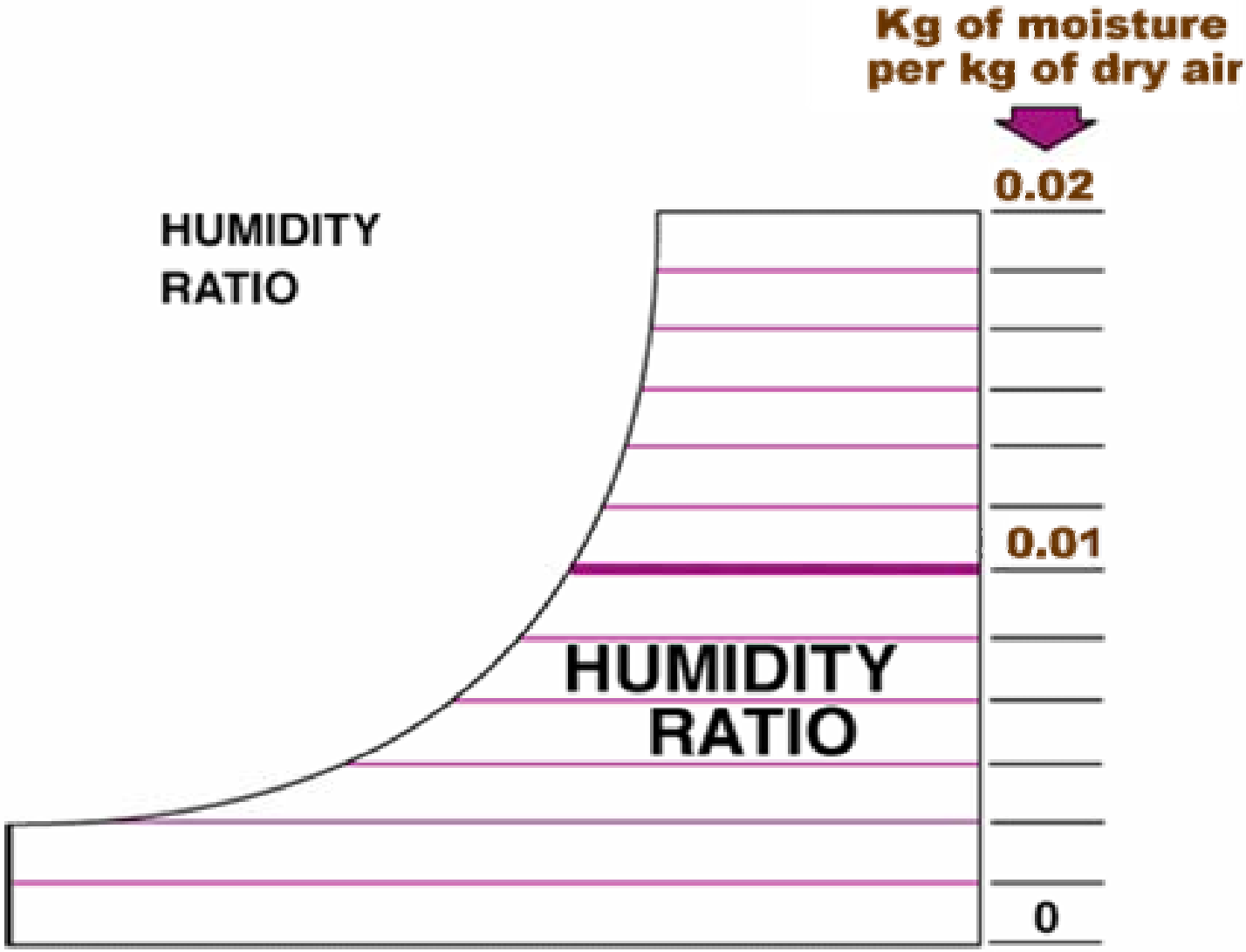

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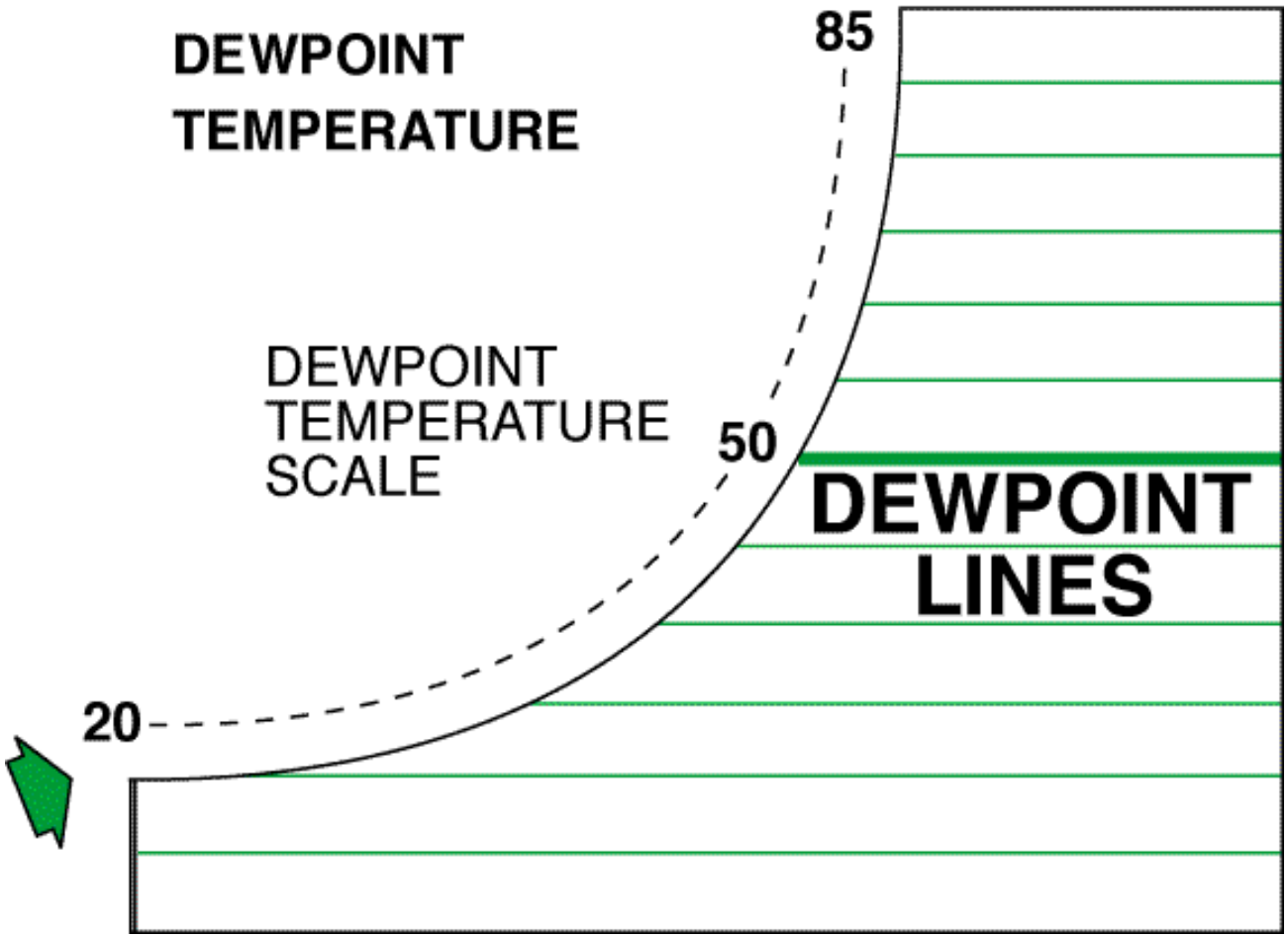

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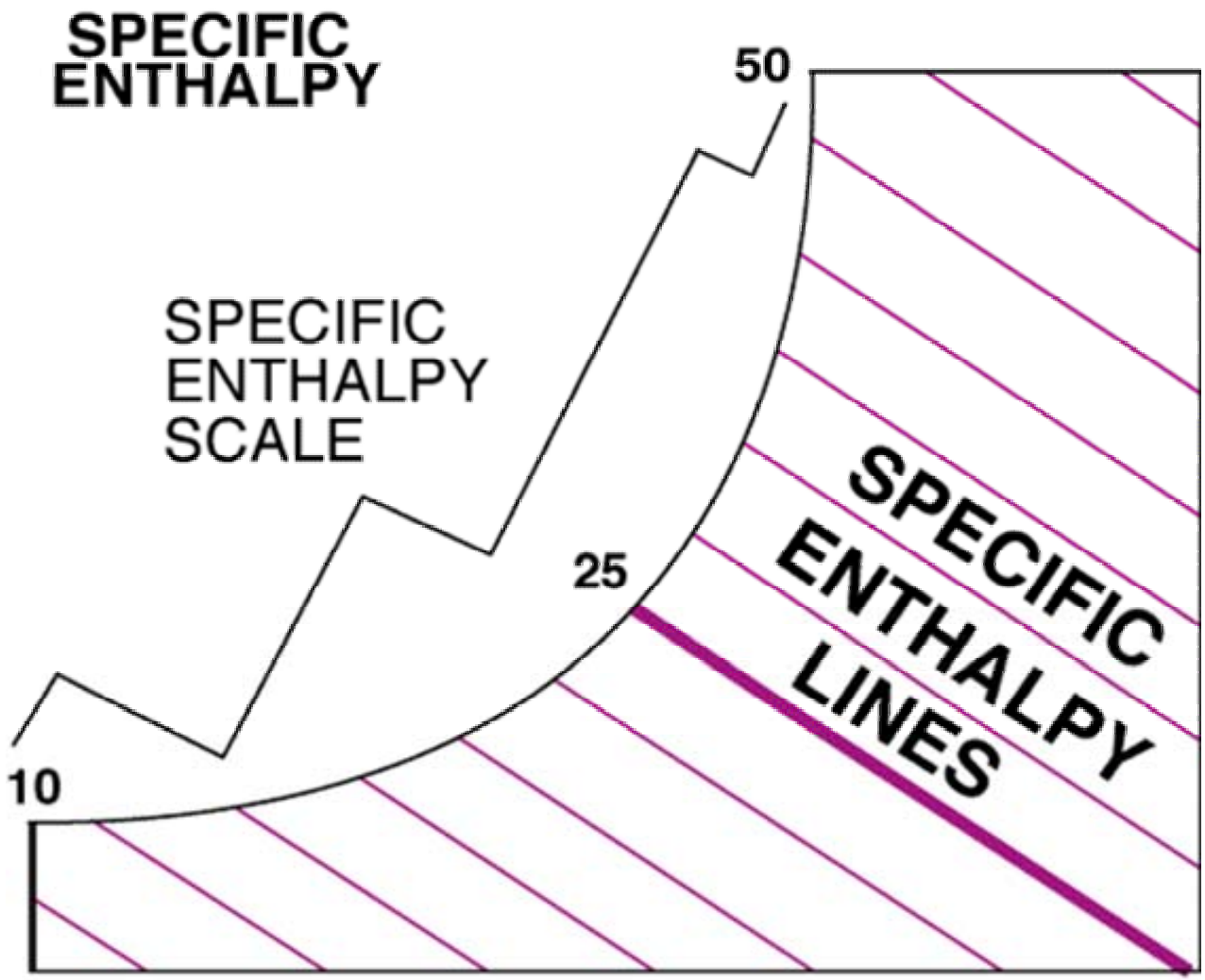

