1. Moist air exists at 40°C dry-bulb temperature, 20°C thermodynamic wet-bulb temperature, and 101.325 kPa pressure. Determine the humidity ratio, enthalpy, dew-point temperature, relative humidity, and specific volume.

Solution:

Locate state point on the psychrometric chart at the intersection of 40°C dry-bulb temperature and 20°C thermodynamic wet-bulb temperature lines. Read humidity ratio W = 6.5 g (water)/kg (dry air).

The enthalpy can be found by using two triangles to draw a line parallel to the nearest enthalpy line [60 kJ/kg (dry air)] through the state point to the nearest edge scale. Read h = 56.7 kJ/kg (dry air).

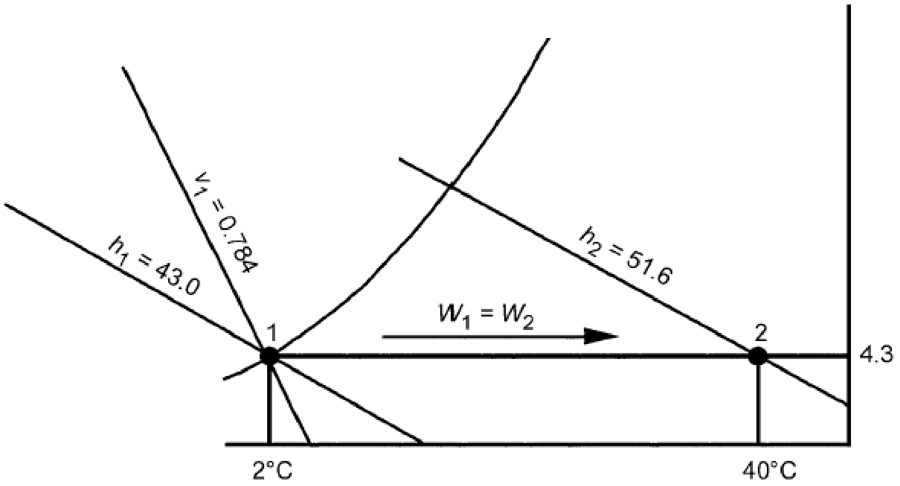
Dew-point temperature can be read at the intersection of W = 6.5 g (water)/kg (dry air) with the saturation curve. Thus, t_d = 7°C.

Relative humidity φ can be estimated directly. Thus, φ = 14%.

Specific volume can be found by linear interpolation between the volume lines for 0.88 and 0.90 m^3/kg (dry air). Thus, v = 0.896 m^3/kg (dry air).

2. Moist air, saturated at 2°C, enters a heating coil at a rate of 10 m^3/s. Air leaves the coil at 40°C. Find the required rate of heat addition.

Solution:



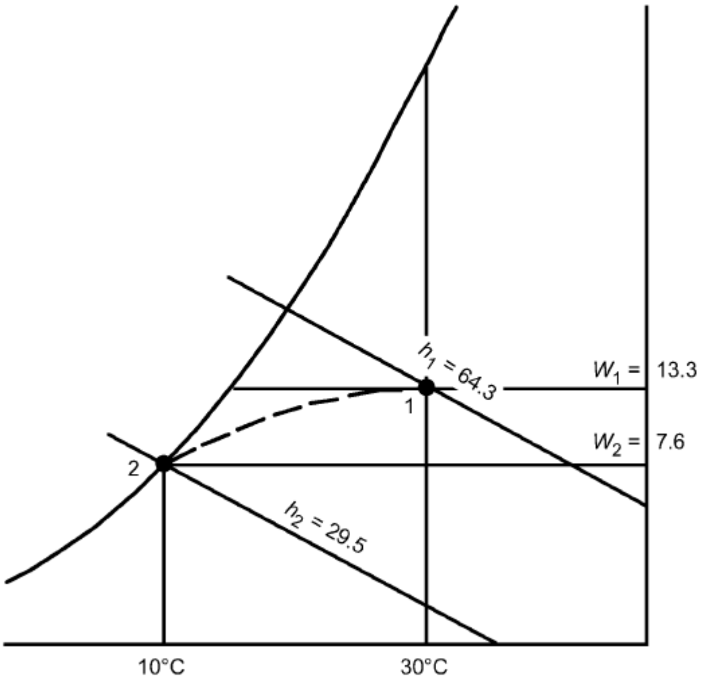
The above figure schematically shows the solution. State 1 is located on the saturation curve at 2°C. Thus, h_1 = 13.0 kJ/kg (dry air), W_1 = 4.3 g (water)/kg (dry air), and v_1 = 0.784 m^3/kg (dry air). State 2 is located at the intersection of t = 40°C and $W_2 = W_1$ = 4.3 g (water)/kg (dry air). Thus, h_2 = 51.6 kJ/kg (dry air). The mass flow of dry air is:

