Chapter 8 Examples

The following examples are taken from the textbook and cover psychrometrics.

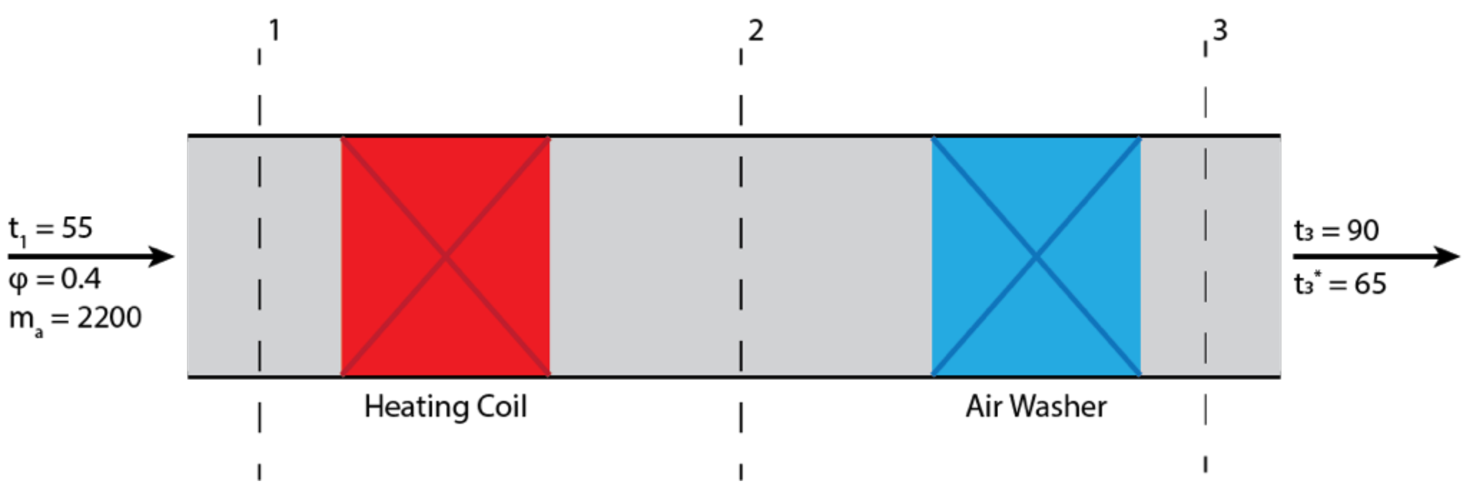
8.1

In a heating/humidifying system moist air first flows through a heating coil and then through an air washer. The air enters the system at 55° F dry-bulb temperature and 40% humidity. The air exits the system at 90° F dry-bulb temperature and 65° F thermodynamic wet-bulb temperature. The flow rate through the system is 2200 lbma/hr and the process occurs at a pressure of 29.921 in Hg. Determine:

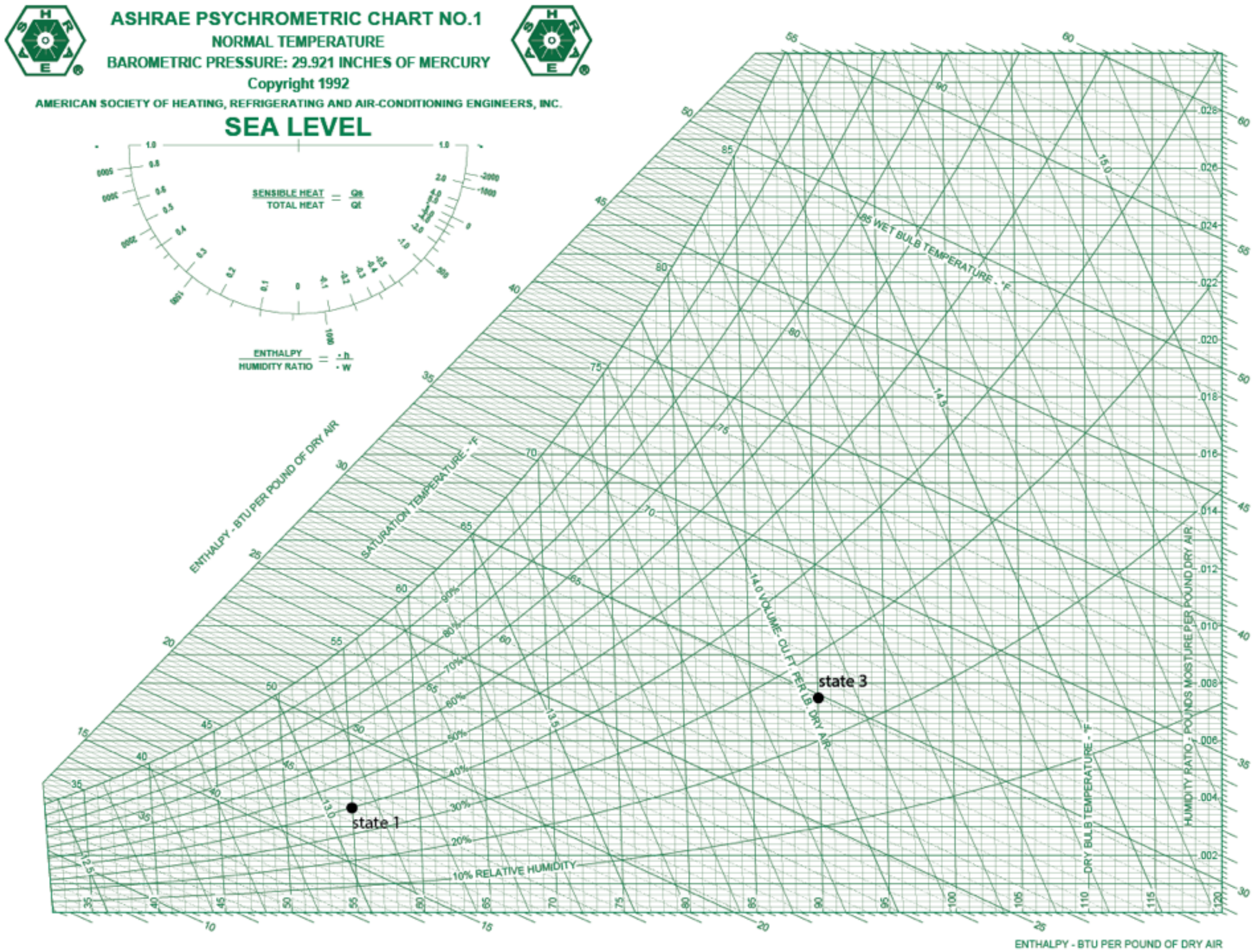
1. the dry-bulb temperature of the air as it exits the heating coil
2. the rate of heat addition to the air by the heating coil
3. the rate of moisture addition to the air by the adiabatic saturator

8.1.1

It helps if we draw a picture of what is going on:



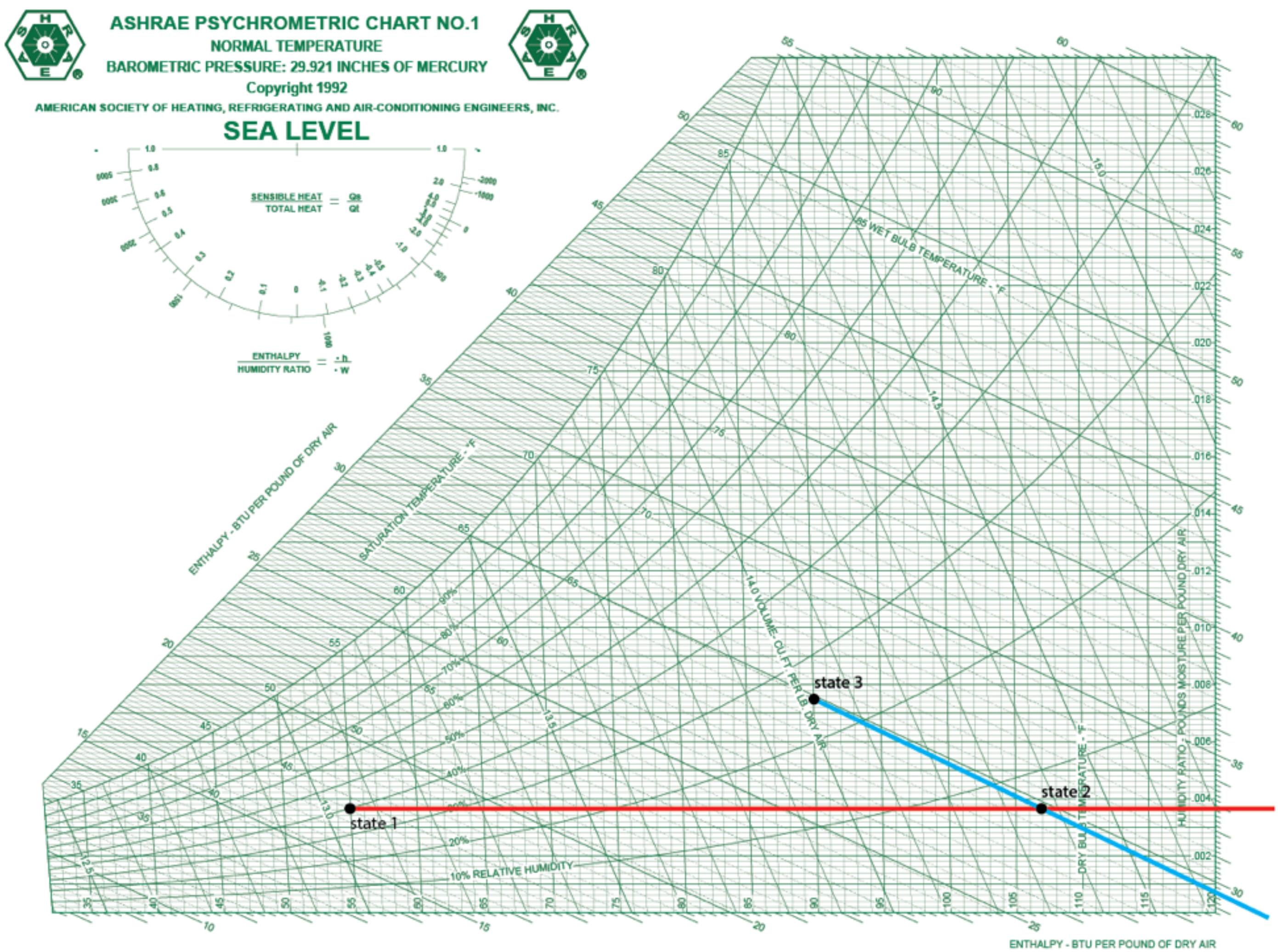
We start by plotting states 1 and 3 on the psychrometric chart.



Then we have to understand the two processes that are occurring:

1. Heating Coil: The heating coil will provide **sensible heating** meaning that we are going to travel along constant humidity ratio lines.
2. Air Washer: The air washer cools the air by providing moisture in the form of **latent** energy. The process for an air washer follows along constant wet-bulb temperature.

Using these two ideas, we can draw two lines and look for their intersection. The first is **horizontal and to the right starting from state 1** while the second is **diagonal along constant wet-bulb from state 2 down and to the right**.