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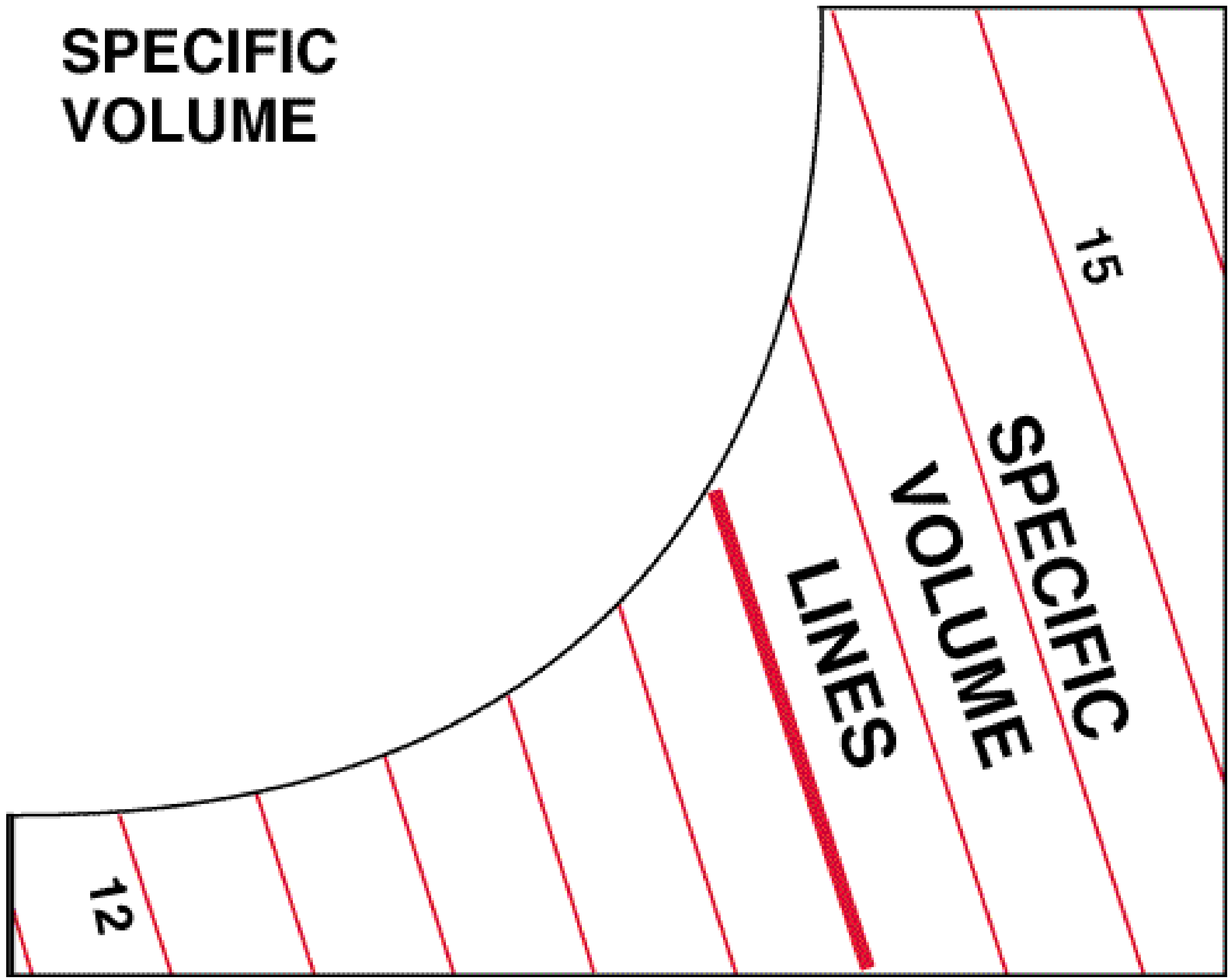
SPECIFIC VOLUME



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Psychrometric chart: Example 1

Given: $T = 25°C$

$T_w = 20°C$

Required: (a) RH, (b) T_{dp}, (c) HR, (d) v, (e) h

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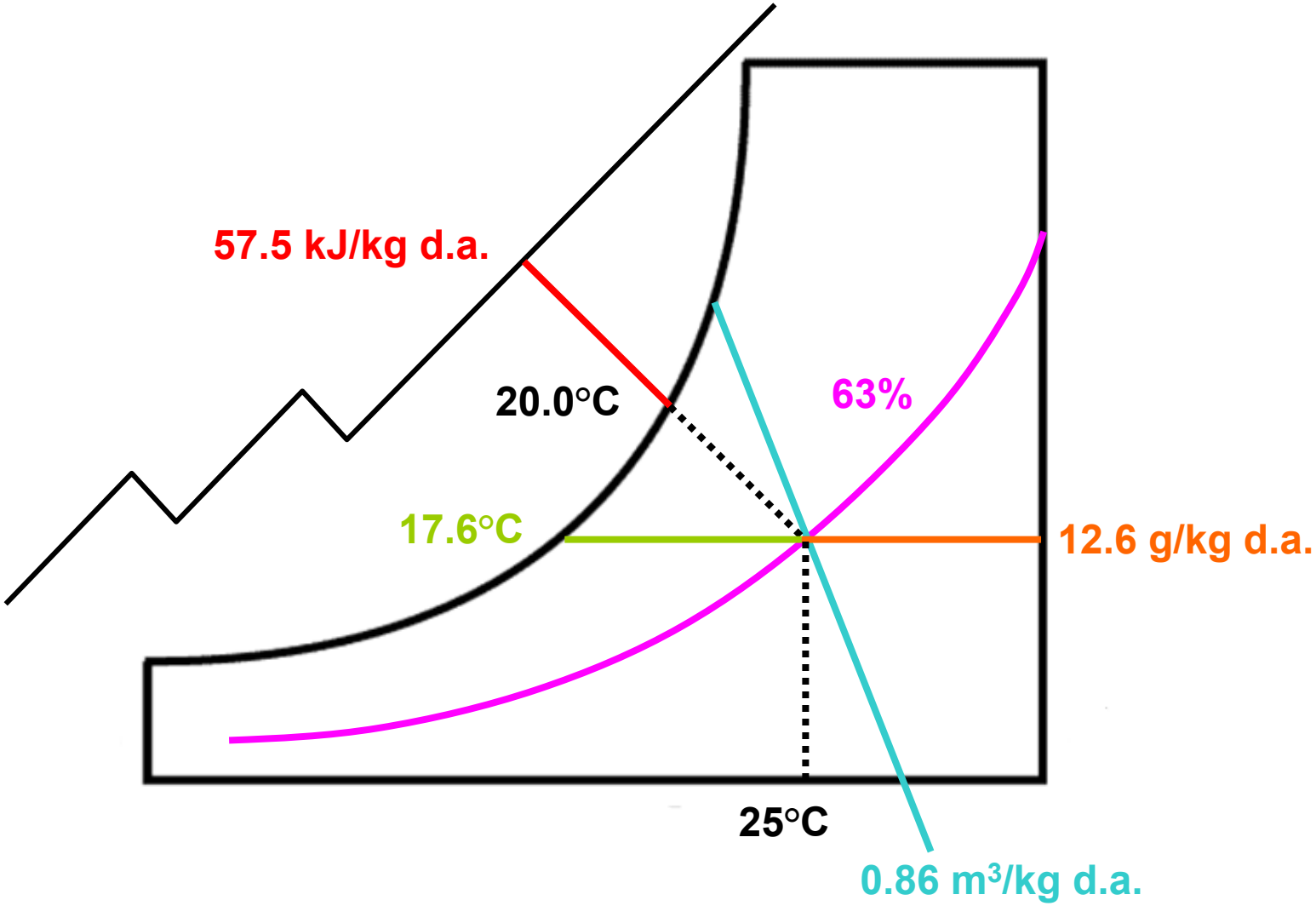

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PSYCHROMETRIC PROCESSES

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Sensible Heating or Cooling

- a psychrometric process that involves the increase or decrease in the temperature of air without changing its humidity ratio
- Example: passing moist air over a room space heater and of kiln air over the heating coils

