

Solutions

1.

a)

Layer Description	h W/m^2-K	k $W/m-K$	L m	Layer R	Units
Indoor air layer	10			0.100	$(W/m^2-K)^{-1}$
Plywood		0.12	0.013	0.108	$(W/m^2-K)^{-1}$
Outdoor air layer	35			0.029	$(W/m^2-K)^{-1}$
Sum = R overall =				0.237	$(W/m^2-K)^{-1}$
U value =				4.22	W/m^2-K

b)

Layer Description	h W/m^2-K	k $W/m-K$	L m	Layer R	Units
Indoor air layer	10			0.100	$(W/m^2-K)^{-1}$
XPS				0.440	$(W/m^2-K)^{-1}$
Outdoor air layer	35			0.029	$(W/m^2-K)^{-1}$
Sum = R overall =				0.569	$(W/m^2-K)^{-1}$
U value =				1.76	W/m^2-K

c)

Layer Description	h W/m^2-K	k $W/m-K$	L m	Layer R	Units
Indoor air layer	10			0.100	$(W/m^2-K)^{-1}$
Plywood		0.12	0.013	0.108	$(W/m^2-K)^{-1}$
XPS				0.440	$(W/m^2-K)^{-1}$
Outdoor air layer	35			0.029	$(W/m^2-K)^{-1}$
Sum = R overall =				0.677	$(W/m^2-K)^{-1}$
U value =				1.48	W/m^2-K

d)

Layer Description	h W/m^2-K	k $W/m-K$	L m	Layer R	Units
Indoor air layer	10			0.100	$(W/m^2-K)^{-1}$
XPS				1.760	$(W/m^2-K)^{-1}$
Outdoor air layer	35			0.029	$(W/m^2-K)^{-1}$
Sum = R overall =				1.889	$(W/m^2-K)^{-1}$
U value =				0.53	W/m^2-K

e)

Layer Description	h W/m^2-K	k $W/m-K$	L m	Layer R	Units
Indoor air layer	10			0.100	$(W/m^2-K)^{-1}$
Glass		1	0.006	0.006	$(W/m^2-K)^{-1}$
Outdoor air layer	35			0.029	$(W/m^2-K)^{-1}$
Sum = R overall =				0.135	$(W/m^2-K)^{-1}$
U value =				7.43	W/m^2-K

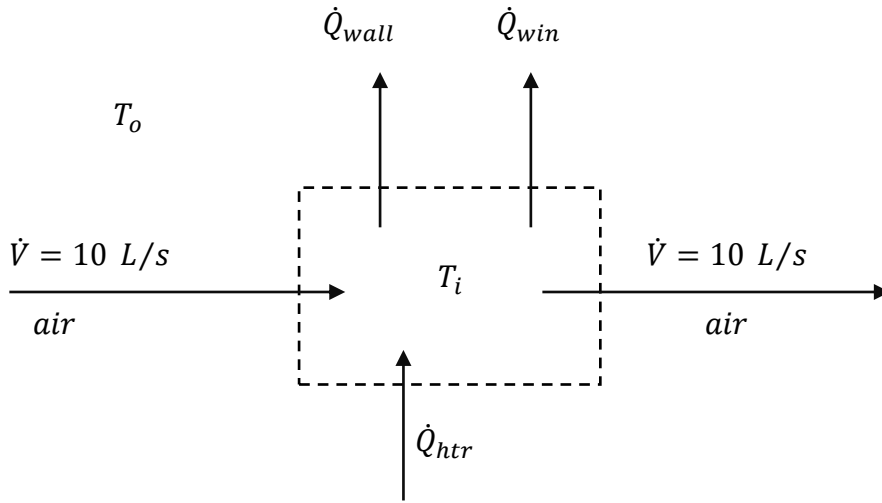
2.