Now we simply have to use the chart to read off the dry-bulb temperature at state 2: **107° F**

8.1.2

To calculate the rate of sensible heat addition from the heating coil we can use either equation 8.11 or 8.12 from the textbook. I will opt for 8.11 since it is a bit simpler and we can easily find the values we need:

$$ {}_1\dot{Q}_2 = \dot{m}_a \left(h_2 - h_1\right) $$

```
# defining givens
m_dot = 2200 #lbma/hr
# determining enthalpies from chart
h1 = 17.3 #btu/lbma
h2 = 30
# calculating and reporting
q_dot_1to2 = m_dot * (h2 - h1)
print(f"Rate of heat addition: {round(q_dot_1to2,2)}")
```

```
Rate of heat addition: 27940.0
```

We get approximately **27,900** $\frac{Btu}{hr}$

8.1.3

The rate of water added is a similar equation to the one we just applied but uses the humidity ratios, W, rather then enthalpies (see Example 8.7 for equation):

$$\dot{m}_w = \dot{m}_a\left(W_3 - W_2\right)$$

```
# determining humidity ratios from the chart
W2 = 0.0036 #lbmw/lbma
W3 = 0.0075
# calculating and reporting
m_dot_w = m_dot * (W3 - W2)
print(f"Rate of moisture addition: {round(m_dot_w,2)}")
```

```
Rate of heat addition: 8.58
```

We get approximately **8.6** $\frac{lbm_w}{hr}$

8.2

A space to be conditioned has a sensible-heat loss of 80,000 Btu/hr and a latent-heat loss of 34,000 Btu/hr. The conditions in the space are maintained at 70°F dry-bulb temperature and 44 $^{\circ}$F dew-point temperature. Supply air is introduced into the space at a dry-bulb temperature of 95 $^{\circ}$F (barometric pressure = 29.921 in. Hg). Determine:

1. The required relative humidity of the supply air
2. The flow rate of supply air in lbma/hr

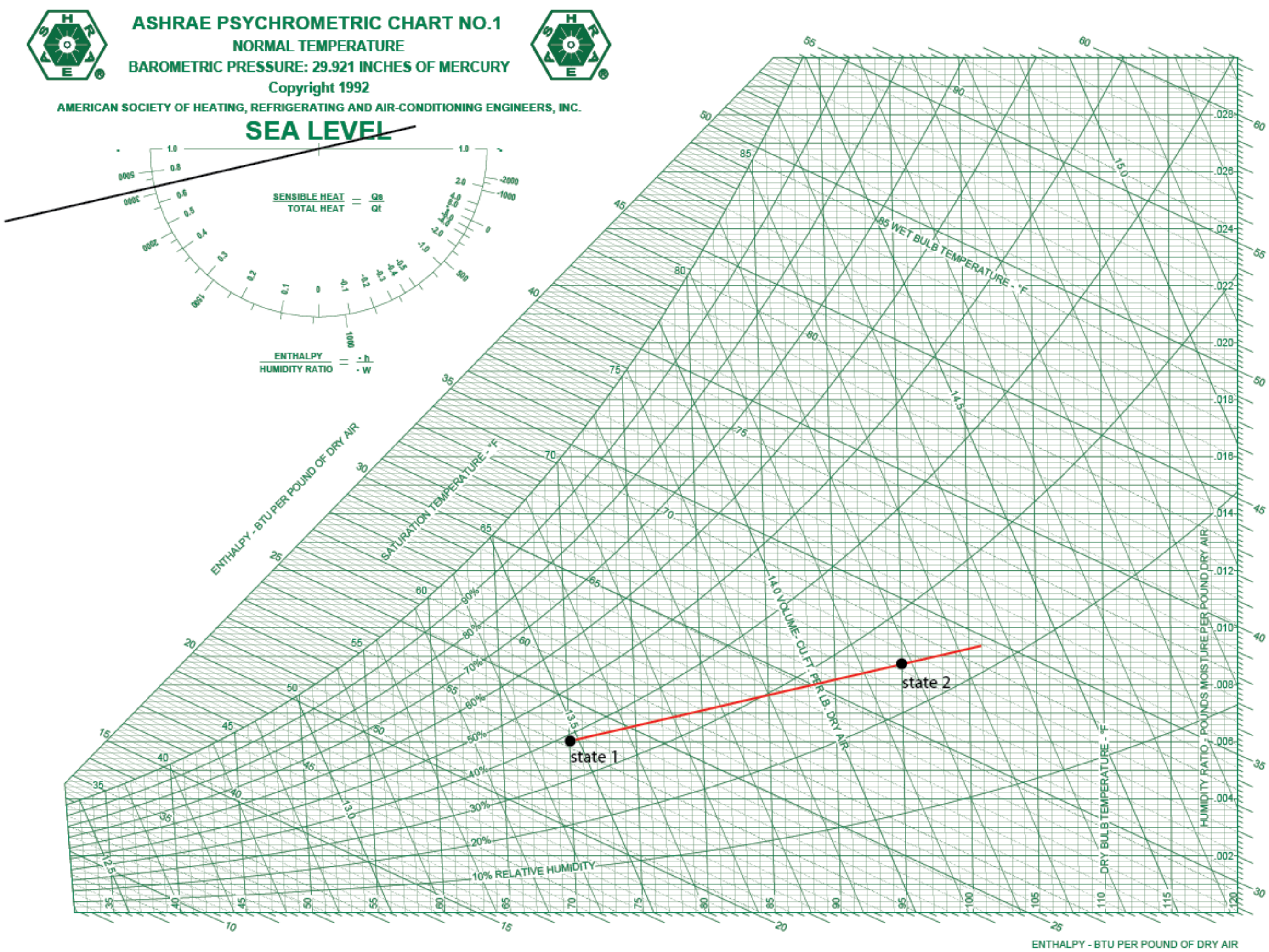
8.2.1

Similar to the last problem, we will start by plotting on the psychrometric chart. However, for this problem we only have one set of conditions for the space. We do have the sensible and latent heat losses so we can calculate a sensible heat ratio, SHR:

```
# defining givens
Qs = 80000
Qell = 34000
# calculating and reporting
SHR = Qs / (Qs + Qell)
print(f"SHR is {round(SHR,2)}")
```

```
SHR is 0.7
```

With this value, we can use the protractor on the psychrometric chart to construct a helping line. We then draw a line parallel to this from the space condition until we intersect with a dry-bulb of 95 $^{\circ}$F. This point will contain the conditions for the supply air.



We can now estimate the relative humidity from the chart as approximately **25%**.

8.2.2

We can determine the mass flow rate of air into the space by rearranging equation 8.25 and use values from our psychrometric chart to solve it:

$$\dot{m}_a = \frac{\dot{Q}_s + \dot{Q}_\ell}{h_2 - h_1}$$

```
# still have our givens from the previous cell (Qs and Qell)
# determining enthalpies from the chart
h1 = 23.4
h2 = 32.2
# calculating and determining
m_dot = (Qs + Qell) / (h2 - h1)
print(f"Mass flow rate of air: {round(m_dot,2)}")
```

```
Mass flow rate of air: 12954.55
```

The mass flow rate of air into the space is approximately **13,000 lbma/hr**.

8.3

Clearly show and label the following process lines and state-points on a psychrometric chart.

1. Outdoor air at 35˚F dry-bulb temperature and 100% relative humidity is heated in a furnace to 100˚F dry-bulb temperature
2. Saturated steam at 200˚F is then sprayed into the air to increase its relative humidity to 40%.
3. The air is then supplied to a space with a condition line having a sensible-heat ratio of 0.7, and the air exits the space at a dry-bulb temperature of 70˚F.

8.3.1

Using a furnace to heat up the outdoor air means that we are going to add sensible heat. On the psychrometric chart, this process moves horizontal along a constant humidity ratio. Starting at the outdoor air conditions, we move along constant humdity ratio until reaching 100˚F.

8.3.2

Saturated steam is injected into the air stream which means we can use Table A.1E to determine the enthalpy to humidity ratio. This value is approximately **1146 Btu/lbma**. With that number, we use the protractor to construct a helping line. We then draw a line parallel to that starting from state 2 until we reach 40% relative humidity.

8.3.3

The final part states that this air is then supplied to the space and the conditions within the space decrease the sensible and latent loads according to an SHR of 0.7. Using the protractor, we construct a helping line with this SHR and then draw a line parallel to this starting from state 2 until we intersect with a dry-bulb temperature of 70° F.