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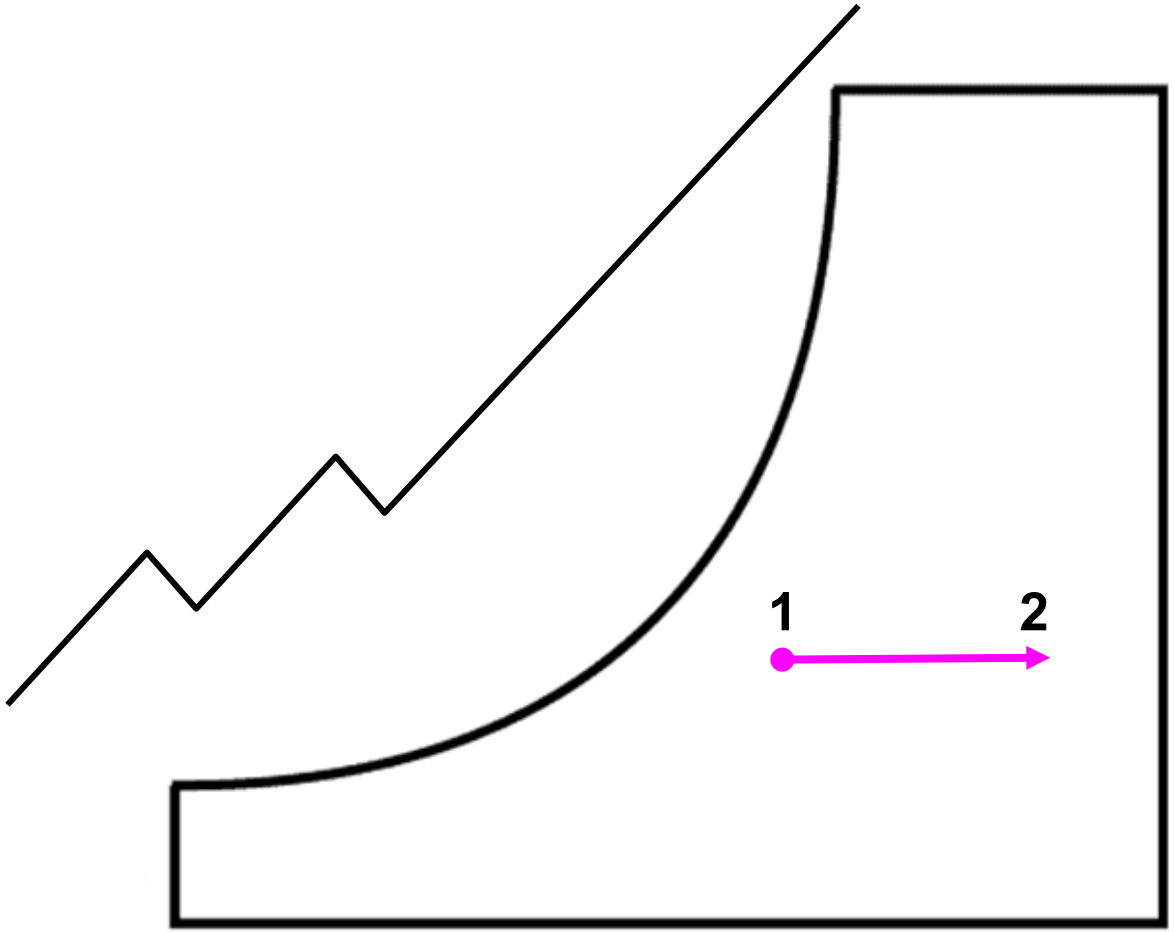

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Sensible heating: Example 5

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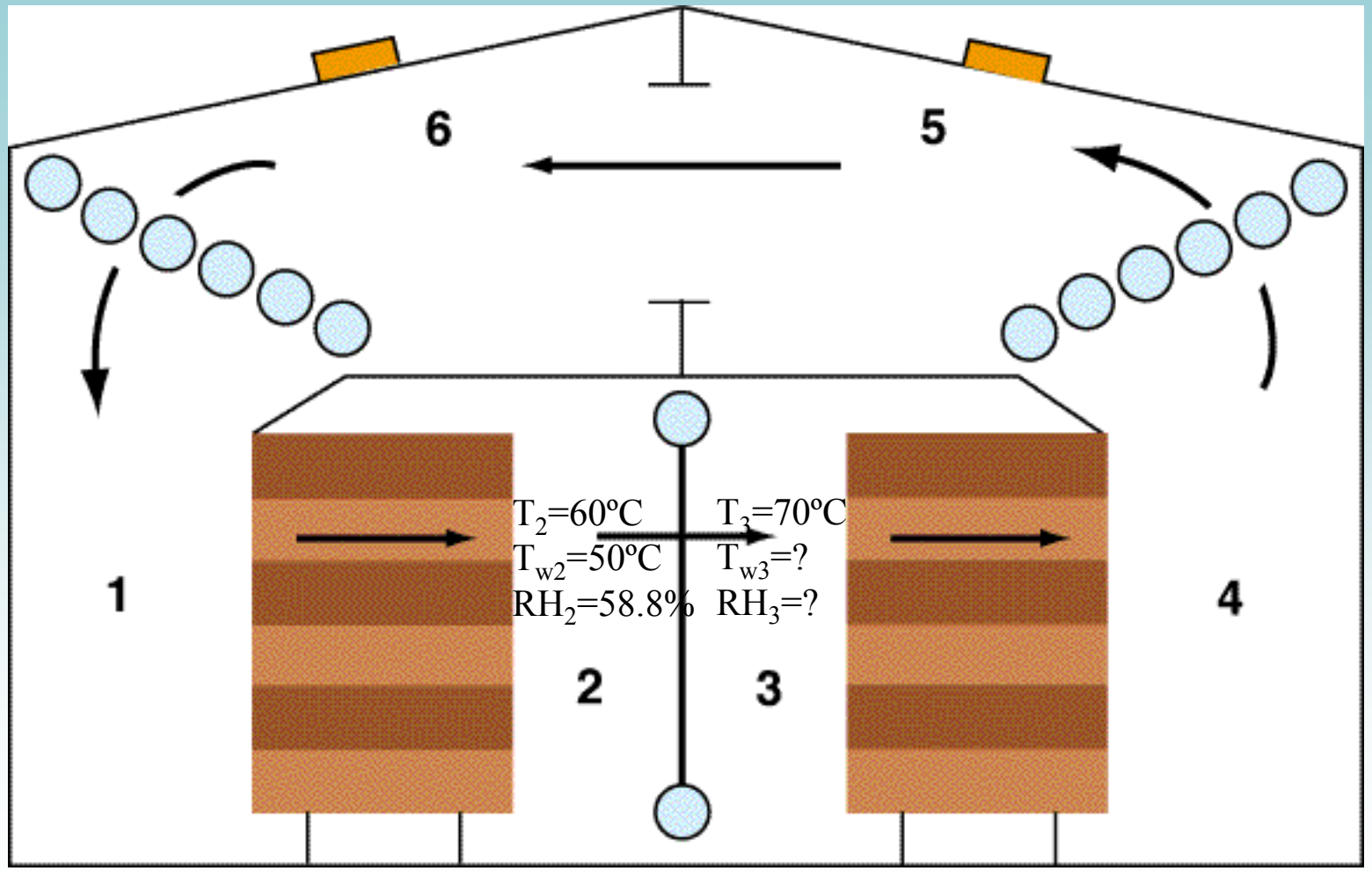

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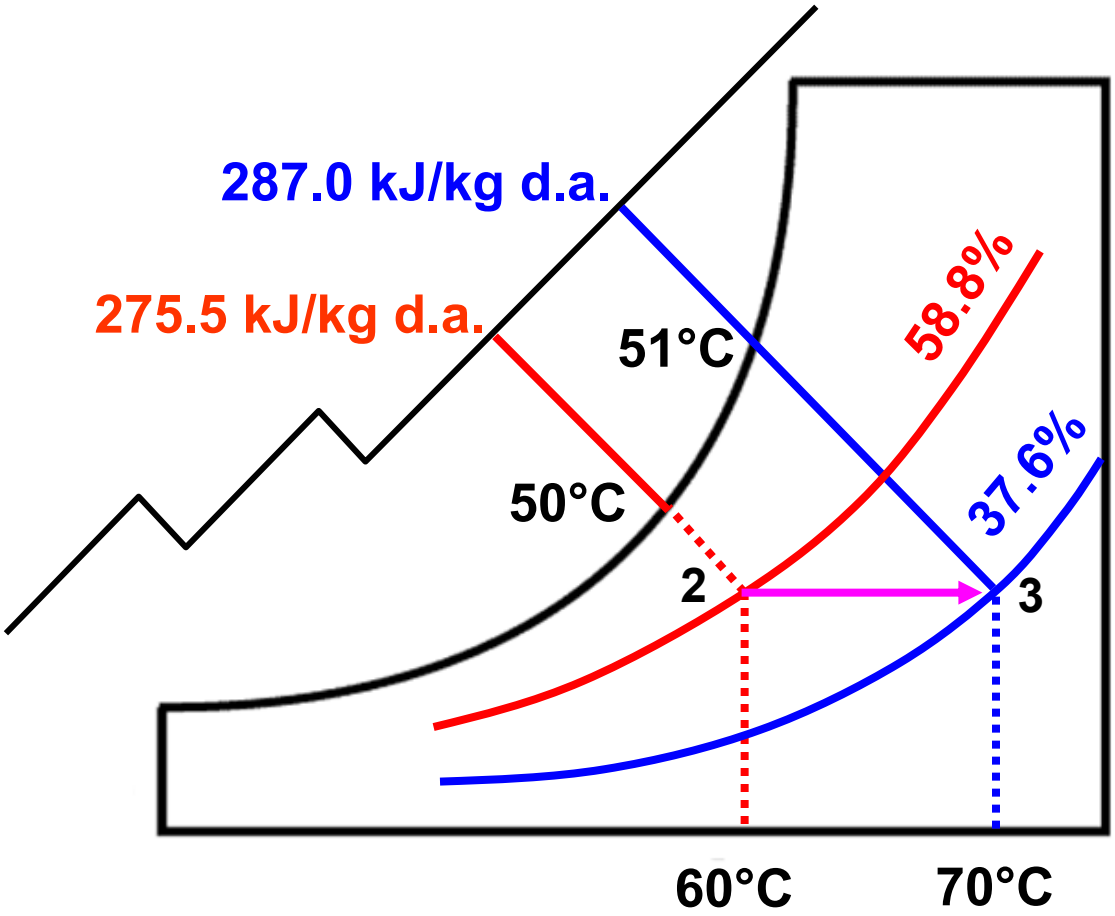

