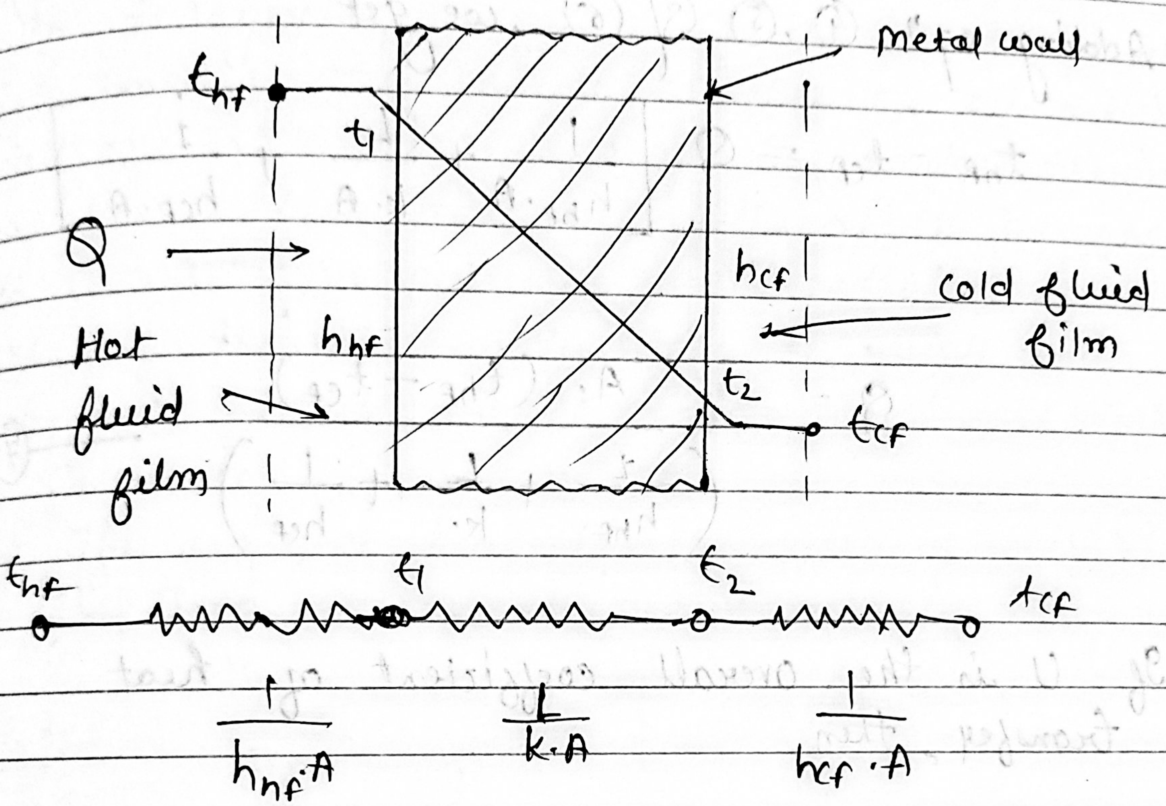
The overall Heat transfer coefficient :-



The equation of heat flow through the fluid and the metal surface are given by

$$Q = h_{hf} \cdot A \cdot (t_{hf} - t_1) \quad \text{--- (1)}$$

$$Q = \frac{k \cdot A \cdot (t_1 - t_2)}{L} \quad \text{--- (2)}$$

$$Q = h_{cf} \cdot A \cdot (t_2 - t_{cf}) \quad \text{--- (3)}$$

$$t_{hf} - t_1 = \frac{Q}{h_{hf} \cdot A} \quad \text{--- (4)}$$

$$t_1 - t_2 = \frac{Q \cdot L}{k \cdot A} \quad \text{--- (5)}$$

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$$t_2 - t_{cf} = Q / h_{cf} \cdot A \quad \text{—— (6)}$$

Adding eqⁿ (4), (5) & (6), we get

$$t_{hf} - t_{cf} = Q \left[\frac{1}{h_{hf} \cdot A} + \frac{L}{k \cdot A} + \frac{1}{h_{cf} \cdot A} \right]$$

$$Q = \frac{A \cdot (t_{hf} - t_{cf})}{\left(\frac{1}{h_{hf}} + \frac{L}{k} + \frac{1}{h_{cf}} \right)} \quad \text{—— (7)}$$

If U is the overall coefficient of heat transfer, then

$$Q = U \cdot A \cdot (t_{hf} - t_{cf}) \quad \text{—— (8)}$$

from eqⁿ (7) & (8)

$$\boxed{U = \frac{1}{\left(\frac{1}{h_{hf}} + \frac{L}{k} + \frac{1}{h_{cf}} \right)}}$$

