$Q_b = 1697.8$

Now, η ②

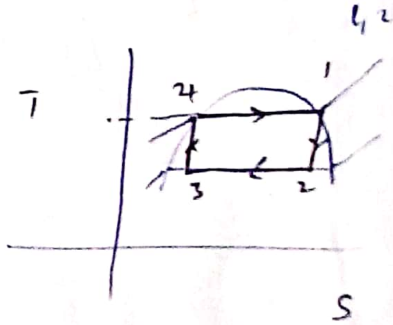
$$\eta = \frac{-\Sigma W}{Q_b}$$

$-\Sigma W = \eta Q_b$ $\quad \because \eta = 0.43.$

By putting values.

$-\Sigma W = 0.43 \times 1679.8$

$\boxed{\Sigma W = -730 J k} \longrightarrow$ ④.



Now $W_T = ?$

$W_T = h_2 - h_1$

Since; $h_1 = h_g = 2799.4 \ KJ/Kg$

To find $h_2 = ?$

First find $x = ?$

at 42 bar $S_1 = S_g$. Table # 2

$S_1 = S_g = 6.048 \ KJ/Kg \ ^\circ K$

Since; $S_1 = S_2 = 6.048 \ KJ/Kg \ ^\circ K$

So at $P = 0.035$ bar x will be;

$S_1 = (1-x) S_f + x S_g$

$6.048 = (1-x)(0.391) + x(8.523)$

$\boxed{x = 0.69}$

Now, at $x = 0.65$ & $P = 0.035$ bar from Table #2.

$h_2 = (1-0.65)(111.8) + 0.65(2550.4)$

$h_2 = 1793.796\ kJ/kg \rightarrow$

$W_T = h_2 - h_1$

By putting values.

$W_T = 1793.796 - 2799.4$

$W_T = -1005.6 \rightarrow (5)$.

As work ratio $= \frac{-\Sigma W}{W_T}$.

By putting values.

$= \frac{-730}{-1005.6}$

$\boxed{W.R = 0.726}$

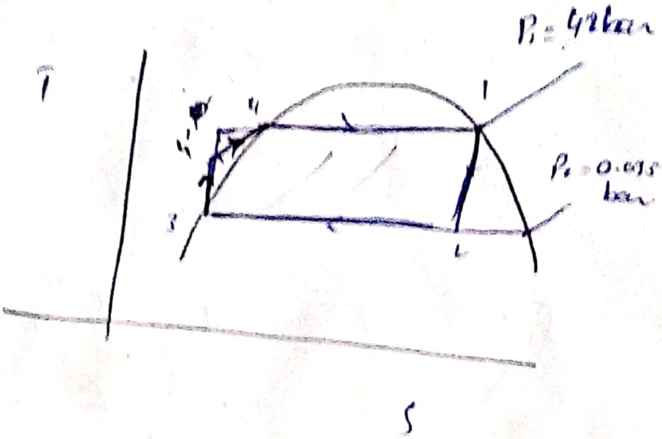
(E) Specific steam consumption = ?

$S.S.C = \frac{1}{\Sigma W}$

$= \frac{1}{730}$

$\boxed{S.S.C = 1.36 \times 10^{-4}}$ Ans

(b) For Rankine Cycle:



(a) Efficiency:

$$\eta = \frac{h_1 - h_2}{h_1 - h_3} \quad \text{---}, (A)$$

Since we calculated;

$h_1 = 2799.4$ KJ/kg

$h_2 = 1793.796$ KJ/kg

To find $h_3 = ?$

As $x = 0$.

$h_3 = h_f$.

at 0.035 bar, table # 2.

$h_3 = 111.8$ KJ/kg.

By putting values in eq (A).

$$\eta = \frac{2799.4 - 1793.796}{2799.4 - 111.8}$$

$\eta = 0.374$.

or $\boxed{\eta = 37.4\,\%}$

(b) Work ratio:-

As $W.R = \frac{-\Sigma W}{W_T} \quad \text{---}, (B)$.