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Heating and Humidifying

- a psychrometric process that involves the simultaneous increase in both the dry bulb temperature and humidity ratio of the air

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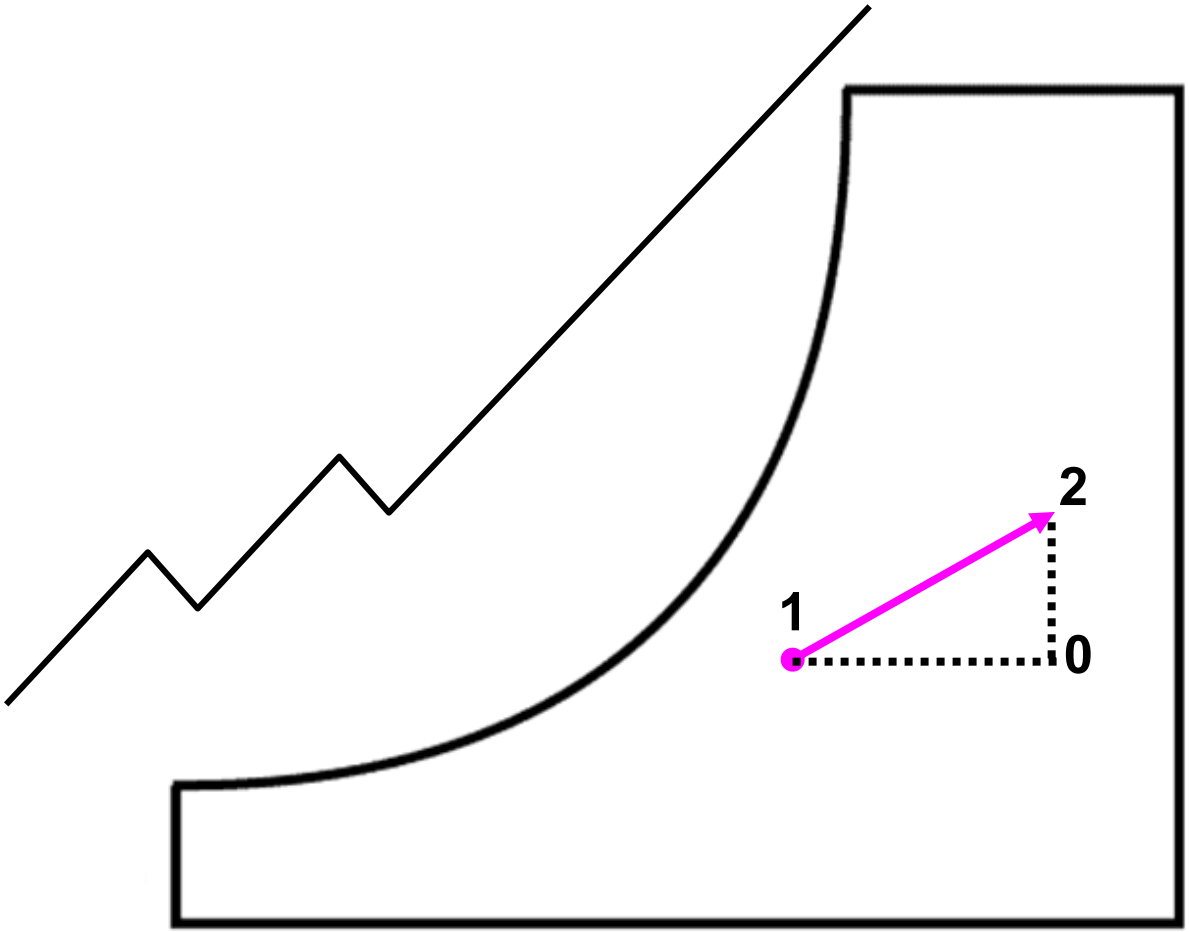

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Heating and humidifying: Example 7

Two and a half cubic meters of lumber is being dried at 60°C dry bulb temperature and 52°C wet bulb temperature. The drying rate of the lumber is 12.5 kg of water per hour. If outside air is at 27°C dry bulb temperature and 80% relative humidity, how much outside air is needed per minute to carry away the evaporated moisture?

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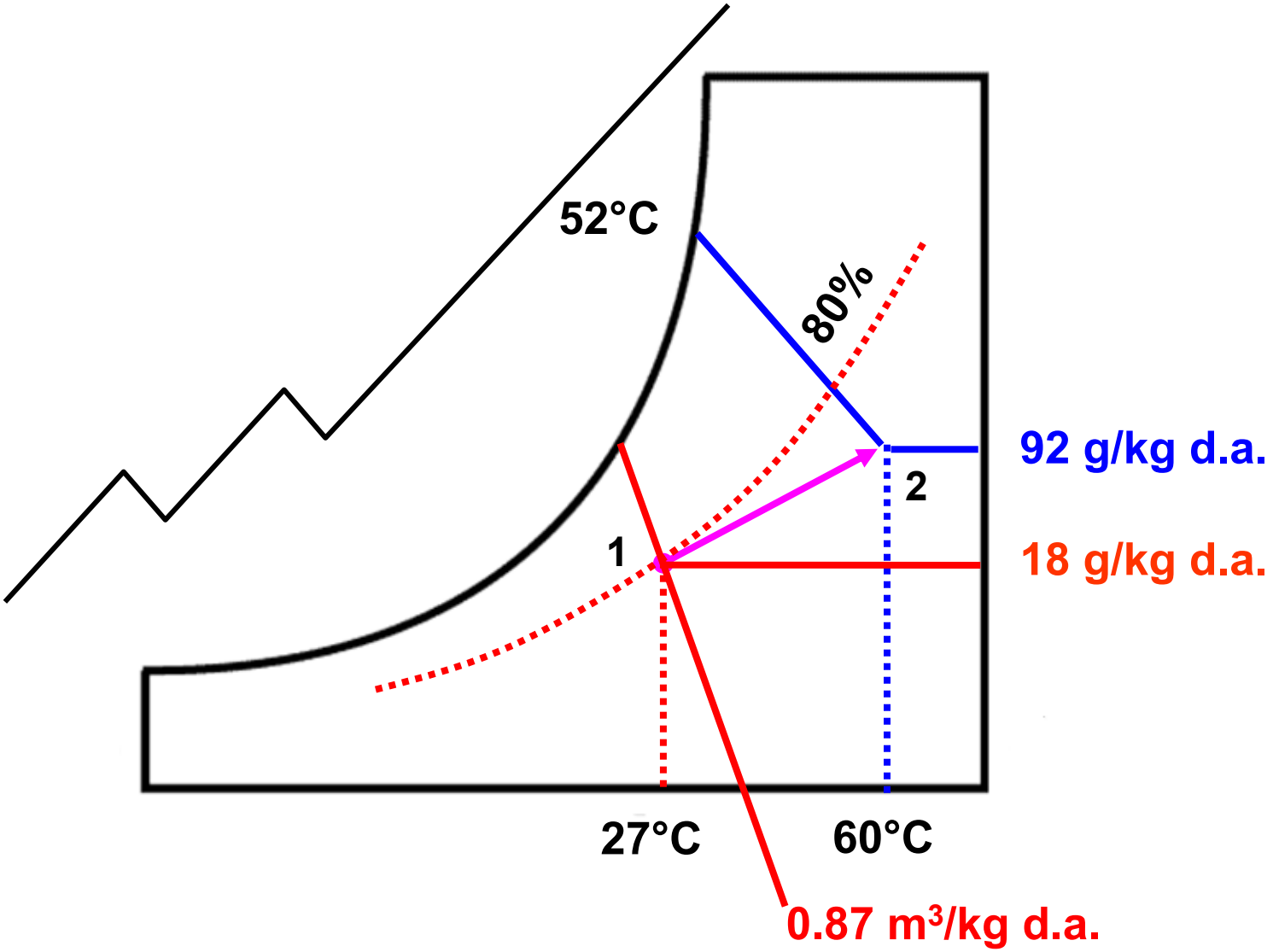

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Heating and humidifying: Example 7

$\Delta HR = (92.0 - 18.0)$ g/kg dry air

$= 74.0$ g/kg dry air

w_{a1} = drying rate/ΔHR

$= (12.5 \text{ kg/hour})/(0.074 \text{ kg/kg dry air})$

$= 168.9$ kg dry air/hour

$VF_1 = (w_{a1})(v_1)$

$= (168.9 \text{ kg dry air/hour})(0.87 \text{ m}^3\text{/kg dry air})$

$= 147 \text{ m}^3\text{/hour} = 2.45 \text{ m}^3\text{/minute}$

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Cooling and Dehumidifying

- a psychrometric process that involves the removal of water from the air as the air temperature falls below the dew-point temperature