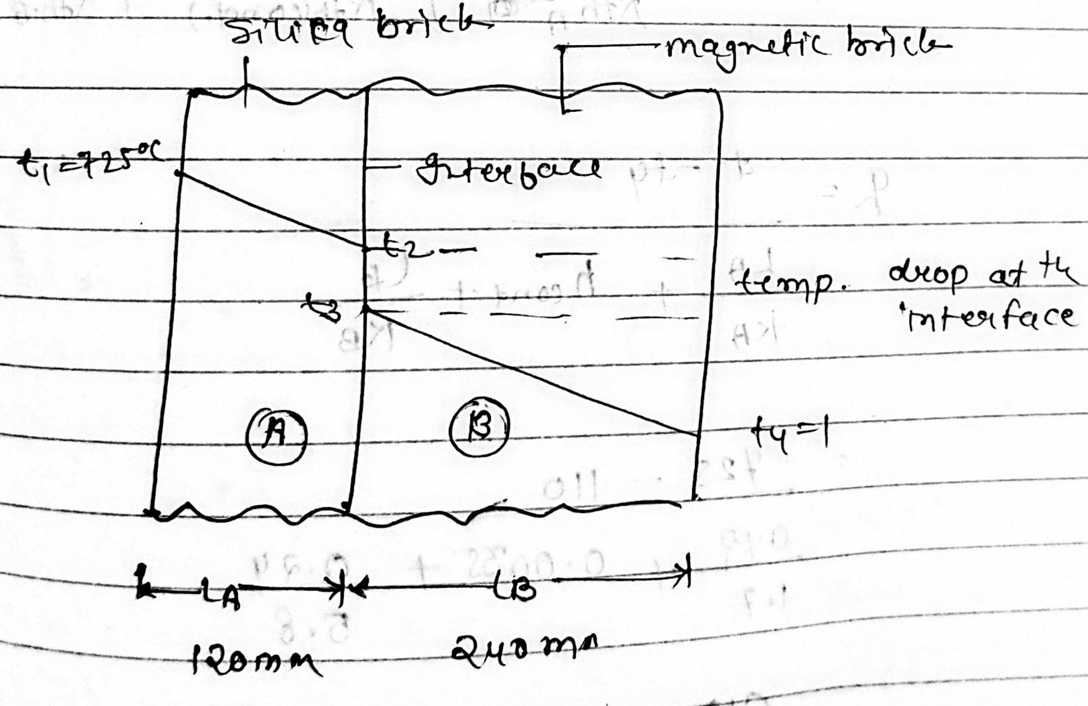
Overall coefficient of heat transfer.

Numerical

A wall of a furnace is made up of inside layer of silica brick 120 mm thick covered with a layer of magnetic brick 240 mm thick. The temp. at the inside surface of silica brick wall are 725 °C & 110 °C resp. The contact thermal resistance b/w the two walls at the interface is 0.0035 °C/w per unit wall at the interface area. If thermal conductivity of silica and magnesite brick are 1.7 w/m°C and 5.8 w/m°C
Calculate!

(1) The rate of heat loss/unit area of walls &
(2) The temp. drop at the interface.

Soln:-



Given:- $L_A = 120$ mm $= 0.12$ meter, $L_B = 240$ mm $= 0.240$ meter

$K_A = 1.7$ w/m°C, $K_B = 5.8$ w/m°C

$t_1 = 725°C$, $t_4 = 110°C$

1. The rate of heat loss / unit area,

$$Q = -kA \frac{dt}{dx}$$

$$\frac{Q}{A} = \frac{dt}{dx/k}$$

$$q = \frac{dt}{4k}$$

$$q = \frac{\Delta t}{\Sigma R_{th}} = \frac{t_1 - t_4}{R_{th_A} + R_{th(cond.)} + R_{th_B}}$$

$$q = \frac{t_1 - t_4}{\frac{L_A}{k_A} + h_{cond} + \frac{L_B}{k_B}}$$

$$= \frac{725 - 110}{\frac{0.12}{1.7} + 0.0035 + \frac{0.24}{5.8}}$$

$$= \frac{615}{0.0705 + 0.0035 + 0.0413} = \frac{615}{0.1153}$$

$$= q = 5330.24 \text{ W/m}^2$$ Ans.