$$\dot{m}_{da} = 10 / 0.784 = 12.76 \text{ kg/s (dry air)}$$

The rate of heat addition = $_1q_2$ = 12.76 (51.6 – 13.0) = 492 kW

3. Moist air at 30°C dry-bulb temperature and 50% rh enters a cooling coil at 5 m^3/s and is processed to a final saturation condition at 10°C. Find the kW of refrigeration required.

<u>Solution</u>:



The above figure shows the schematic solution. State 1 is located at the intersection of t = 30°C and φ = 50%. Thus, h_1 = 64.3 kJ/kg (dry air), W_1 = 13.3 g (water)/kg (dry air), and v_1 = 0.877 m^3/kg (dry air). State 2 is located on the saturation curve at 10°C. Thus, h_2 = 29.5 kJ/kg (dry air) and W_2 = 7.66 g (water)/kg (dry air). Given: h_{w2} = 42.11 kJ/kg (water). The mass flow of dry air is:

$$\dot{m}_{da} = 5 / 0.877 = 5.70 \text{ kg/s (dry air)}$$

The kW of refrigeration = ${}_1q_2$

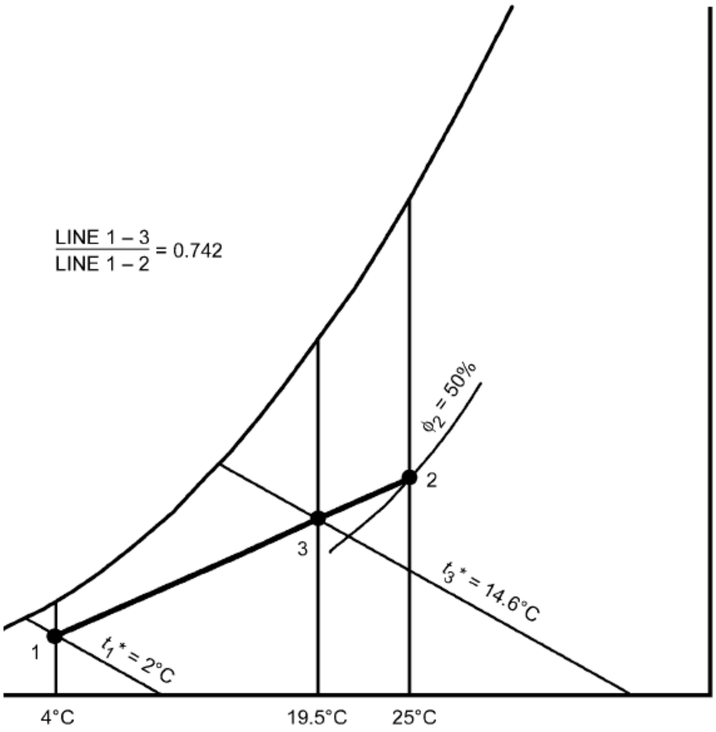
$= \dot{m}_{da} \; [(h_1 - h_2) - (W_1 - W_2)\, h_{w2}]$

$= 5.70\, [(64.3 - 29.5) - (0.0133 - 0.00766)\, 42.11]$

= 197 kW

4. A stream of 2 m^3/s of outdoor air at 4°C dry-bulb temperature and 2°C thermodynamic wet-bulb temperature is adiabatically mixed with 6.25 m^3/s of recirculated air at 25°C dry-bulb temperature and 50% rh. Find the dry-bulb temperature and thermodynamic wet-bulb temperature of the resulting mixture.