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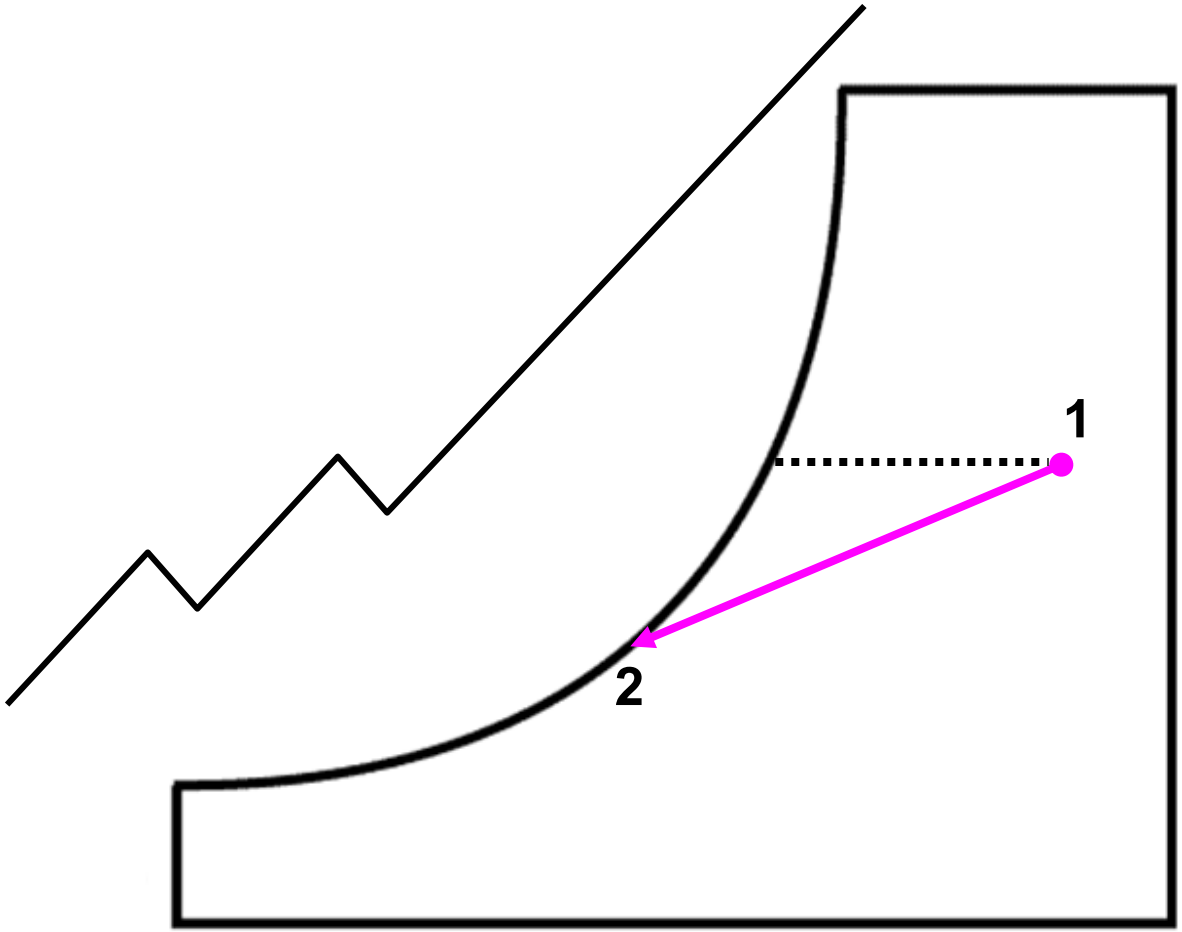

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Cooling and dehumidifying: Example 9

Moist air at 50°C dry bulb temperature and 32% relative humidity enters the cooling coil of a dehumidification kiln heat pump system and is cooled to a temperature of 18°C. If the drying rate of 6 m^3 of red oak lumber is 4 kg/hour, determine the kW of refrigeration required.

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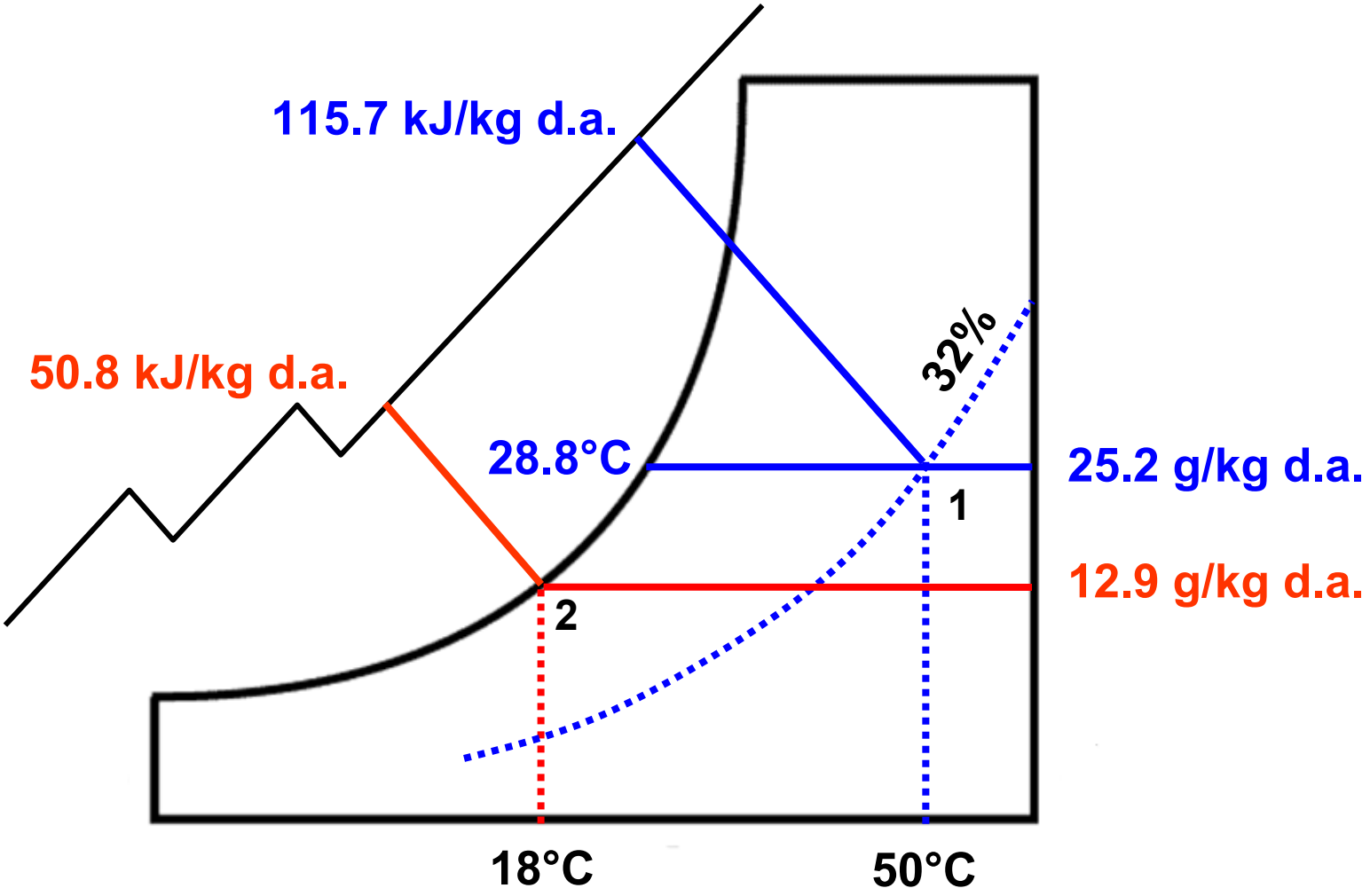

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Cooling and dehumidifying: Example 9

$$\Delta HR = (25.2 - 12.9)\ \text{g water/kg dry air}$$
$$= 12.3\ \text{g water/kg dry air}$$

$$w_a = \frac{\text{drying rate}}{\Delta HR}$$

$$= \frac{4\ \text{kg water}/\text{h}}{0.0123\ \text{kg water}/\text{kg dry air}}$$

$$= 325.2\ \frac{\text{kg dry air}}{\text{h}}$$

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Cooling and dehumidifying: Example 9

$$\Delta h = (115.7 - 50.8)\ \text{kJ/kg dry air}$$
$$= 64.9\ \text{kJ/kg dry air}$$

$$q = (\Delta h)(w_a)$$

$$= \left[64.9 \frac{\text{kJ}}{\text{kg dry air}}\right]\left[325.2 \frac{\text{kg dry air}}{\text{h}}\right]$$

$$= 21105.7 \frac{\text{kJ}}{\text{h}} = 5.9\ \text{kW}$$

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Adiabatic or Evaporative Cooling

- a psychrometric process that involves the cooling of air without heat loss or gain. Sensible heat lost by the air is converted to latent heat in the added water vapor