(ii) The temp. drop at the Interface ($t_2 - t_3$)
As the same heat flows through layer of composite wall.

$$\therefore \quad q = \frac{t_1 - t_2}{L_A / K_A} = \frac{t_3 - t_4}{L_B / K_B}$$

$$5330.24 = \frac{725 - t_2}{0.12/1.7}$$

$$t_2 = 348.72 \approx 349°C$$

and

$$5330.24 = \frac{t_3 - t_4}{L_B / K_B}$$

$$5330.24 = \frac{t_3 - 110}{0.24/5.8}$$

$$t_3 = 330.56°C$$

Interface $\quad t_2 - t_3 = 349°C - 330°C$
$= 18.4°C$ Ans.

Q4. (2)

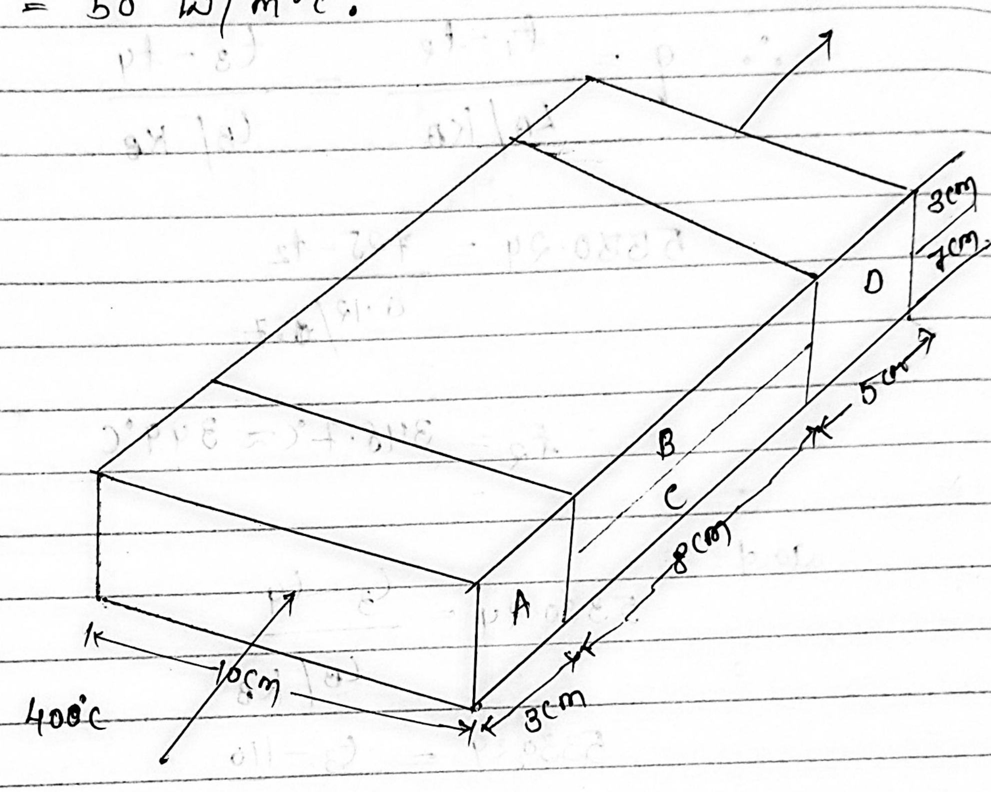
Find the heat flow rate through the composite wall shown in figure. Assume one dimensional flow.