$-\Sigma W = W_T + W_P$ But $W_P = 0$

So, $-\Sigma W = W_T \quad \text{---}, (C)$

Put eq (c) in (B)

$W.R = \frac{W_T}{W_T}$

∴ W.R in case of Rankine cycle is always 1.

$\boxed{W.R = 1}$

(c) Specific Steam Consumption:—

$S.S.C = \frac{1}{-(W_T)}$

$S.S.C = \frac{1}{-(-1005.6)}$

$\boxed{S.S.C = 9.9\times10^{-4}\ kg/kWh}$

Pb # 8.1

8.1 Steam is supplied dry saturated at 40 bar to a turbine and condenser pressure is 0.035 bar. If plant operate on Rankine cycle. Calculate per kg of steam.

i. Work output neglecting the feed pump work

ii. The Rankine efficiency

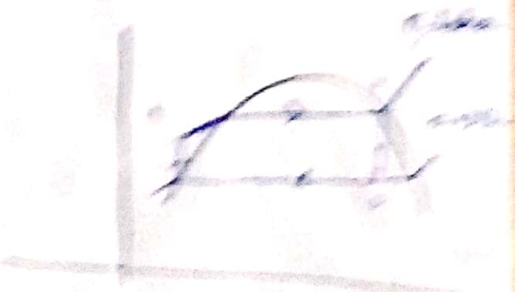
iii. The specific steam consumption.

iv) For the same steam condition calculate the efficiency & specific steam consumption for a Carnot cycle operating with wet steam.

Solution For Rankine Cycle:-

i. Work output = ? (neglecting feed pump work)

$W_{net} = W_T - \cancel{W_P}$



$W_{net} = W_T$

where $W_T = h_1 - h_2$

$W_{net} = h_1 - h_2$

at 40 bar Table

Since $h_1 = h_{g1}$

$h_g = 2800.3$

Since it is isentropic

$h_1 = h_g = 2800.3 \, kJ/kg$

$\boxed{h_1 = h_g}$

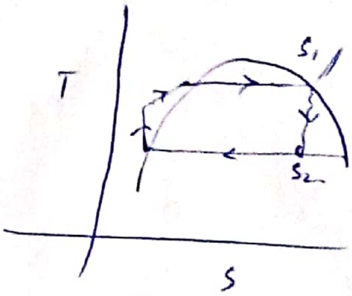
To find $h_2 = ?$
First find $x = ?$

As; $S_2 = S_g$ since $x = 1$. So $S = S_g$.

From Table # 2 $P = 40$ bar.

$S_2 = S_g = 6.069$ KJ/kg °K

As $S_1 = S_2$



So; To find x

$S_2 = (1-x) S_f + x S_g$.

Put $S_2 = 6.069$.

S_f & S_g value from Table #2.

$P = 0.035$ bar.

$6.069 = (1-x)\,0.391 + x(8.523)$

$\boxed{x = 0.698}$

Now; $h_2 = (1-x) h_f + x h_g$.

By putting values from Table #2 at $P = 0.035$ bar

$h_2 = (1-0.698)(111.8) + 0.698(2550.4)$

$h_2 = 1814.5236$

By putting values to get W_{out}.

$W_{out} = 1814.5236 - 2800.3$

$\boxed{W_{out} = -985.77 \text{ kJ}}$ Ans

∵ Negative as heat is rejected.

(ii) Rankine efficiency = ?
As;

$$\eta = \frac{h_1 - h_2}{h_1 - h_3} \longrightarrow (A).$$

Here;

$h_1 = 2800.3 \, kJ/kg$ } As calculated before
$h_2 = 1814.5236$

to find $h_3 = ?$

Since for $h_3 = ?$
$x = 0$
& $h_3 = h_f$.
So from table # 2 at $P = 0.035$ bar.

$h_3 = 111.8 \, kJ/kg$.

