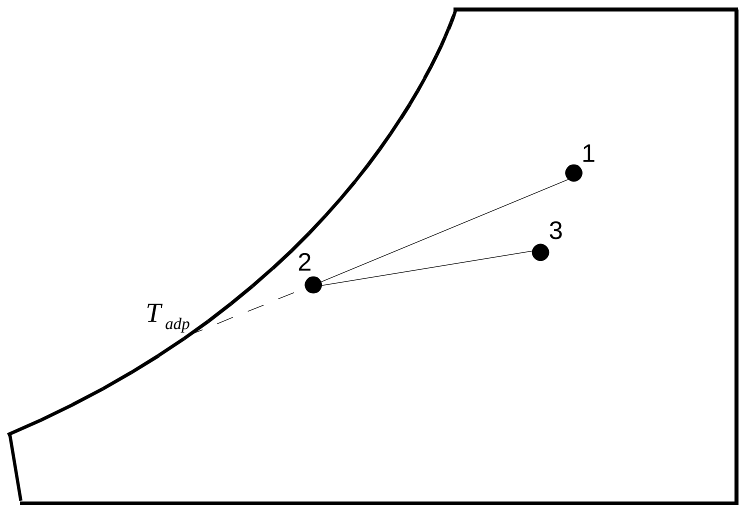
SOLUTION:

The processes described in the problem statement are shown schematically in this sketch of a psychrometric chart:



Process 1 – 2 represents the cooling in the coil. The air at the discharge of the coil (state 2) is used as supply air to the conditioned space. For a cooling coil, the air temperature at the discharge is a function of the bypass factor BF, the apparatus dew point T_{adp} , and the entering air temperature T_1 :

$$T_2 = T_{adp} + \mathrm{BF} \cdot (T_1 - T_{adp})$$

inserting the given values, we obtain:

$$T_2 = 45\,°\mathrm{F} + 0.12 \cdot (80\,°\mathrm{F} - 45\,°\mathrm{F}) = 49.2\,°\mathrm{F}$$

Now, on a psychrometric chart, draw a line from point 1 [80°F (db)/67°F (wb)] to $T_{adp} = 45\,°\mathrm{F}$, which is located on the saturation $(\phi = 100\%)$ line. Point 2 is located on the intersection of this line and the line for $T_2 = 49.2\,°\mathrm{F}$.

Process 2 – 3 occurs as the conditioned air enters the room and leaves at state 3. For typical calculations of moist air, it is convenient to use the approximate equations:

$$q_{room,\,\mathrm{sensible}} = 1.1 \cdot Q \cdot (T_3 - T_2) \quad (1)$$

and

$$q_{room,\,\mathrm{latent}} = 4840 \cdot Q \cdot (w_3 - w_2) \quad (2)$$

where $q_{room,\,\mathrm{sensible}}$ and $q_{room,\,\mathrm{latent}}$ are the room loads in Btu/hr, Q is the air flow rate in CFM and w is the humidity ratio in pounds of water per pound of dry air. The values 1.1, and 4840 are useful in air-conditioning calculations for an atmospheric pressure of approximately 14.7 psia and typical temperatures and moisture ratios. For other conditions, calculations should use more precise values.

The problem statement provides the total room cooling load, and the sensible heat ratio SHR. This allows us to calculate the sensible and latent room loads as follows:

$$q_{room,\text{total}} = q_{room,\text{sensible}} + q_{room,\text{latent}} = 3\,\text{tons} = 36{,}000\,\text{Btu/hr} \quad (3)$$

$$\text{SHR} = \frac{q_{room,\text{sensible}}}{q_{room,\text{total}}} = 0.8 \quad (4)$$

Therefore, $q_{room,\text{sensible}} = 28{,}800\,\text{Btu/hr}$ and $q_{room,\text{latent}} = 7{,}200\,\text{Btu/hr}$.

We can now use equation (1) to obtain the temperature of the air leaving the room, T_3 :

$$T_3 = T_2 + \frac{q_{room,\text{sensible}}}{1.1 \cdot Q} = 49.2 + \frac{28{,}800}{1.1 \cdot 1{,}400} \approx 67.9\,°\text{F} \quad (5)$$

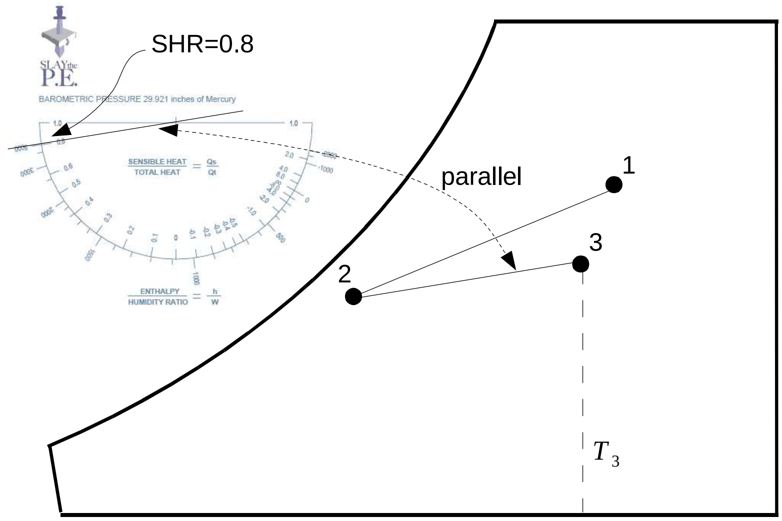
and equation (2) to obtain the humidity ratio of the air leaving the room w_3 . We will need w_2 which can be read from the psychrometric chart as $w_2 \approx 48\,\text{gr/lb} = 0.0069\,\text{lb}_w/\text{lb}_a$:

$$w_3 = w_2 + \frac{q_{room,\text{latent}}}{4{,}840 \cdot Q} = 0.0069 + \frac{7{,}200}{4{,}840 \cdot 1{,}400} \approx 0.0079\,\text{lb}_w/\text{lb}_a$$

With these value of T_3 and w_3 , the psychrometric chart can be used to obtain the relative humidity, $\phi_3 \approx 54\,\%$

THE CORRECT ANSWER IS (B)

Alternate Solution: This problem can be solved a little quicker if you use a psychrometric chart with an SHR protractor. Once you locate point "2" on the chart, and you know T_3 from equation (5) you then draw a line originating at point 2 parallel to the SHR=0.8 line from the protractor. Point "3" is at the intersection of this line and the line for $T_3 = 67.9\,°\text{F}$. Once point "3" is located, read the relative humidy from the psychrometric chart.


SHR=0.8
BAROMETRIC PRESSURE 29.921 inches of Mercury
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = h / W
parallel
1
2
3
T_3