$k_A = 150 \ W/m^\circ C,$

$k_B = 30 \ W/m^\circ C,$

$k_C = 65 \ W/m^\circ C,$

$k_D = 50 \ W/m^\circ C.$



thickness,

$L_A = 3cm = 0.03 \ m \quad , L_B = L_C = 8 \ cm = 0.08 \ m$

$L_D = 5 \ cm, \ = 0.05 \ m$

Areas $\quad A_A = 0.1 \times 0.1 = 0.01 \ m^2$

$A_B = 0.1 \times 0.03 = 0.003 \ m^2$

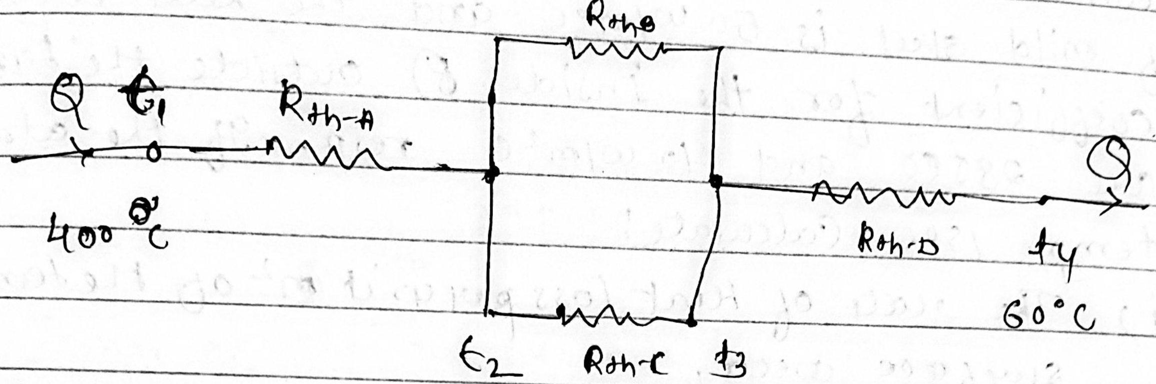
$A_C = 0.1 \times 0.07 = 0.007 \ m^2$

$A_D = 0.1 \times 0.\cancel{1} = 0.01 \ m^2$

Heat flow rate Q

$$R_{th-A} = \frac{L_A}{k_A \cdot A_A} = \frac{0.03}{150 \times 0.01} = 0.02$$

$$R_{th-B} = \frac{L_B}{K_B \cdot A_B} = \frac{0.08}{30 \times 0.003} = 0.89$$



$$R_{th-C} = \frac{L_C}{K_C \cdot A_C} = \frac{0.08}{65 \times 0.007} = 0.176$$

$$R_{th-D} = \frac{L_D}{K_C \cdot A_D} = \frac{0.05}{50 \times 0.01} = 0.1$$

$$\frac{1}{(R_{th})_{eq.}} = \frac{1}{R_{th-B}} + \frac{1}{R_{th-C}} = \frac{1}{0.89} + \frac{1}{0.176} = 6.805$$

$$R_{th\ eq.} = \frac{1}{6.805} = 0.147$$

$$R_{th-total} = R_{th-A} + R_{th-BC} + R_{th-D}$$

$$= 0.02 + 0.147 + 0.1$$

$$= 0.267$$

$$Q = \frac{(\Delta t)_{overall}}{(R_{th})_{total}} = \frac{400-60}{0.267}$$

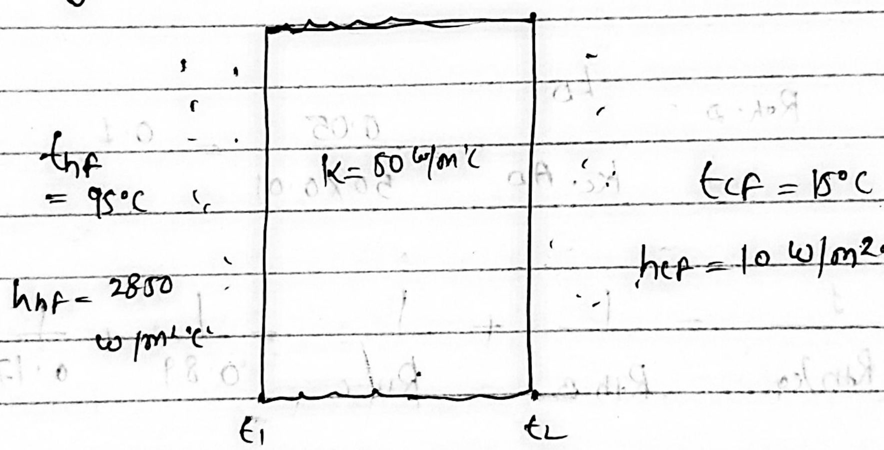
Ans. $Q = 1273.4\ W$

(8) A mild steel tank of wall thickness 12 mm contains water at 95°C. The thermal conductivity of mild steel is 50 W/m°C and the heat transfer coefficient for the inside & outside the tank are 2850 and 10 W/m²C resp. If the atmo. temp. 15°C Calculate:

(i) The rate of heat loss per unit m² of the tank surface area,

(ii) The temp. of outside surface of the tank

Soln:- Given: $L = 12$ mm, $= 0.012$ meters



(i) Rate of heat loss per unit m²

$$q = U \cdot A \cdot (t_{hf} - t_{cf})$$

$$U = \frac{1}{\frac{1}{h_{hf}} + \frac{L}{K} + \frac{1}{h_{cf}}}$$

$$= \frac{1}{1/2850 + 12/50 + 1/10}$$

$U = 9.94 \ W/m°C$

$$\frac{q}{A} = U \cdot (t_{hf} - t_{cf})$$

$$q = 9.94 \, (95° - 15°)$$
$$= 795.3 \ W/m^2$$

(ii) Temp. of the outside surface of tank

$$q = h_{cf} \times 1 \times (t_2 - t_{cf})$$

$$795.3 = 10 \times 1 \, (t_2 - 15°C)$$
$$t_2 = 94.53°C$$

Ans.