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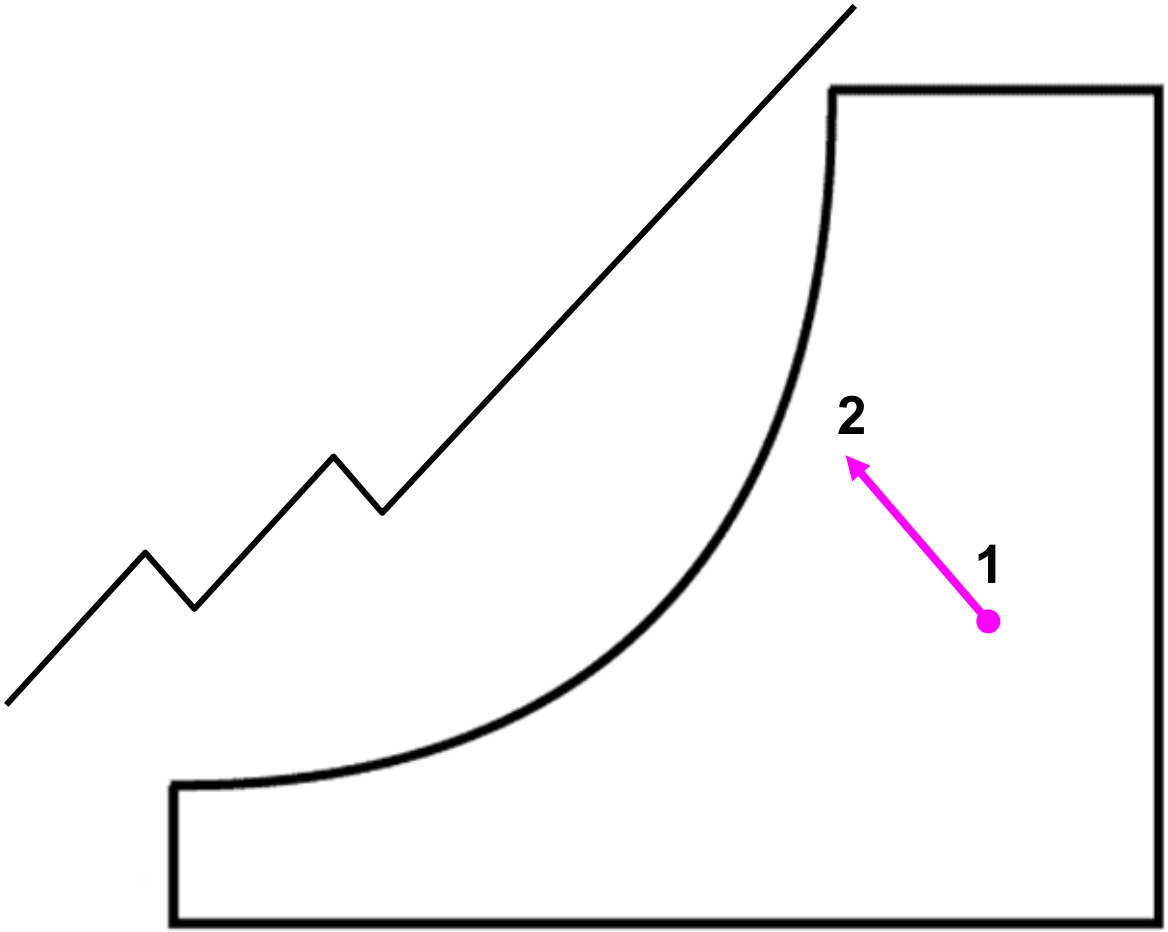

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Evaporative cooling: Example 10

Referring to Figure 21, air at state point 1 (65°C dry bulb temperature and 57°C wet bulb temperature) experiences a temperature drop of 3°C as it passes through the 1.2-m wide stack of lumber. Determine the properties of the air at state point 2 and compare them with those at state point 1. If the air is flowing at a rate of 2 meters per second, determine the drying rate assuming that the volume of the stack of 2.5-cm-thick lumber is 2.5 m^3. The stack is 1.2 m wide x 3.6 m long, and the boards are separated by stickers 3.8 cm wide x 1.9 cm thick that are spaced 0.6 m apart.

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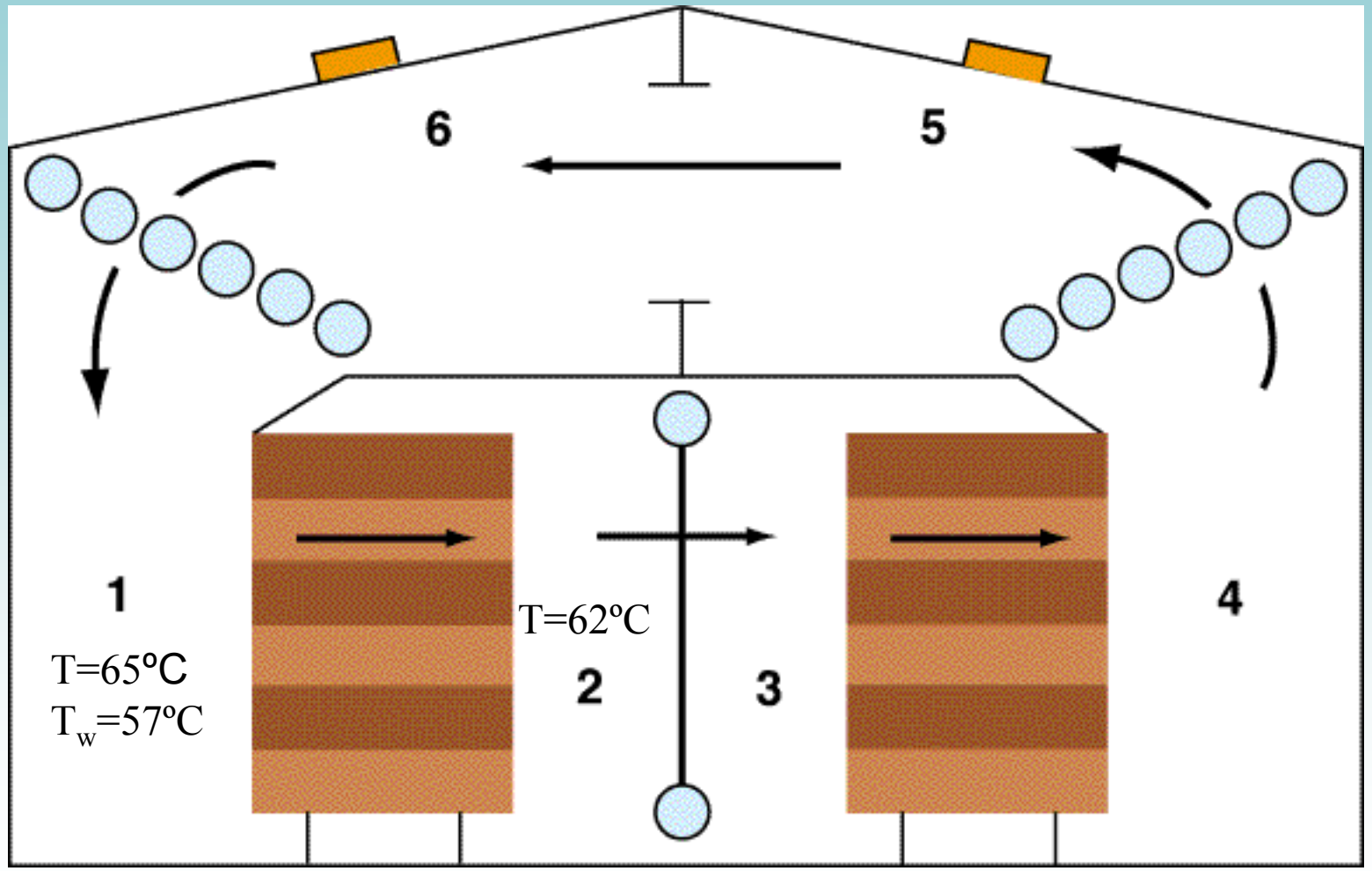

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Evaporative cooling: Example 10

Given: $T_1 = 65°C$; $T_{w1} = 57°C$
Adiabatic cooling to $T_2 = 62°C$
Air flow rate = 2 m/s
Volume of lumber = 2.5 m^3
Board thickness = 2.5 cm
Stack dimensions: 1.2 m wide x 3.6 m long
Sticker dimensions: 3.8 cm wide x 1.9 cm thick
Sticker spacing = 0.6 m

Required: (a) Properties of the air at state point 2 relative to that at state point 1
(b) Drying rate

Solution:

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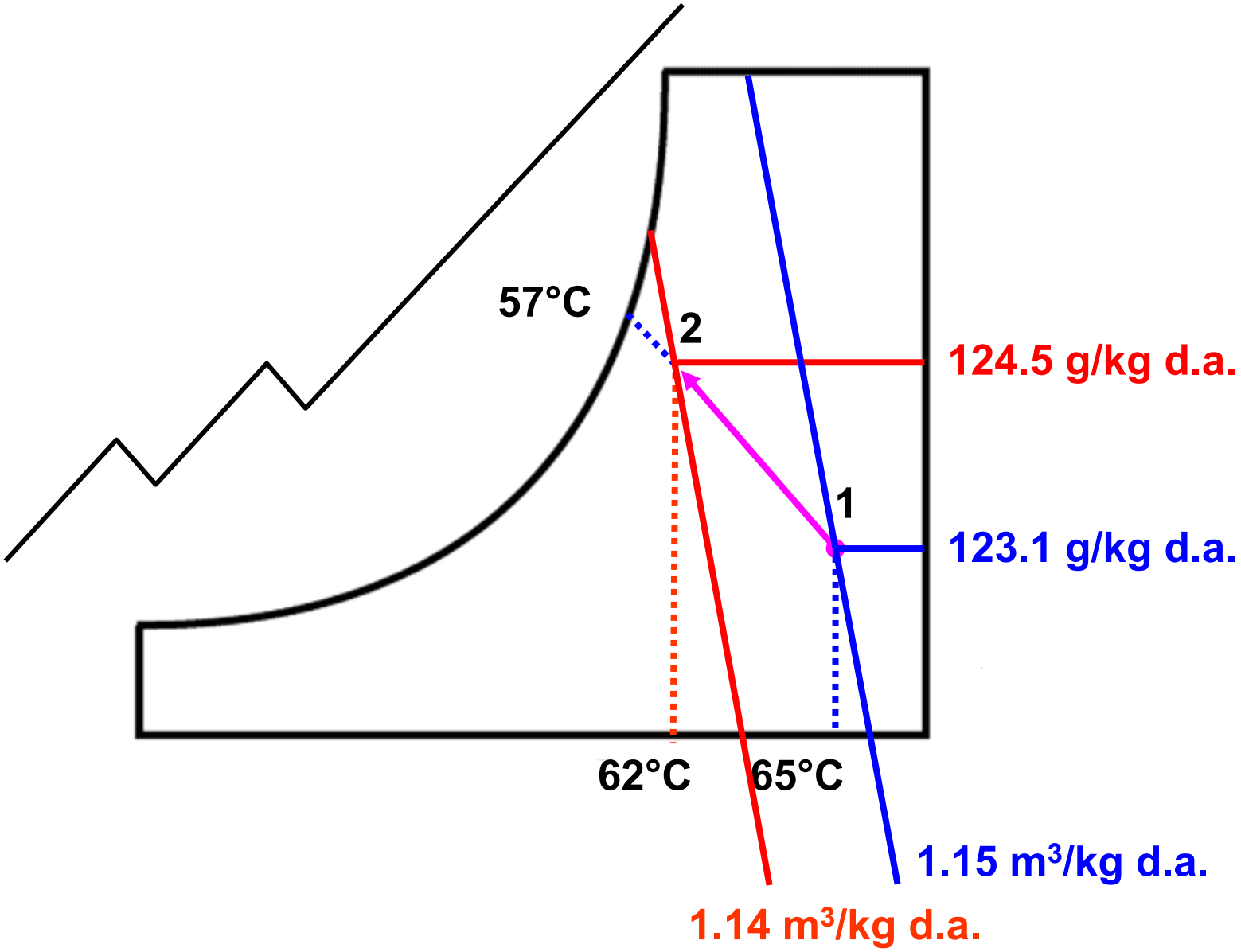