<i>Section</i>	<i>Area</i> <i>m²</i>	<i>RSI</i> <i>m² · °C/W</i>	<i>USI</i> <i>W/m² · °C</i>	<i>U · A</i> <i>W/°C</i>	<i>Q̇ @ ΔT = 10°C</i> <i>W</i>
A	60	4.58	0.218	13.08	130.8
B	10	1.06	0.950	9.50	95.0
C	30	2.82	0.355	10.65	106.5
Sum	100	-	-	33.23	332.3

$$U_{avg} = \frac{\sum(UA)}{\sum A} = \frac{33.23 \text{ W/°C}}{100 \text{ m}^2} = 0.332 \frac{\text{W}}{\text{m}^2 \cdot \text{°C}}$$

$$R_{avg} = (U_{avg})^{-1} = 3.01 \left(\frac{\text{W}}{\text{m}^2 \cdot \text{°C}} \right)^{-1}$$

3.



$$\begin{aligned}
 \dot{Q}_{htr} &= \dot{V} \rho c_p \cdot (T_i - T_o) + \dot{Q}_{wall} + \dot{Q}_{win} \\
 &= \dot{V} \rho c_p \cdot (T_i - T_o) + (UA)_{wall} \cdot (T_i - T_o) + (UA)_{win} \cdot (T_i - T_o) \\
 &= [\dot{V} \rho c_p + (UA)_{wall} + (UA)_{win}] \cdot (T_i - T_o)
 \end{aligned}$$

$$\left. \begin{aligned}
 (UA)_{wall} &= 5.7 \text{ W/}^\circ\text{C} \\
 (UA)_{win} &= 10.3 \text{ W/}^\circ\text{C} \\
 \dot{V} \rho c_p &= 12.3 \text{ W/}^\circ\text{C}
 \end{aligned} \right\} K_T = 28.3 \text{ W/}^\circ\text{C}$$

$$\dot{Q}_{htr} = K_T \cdot (T_i - T_o) = (28.3)(20) = \mathbf{566 \text{ W}}$$

$$\frac{(UA)_{wall}}{K_T} = 20.1\%$$

$$\frac{(UA)_{win}}{K_T} = 36.4\%$$

$$\frac{\dot{V} \rho c_p}{K_T} = 43.5\%$$

4.

Roof

Layer Description	h W/m ² -K	k W/m-K	L m	Layer R	Units
Indoor air layer	10			0.100	(W/m ² -K) ⁻¹
XPS		0.028	0.075	2.679	(W/m ² -K) ⁻¹
Concrete		0.8	0.15	0.188	(W/m ² -K) ⁻¹
Outdoor air layer	25			0.040	(W/m ² -K) ⁻¹
Sum = R overall =				3.006	(W/m ² -K) ⁻¹
U value =				0.33	W/m ² -K

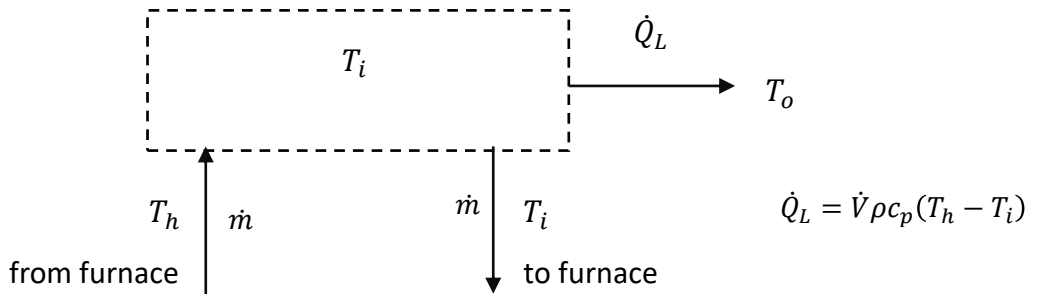
Wall

Layer Description	h W/m ² -K	k W/m-K	L m	Layer R	Units
Indoor air layer	10			0.100	(W/m ² -K) ⁻¹
XPS		0.028	0.05	1.786	(W/m ² -K) ⁻¹
Concrete		0.8	0.1	0.125	(W/m ² -K) ⁻¹
Outdoor air layer	25			0.040	(W/m ² -K) ⁻¹
Sum = R overall =				2.051	(W/m ² -K) ⁻¹
U value =				0.49	W/m ² -K

$$\dot{Q}_{wall} = (UA)_{wall} \cdot (T_i - T_o) = (0.49)(30)(20 - (-22)) = 617 \text{ W}$$

$$\dot{Q}_{roof} = (UA)_{roof} \cdot (T_i - T_o) = (0.33)(35)(20 - (-22)) = 485 \text{ W}$$

$$\dot{Q}_L = 617 + 485 \text{ W} = \mathbf{1102 \text{ W}} \quad \text{total heat loss rate}$$



$$\dot{V} = \frac{\dot{Q}_L}{\rho c_p (T_h - T_i)} = \frac{1102}{(1.23)(45 - 20)} \approx \mathbf{36 \text{ L/s}}$$

5.