Solution:



The above figure shows the schematic solution. States 1 and 2 are located on the ASHRAE chart, revealing that $v_1 = 0.789$ m3/kg (dry air), and $v_2 = 0.858$ m^3/kg (dry air). Therefore,

$$\dot{m}_{da1} = 2 / 0.789 = 2.535 \text{ kg/s (dry air)}$$

$$\dot{m}_{da2} = 6.25 / 0.858 = 7.284 \text{ kg/s (dry air)}$$

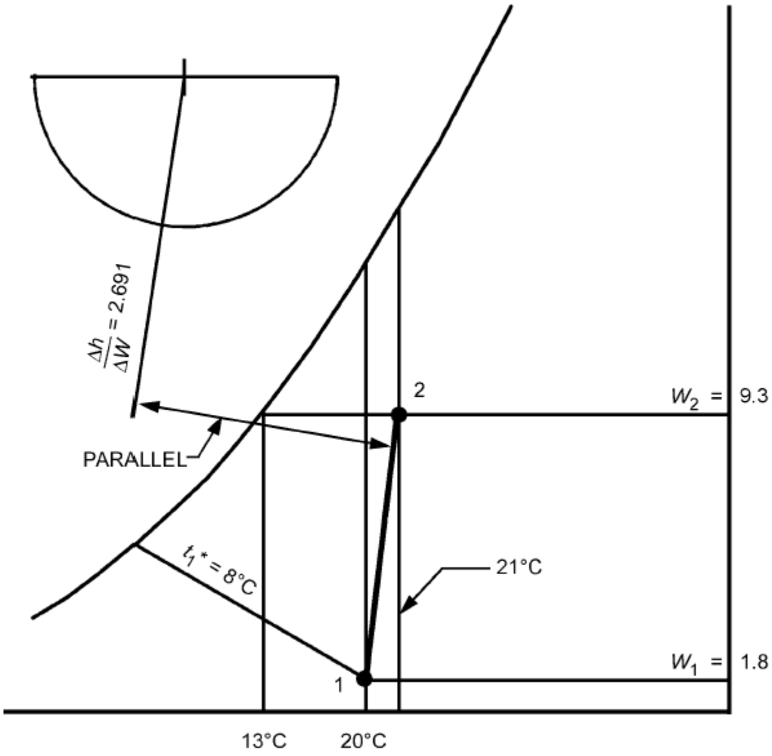
By comparing the proportion of the lines,

$$\frac{\text{Line 3–2}}{\text{Line 1–3}} = \frac{\dot{m}_{da1}}{\dot{m}_{da2}} \text{ or } \frac{\text{Line 1–3}}{\text{Line 1–2}} = \frac{\dot{m}_{da2}}{\dot{m}_{da3}} = \frac{7.284}{9.819} = 0.742$$

Consequently, the length of line segment 1–3 is 0.742 times the length of entire line 1–2. Using a ruler, State 3 is located, and the values $t_3 = 19.5°C$ and $t_3* = 14.6°C$ found.

5. Moist air at 20°C dry-bulb and 8°C thermodynamic wet-bulb temperature is to be processed to a final dew-point temperature of 13°C by adiabatic injection of saturated steam at 110°C. The rate of dry airflow is 2 kg/s (dry air). Find the final dry-bulb temperature of the moist air and the rate of steam flow.

<u>Solution</u>:



The above figure shows the schematic solution. From a steam properties table, the enthalpy of the steam h_g = 2691 kJ/kg (water). Therefore, according to the psychrometric equation, the condition line on the psychrometric chart connecting States 1 and 2 must have a direction:

$$\Delta h/\Delta W = 2.691 \text{ kJ/g (water)}$$

The condition line can be drawn with the $\Delta h/\Delta W$ protractor. First, establish the reference line on the protractor by connecting the origin with the value $\Delta h/\Delta W$ = 2.691 kJ/g (water). Draw a second line parallel to the reference line and through the initial state point of the moist air. This second line is the condition line. State 2 is established at the intersection of the condition line with the horizontal line extended from the saturation curve at 13°C (t_{d2} = 13°C). Thus, t_2 = 21°C. Values of W_2 and W_1 can be read from the chart. The required steam flow is,

$$\dot{m}_w = \dot{m}_{da} \ (W_2 - W_1) = 2 \times 1000 \ (0.0093 - 0.0018) = 15.2 \text{ g/s (steam)}$$

6. Which mechanism in thermal comfort study is each of the following referring to?

   - A warm body transferring heat across space to surrounding surface. ➔ <u>Radiation</u>
   - The heat flow through a substance by physical contact. ➔ <u>Conduction</u>
   - Cooler air warmed by the body rise, drawing in more cool air to the body. ➔ <u>Convection</u>
   - Moisture exits the body through pores in the skin and changes to a vapour causing the skin to cool. ➔ <u>Evaporation</u>

7. The mean radiant temperature (MRT) is defined as: (b) the weighted average of temperature of each surface and the angle of exposure of your body to the surface.

8. What are the two important conditions for achieving thermal comfort?

   Ans: (1) Heat produced must equal heat lost, and
   (2) Signals from Heat- and Cold-sensors must neutralise each other