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Evaporative cooling: Example 10

(a) At state point 1: $T_1 = 65°C$

$T_{w1} = 57°C$

$T_{dp1} = 56.3°C$

$RH_1 = 66.9\%$

$HR_1 = 123.1$ g/kg of dry air

$v_1 = 1.15$ m^3/kg of dry air

$h_1 = 387.7$ kJ/kg of dry air

At state point 2: $T_2 = 62°C$

$T_{w2} = 57°C$

$T_{dp2} = 56.5°C$

$RH_2 = 77.3\%$

$HR_2 = 124.5$ g/kg of dry air

$v_2 = 1.14$ m^3/kg of dry air

$h_2 = 387.7$ kJ/kg of dry air

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Evaporative cooling: Example 10

(b) Drying rate $= (\Delta HR)(w_a)$

$$w_a = \frac{VF}{v_2}$$

$$VF = (A)(\text{air flow rate})$$

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Evaporative cooling: Example 10

$$A = \left(\frac{V}{P_l \, P_w \, B_t} \right) \left(P_l \, S_t - \frac{P_l + S_s}{S_s} S_t \, S_w \right)$$

$$A = \left(\frac{2.5}{3.6 * 1.2 * 0.025} \right) \left(3.6 * 0.019 - \frac{3.6 + 0.6}{0.6} 0.019 * 0.038 \right)$$

$$A = 1.47 \ m^2$$

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Evaporative cooling: Example 10

$$A = 1.47\ \mathrm{m}^2$$

$$VF = (A)(\text{air flow rate})$$

$$VF = \left(1.47\ \mathrm{m}^3\right)\left(2\ \frac{\mathrm{m}}{\mathrm{s}}\right) = 2.9\frac{\mathrm{m}^3}{\mathrm{s}}$$

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Evaporative cooling: Example 10

$$VF = 2.9 \frac{m^3}{s}$$

$$w_a = \frac{VF}{v_2}$$

$$w_a = \frac{2.9 \dfrac{m^3}{s}}{1.14 \dfrac{m^3}{\text{kg dry air}}} = 2.6 \frac{\text{kg dry air}}{s}$$

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Evaporative cooling: Example 10

$$w_a = 2.6 \frac{\text{kg dry air}}{\text{s}}$$

$$\text{Drying rate} = (w_a)(\Delta HR)$$

$$\text{Drying rate} = \left(2.6 \frac{\text{kg dry air}}{\text{s}}\right)\left(1.4 \frac{\text{g}}{\text{kg dry air}}\right)$$

$$= 3.6 \frac{\text{g}}{\text{s}} = 13.0 \frac{\text{kg}}{\text{h}}$$

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Adiabatic Mixing of Moist Air Stream

- A psychrometric process that involves no net heat loss or gain during the mixing of two air streams

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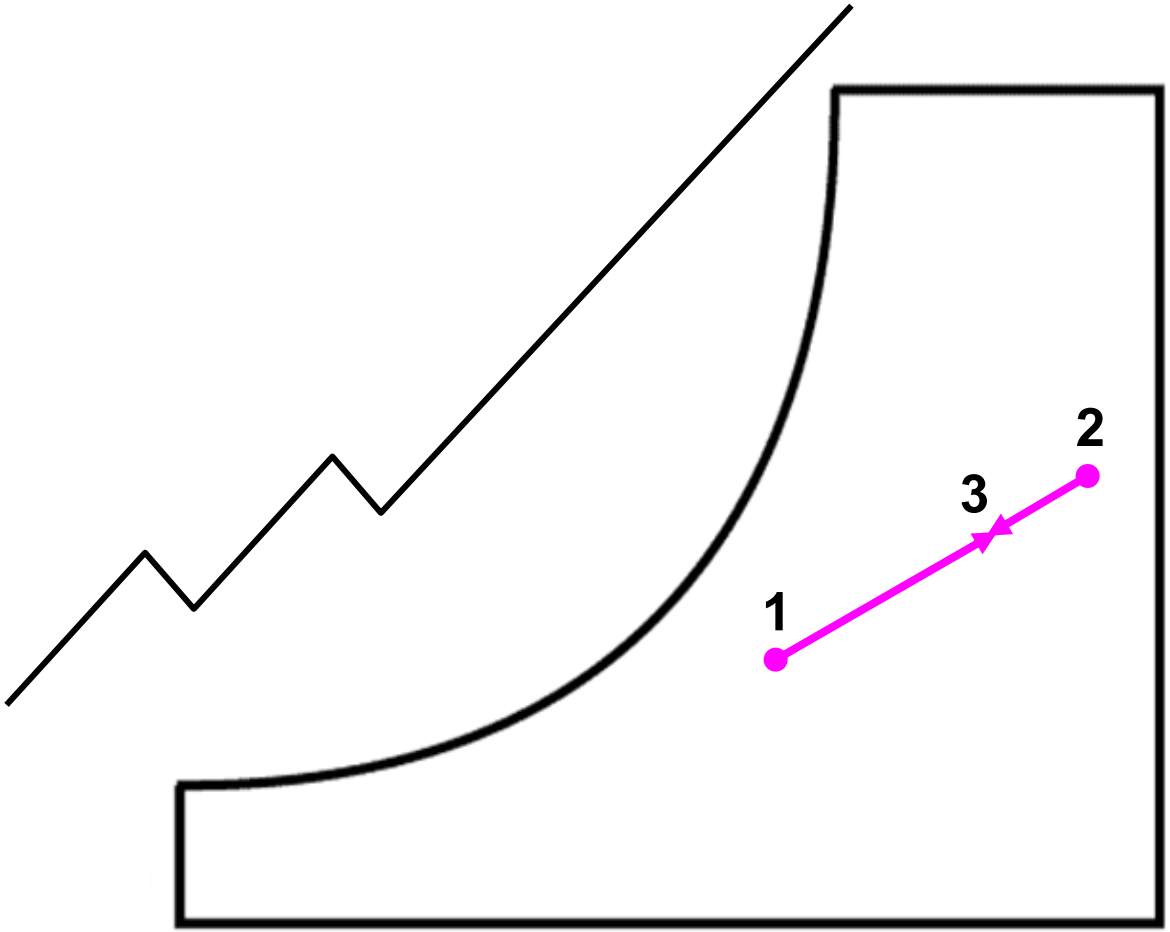

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Adiabatic mixing: Example 11

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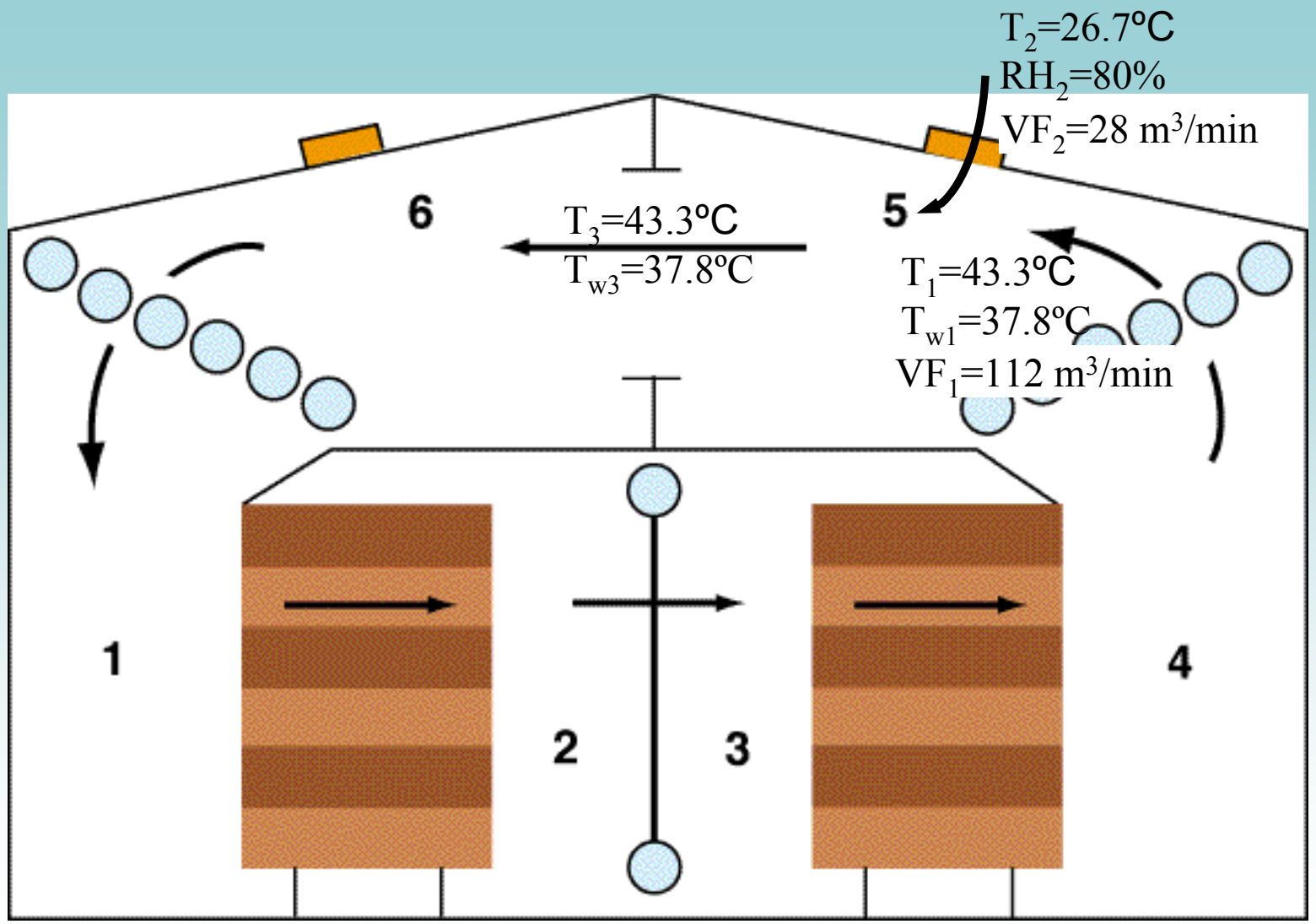

