### 1 Some Terminology

- **atmospheric air** refers to air existing in the atmosphere, where its composition may vary—can include moisture content, trace gases, and contaminants.
- **dry air** refers to oxygen and nitrogen only—air without moisture content, trace gases, or contaminants.
- **dry bulb** is ordinary temperature; can be measured with a dry bulb thermometer.
- **humidity ratio (also specific humidity/absolute humidity)** ratio of mass of water vapor present in the air to mass of dry air.
- **moist air** refers to air that has moisture content (water vapor).
- **relative humidity** ratio of mass of water vapor present in the air to the maximum amount of water that the air could hold at the same temperature.
- **psychrometrics** branch of physics that deals with properties and behavior of moist air.
- **saturated air** means that the air cannot hold any more water (i.e. additional water must condense/will not evaporate).
- **wet bulb** is a temperature that indicates the air’s humidity content (based on evaporation); can be measured with a thermometer whose bulb is covered with a wetted wick.

### 2 Some Types of Processes

- **Simple Heating** process moves horizontally to the right on the psychrometric chart.
- **Simple Cooling** process moves horizontally to the left on the psychrometric chart.
- **Heating and Humidifying** process moves up (adding moisture) and to the right on the psychrometric chart.
- **Cooling and Dehumidifying** process moves down (removing moisture) and to the left on the psychrometric chart.

### 3 Heating

\[
T_{\text{final}} > T_{\text{initial}} \\
\phi_{\text{final}} < \phi_{\text{initial}}
\]

### 3.1 Mass Balance

3.1.1 Air

\[
\dot{m}_{a,\text{in}} = \dot{m}_{a,\text{out}} = \dot{m}_a
\]

3.1.2 Water

\[
\dot{m}_{w,\text{in}} = \dot{m}_{w,\text{out}} \\
\omega_{\text{in}} = \omega_{\text{out}}
\]

### 3.2 Energy Balance (First Law)

\[
\dot{Q} = \dot{m}_a (h_{\text{out}} - h_{\text{in}})
\]

per unit mass

\[
q = h_{\text{out}} - h_{\text{in}}
\]

### 4 Cooling

\[
T_{\text{final}} < T_{\text{initial}} \\
\phi_{\text{final}} > \phi_{\text{initial}}
\]

### 4.1 Mass Balance

4.1.1 Air

\[
\dot{m}_{a,\text{in}} = \dot{m}_{a,\text{out}} = \dot{m}_a
\]

4.1.2 Water

\[
\dot{m}_{w,\text{in}} = \dot{m}_{w,\text{out}} \\
\omega_{\text{in}} = \omega_{\text{out}}
\]

### 4.2 Energy Balance (First Law)

\[
\dot{Q} = \dot{m}_a (h_{\text{out}} - h_{\text{in}})
\]

per unit mass

\[
q = h_{\text{out}} - h_{\text{in}}
\]

**NOTE:**

\(\dot{Q}\) will be negative for a cooling problem in the above formulation (because \(h_{\text{in}}\) will be \(> h_{\text{out}}\)).

### 5 Heating and Humidifying

\[
T_{\text{final}} > T_{\text{initial}} \\
\phi_{\text{final}} < \phi_{\text{initial}}
\]

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5.1 Mass Balance

5.1.1 Air
\[ \dot{m}_{a,in} = \dot{m}_{a,out} = \dot{m}_a \]

5.1.2 Water
\[ \dot{m}_{w,in(air)} + \dot{m}_{w,added} = \dot{m}_{w,out} \]
\[ \dot{m}_a \omega_{in} + \dot{m}_{w,added} = \dot{m}_a \omega_{out} \]

5.2 Energy Balance (First Law)
\[ \dot{Q} + \dot{m}_a h_{in} + \dot{m}_{w,added} h_w = \dot{m}_a h_{out} \]

6 Cooling and Dehumidifying

\[ T_{final} < T_{initial} \]
\[ \omega_{final} < \omega_{initial} \]

6.1 Mass Balance

6.1.1 Air
\[ \dot{m}_{a,in} = \dot{m}_{a,out} = \dot{m}_a \]

6.1.2 Water
\[ \dot{m}_{w,in} = \dot{m}_{w,condensate} + \dot{m}_{w,out(air)} \]
\[ \dot{m}_a \omega_{in} = \dot{m}_{w,condensate} + \dot{m}_a \omega_{out} \]

6.2 Energy Balance (First Law)
\[ \dot{m}_a h_{in} + \dot{Q} = \dot{m}_{w,condensate} h_w + \dot{m}_a h_{out} \]

NOTE:
\[ \dot{Q} \] will be negative for a cooling problem in the above formulation, since I have it on the left side, which agrees with thermodynamic sign conventions (Heat entering a system is positive, where the system here is the control volume the air passes through).

\[ h_w \] here is commonly taken to be \( h_f \) at the same temperature as the condensate leaving the system.

8 Conditioning the Air for People

Humans are constantly rejecting heat to the atmosphere. This depends strongly on your body type, clothing and activity level, but is generally \( \approx 100 \) W when at rest.

Human comfort and productivity is affected by our ability to reject heat at the proper rate to maintain an optimal temperature for our body. Especially important variables are:

1. Dry bulb temperature
2. Relative humidity
3. Air velocity
4. Mean radiant temperature \(^3\)
5. Clothing level
6. Activity level

NOTE:
Each chart is good for a certain atmospheric pressure (expressed as the typical pressure at a particular elevation).

7 On the Psychrometric Chart

You should be able to locate the following on the chart:

- Humidity ratio/specific humidity
- Relative humidity
- Specific volume

NOTE:

These are not lines on the chart. This is the temperature where condensation would start to happen, based on …

… The curved line that represents 100% relative humidity.

This is beyond the scope to define here, but it is a measure that takes into account not just the temperature differences between a person and their surroundings, but also the radiant characteristics of those surroundings (absorptivity/reflectivity/transmissivity) and the view factors for the surrounding surfaces given that person's position.

\(^3\)This is beyond the scope to define here, but it is a measure that takes into account not just the temperature differences between a person and their surroundings, but also the radiant characteristics of those surroundings (absorptivity/reflectivity/transmissivity) and the view factors for the surrounding surfaces given that person's position.