State 1: 38 deg C, 30% RH

from chart: $\omega_1 \approx 12.5 \text{ g}_v/\text{kg}_a$
 $h_1 \approx 70.5 \text{ kJ/kg}_a$

State 2: 13 deg C, 100% RH

from chart: $\omega_2 \approx 9.4 \text{ g}_v/\text{kg}_a$
 $h_2 \approx 37 \text{ kJ/kg}_a$

For a cooling and dehumidifying process:

$$\dot{m}_w = \dot{m}_a(\omega_1 - \omega_2) \quad \text{and} \quad \dot{Q} \approx \dot{m}_a \cdot (h_1 - h_2)$$

$$\frac{\dot{m}_w}{\dot{m}_a} = \omega_1 - \omega_2$$

$$= 3.1 \text{ g}_v/\text{kg}_a$$

$$\frac{\dot{Q}}{\dot{m}_a} \approx h_1 - h_2$$

$$= 33.5 \text{ kJ/kg}_a$$

6.

A sensible heating process. This is “horizontal movement” on the chart ($\omega = \text{constant}$).

$$\text{State 1:} \quad h_1 \approx 33 \text{ kJ/kg}_a \quad \omega_1 = 5.7 \text{ g}_v/\text{kg}_a$$

$$v_1 \approx 0.833 \frac{\text{m}^3}{\text{kg}_a}$$

$$\dot{V}_1 = 700 \text{ L/s} = 0.7 \text{ m}^3/\text{s}$$

$$\dot{Q} = 25 \text{ kW}$$

$$\dot{Q} = \dot{m}_a(h_2 - h_1) = \frac{\dot{V}_1}{v_1}(h_2 - h_1)$$

$$h_2 = h_1 + \frac{\dot{Q}v_1}{\dot{V}_1} = 33 + \frac{(25)(0.833)}{0.7} \approx \mathbf{63 \frac{kJ}{kg}_a}$$

$$\omega_2 = \omega_1 = \mathbf{5.7 \text{ g}_v/\text{kg}_a}$$

So we have the “coordinates” h_2 and ω_2 . On the chart, this is at **T \approx 48 deg C, RH \approx 8.5%.**

7. Adiabatic mixing.

Stream 1: 32°C, RH = 40%

$$h_1 \approx 63 \text{ kJ/kg}_a$$

$$\omega_1 \approx 12 \text{ g}_v/\text{kg}_a$$

$$v_1 \approx 0.881 \text{ m}^3/\text{kg}_a$$

$$\dot{V}_1 = 20 \text{ m}^3/\text{min} = 0.333 \text{ m}^3/\text{s}$$

$$\dot{m}_{a1} = \dot{V}_1/v_1 = (0.333 \text{ m}^3/\text{s}) \div (0.881 \text{ m}^3/\text{kg}_a) = 0.378 \text{ kg}_a/\text{s}$$

Stream 2: 12°C, RH = 90%

$$h_2 \approx 32 \text{ kJ/kg}_a$$

$$\omega_2 \approx 7.9 \text{ g}_v/\text{kg}_a$$

$$v_2 \approx 0.817 \text{ m}^3/\text{kg}_a$$

$$\dot{V}_2 = 25 \text{ m}^3/\text{min} = 0.417 \text{ m}^3/\text{s}$$

$$\dot{m}_{a2} = \dot{V}_2/v_2 = (0.417 \text{ m}^3/\text{s}) \div (0.817 \text{ m}^3/\text{kg}_a) = 0.510 \text{ kg}_a/\text{s}$$

Stream 3: $\dot{m}_{a3} = \dot{m}_{a1} + \dot{m}_{a2} = 0.888 \text{ kg}_a/\text{s}$

On chart, state 3 will lie on the line connecting states 1 and 2.

$$h_3 = \frac{h_1 \dot{m}_{a1} + h_2 \dot{m}_{a2}}{\dot{m}_{a1} + \dot{m}_{a2}} = \frac{(63)(0.378) + (32)(0.51)}{0.888} = 45.2 \text{ kJ/kg}_a$$

at intersection: $T \approx 20.6^\circ\text{C}$, RH $\approx 64\%$