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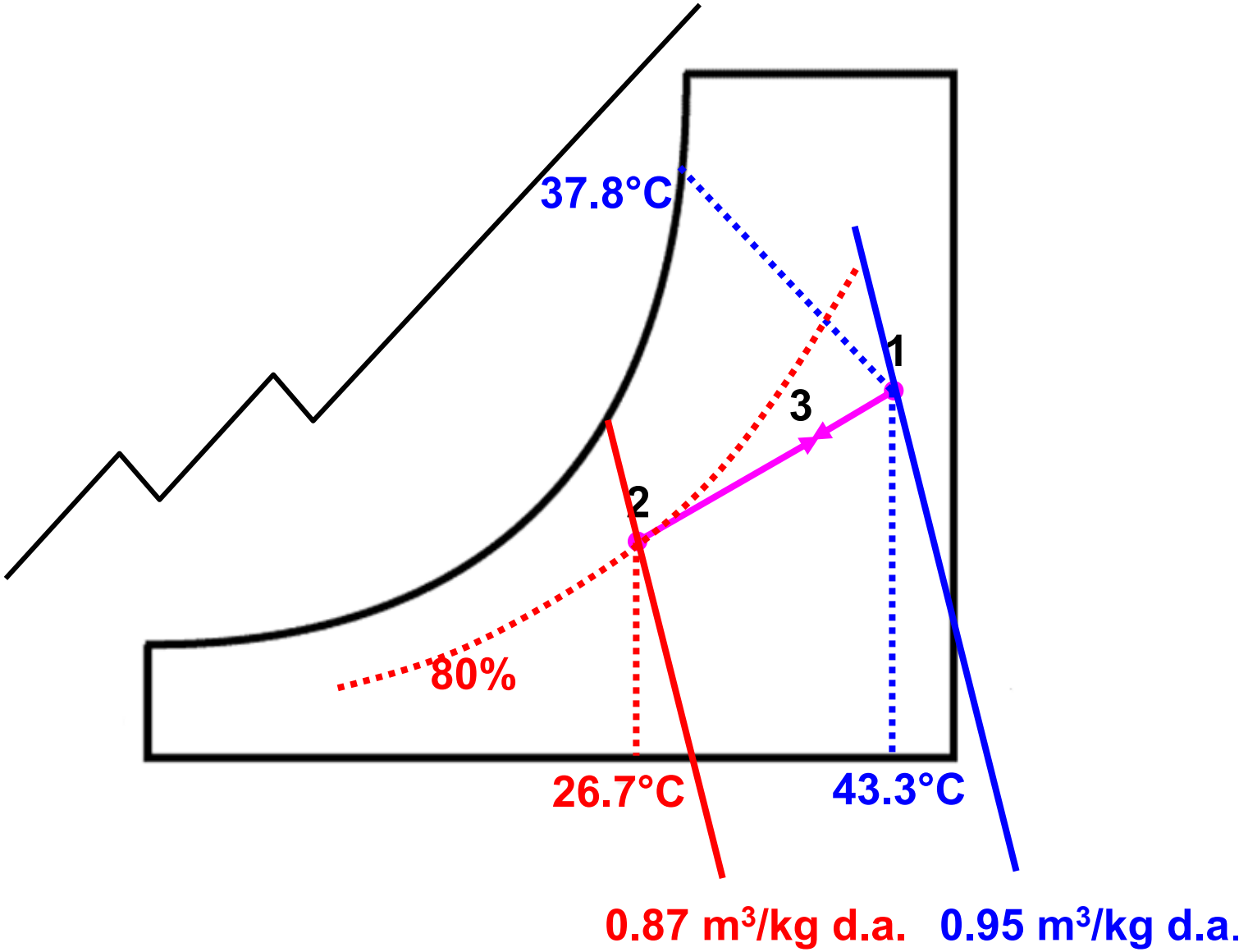

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Adiabatic mixing: Example 11

$$w_a = \frac{VF}{v}$$

$$w_{a1} = \frac{112 \dfrac{m^3}{minute}}{0.95 \dfrac{m^3}{kg\ dry\ air}} = 117.9 \frac{kg\ dry\ air}{minute}$$

$$w_{a2} = \frac{28 \dfrac{m^3}{minute}}{0.87 \dfrac{m^3}{kg\ dry\ air}} = 32.2 \frac{kg\ dry\ air}{minute}$$

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Adiabatic mixing: Example 11

$$\frac{\text{line 1-3}}{\text{line 1-2}} = \frac{w_{a2}}{w_{a2}+w_{a1}} = \frac{32.2}{32.2+117.9} = 0.21$$

Therefore, length of line segment 1-3 is 0.21 times the length of line 1-2

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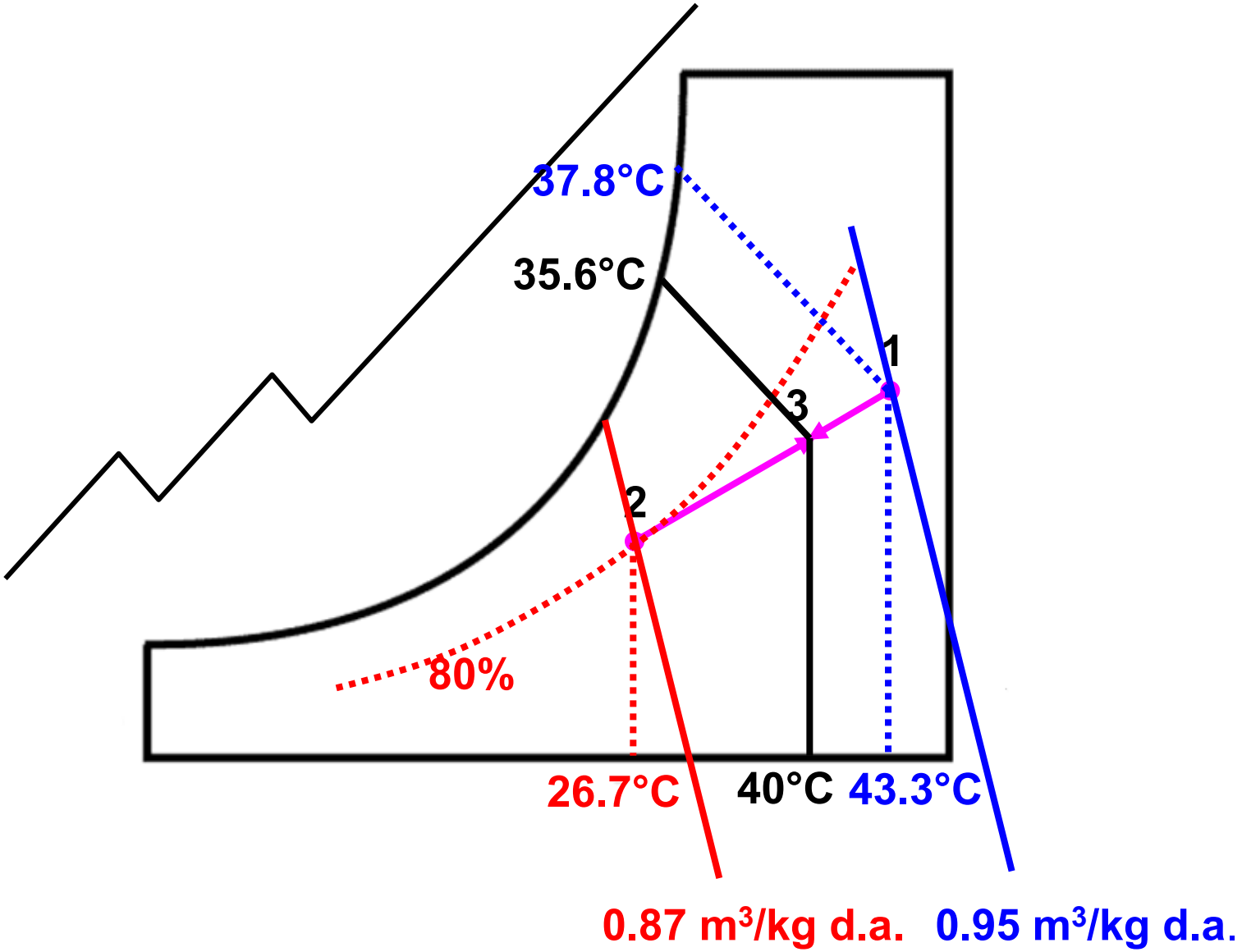

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Adiabatic mixing: Example 11

$T_3 = 40.0°C$

$T_{w3} = 35.6°C$

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