Conditioning Air into the Human Comfort Zone

Introduction
Humans generally feel comfortable between temperatures of 22 °C to 27 °C and a relative humidity of 40% to 60%.

In this application, air at 35 °C and 60% relative humidity will be conditioned into the human comfort zone, with the thermodynamic process plotted on a psychrometric chart. To do this, we will

- first cool the air to 14 °C (this removes some of the water from the air),
- and then heat the air to 24 °C.

Additionally, we will calculate

- the heat and mass of water removed in the cooling phase,
- and the heat added in the heating phase.

Plot the Comfort Zone on the Psychrometric Chart

```wolfram
> restart:
    with(ThermophysicalData) : with(plots):
```

Functions for the lower and upper bounds of the human comfort zone.

```wolfram
> lower := T→Property( humidityratio, HumidAir, P = 101325, Tdb = T, R = 0.4 ) :
> upper := T→Property( humidityratio, HumidAir, P = 101325, Tdb = T, R = 0.6 ) :
```

Shade the human comfort zone between 22 °C and 27 °C.

```wolfram
> comfortZone := shadebetween( lower, upper, 273.15 + 22 .. 273.15 + 27 ) :
```

Plot the human comfort zone on a psychrometric chart.

```wolfram
> display( PsychrometricChart( ), comfortZone )
```
Plotting the Thermodynamic Cycle

Initially the air is at a temperature of 35 °C at a relative humidity of 60%

> \( T_1 := 35 + 273.15 \)

> \( hr_1 := \text{Property}(\text{humidityratio, HumidAir, Tdb} = T_1, "P" = 101325, "R" = 0.6) \)

\[ hr_1 := 0.0215466608092004797 \]

Then, we cool the air, and calculate the temperature at saturation (that is, the temperature at which the relative humidity is 1).

> \( T_2 := \text{Property}(\text{Tdb, HumidAir, R = 1, P = 101325, humidityratio} = hr_1) \)

\[ T_2 := 299.222762357176293 \]

> \( hr_2 := hr_1 \)

We continue cooling along the saturation line until we reach 14 °C (in this process, water condenses out of the air).

> \( T_3 := 14 + 273.15 \)

> \( hr_3 := \text{Property}(\text{humidityratio, HumidAir, Tdb} = T_3, P = 101325, R = 1) \)

\[ hr_3 := 0.0100133227960854491 \]

Now we heat the air until it reaches 24 °C.

> \( T_4 := 273.15 + 24 \)
> $h_r^4 := h_r^3$

Hence the entire thermodynamic cycle can then be plotted.

> route1 := pointplot ( [[ $T_1$, $h_r^1$], [ $T_2$, $h_r^2$] ], connect = true, thickness = 4 ) :
> route2 := pointplot ( [[ $T_3$, $h_r^3$], [ $T_4$, $h_r^4$] ], connect = true, thickness = 4 ) :
> satLine := plot ( Property( "humidityratio", HumidAir, Tdb = T, P = 101325, R = 1 ), T = $T_2..T_3$ color = black, thickness = 4 ) :
> display ( PsychrometricChart ( ), comfortZone, route1, route2, satLine )

**Heat Changes and Water Removed over the Thermodynamic Cycle**

Water removed in the cooling process (in kg water per kg dry air)

> $h_r^2 - h_r^3$

0.01153333801

Heat removed in the cooling process (in J kg$^{-1}$)

> $h_1 :=$ Property ( enthalpydryair, HumidAir, Tdb = $T_x$, P = 101325, R = 0.6 ) :
> $h_3 :=$ Property ( enthalpydryair, HumidAir, Tdb = $T_y$, P = 101325, R = 1 ) :
> $h_1 - h_3$

51101.11785
Heat added in the heating process (in J kg$^{-1}$)

> $h_4 := \text{Property(enthalpydryair, HumidAir, Tdb = } T_4 P = 101325, R = 0.5) :$

> $h_4 - h_3$

8537.89452