By putting values in (A)

$$\eta = \frac{2800.3 - 1814.5236}{2800.3 - 11.8}.$$

$\eta = 0.366$.

or $\boxed{\eta = 36.6\%}$

(iii) Specific Steam Consumption:–

Since $S.S.C = \frac{1}{\Sigma W}$ ∵ $\Sigma W = W_T + \cancel{W_P}^{\,no}$
$\Sigma W = W_T$

$S.S.C = \frac{1}{\Sigma W_T} \rightarrow (B)$

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As $W_T = 985.77$

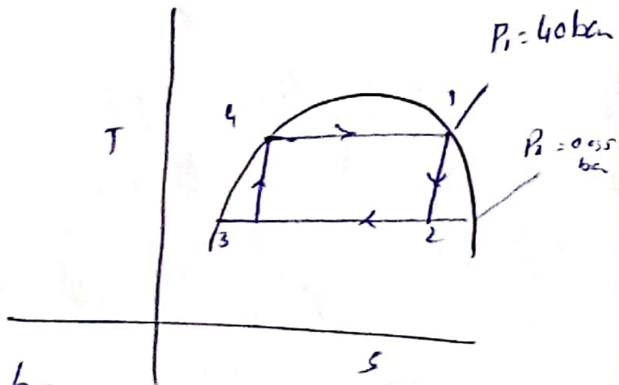
$$S.S.C = \frac{1}{985.77}$$

$$\boxed{S.S.C = 1.014 \times 10^{-3}\ kg/kWh}$$

iv) For Carnot Cycle Calculate η (efficiency) & S.S.C operating with wet steam.

For Carnot Cycle

$$\eta = 1 - \frac{T_2}{T_1} \longrightarrow (C)$$



As;

From Table #2 at 0.035 bar

$t_2 = 26.69\ °C$

$$T_2 = 26.69 + 273\ K \Rightarrow \boxed{T_2 = 299.69\ K}$$

at 40 bar. (Table #2

$t_1 = 250.3\ °C.$

$T_1 = 250.3 + 273\ K.$

$$\boxed{T_1 = 523.3\ K}$$

$$\text{eq } (C) \Rightarrow \quad \eta = 1 - \frac{299.69\ K}{523.3\ K}.$$

$$\eta = 0.427 \Rightarrow \text{or } \boxed{\eta = 42.7\ \%}$$

2.797 $\cancel{6.065} = 0.391 - 0.391x + 8.523x$

2.406 $\cancel{5.678}$ $= 8.132x$

$h_3 = (1-x)h_f + xh_g$

$\boxed{x = 0.3}$

at $P = 0.035$ bar
{ table A2

now,

$h_3 = (1-0.3)(111.8) + 0.3(2550.4)$

$h_3 = 0.7(111.8) + 0.3(2550.4)$

$h_3 = 33.54 + 765.12$

$h_3 = 798.66$ kJ/kg.

let $W_p = h_4 - h_3$.

$= 1087.4 - 798.66$.

$W_p = 288.74$ kJ.

Now,

$\Sigma W = 985.77 + 288.74$

$\Sigma W = 1074.5$ kJ.

$S.S.C = \frac{1}{\Sigma W}$ By putting value

$S.S.C = \frac{1}{1074.5}$

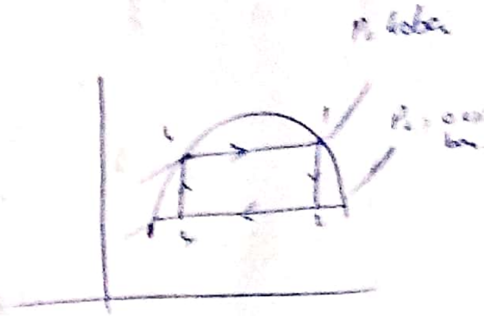
$\boxed{S.S.C = 0.000931 \text{ kg/kWh}}$

Ans

Specific steam consumption for Carnot cycle:-

Since;

$$S.S.C = \frac{1}{\Sigma W} \rightarrow ①$$



$\Sigma W = W_T + W_P$

$W_T = h_2 - h_1$

$h_1 = h_g$ at 40 bar

$h_1 = 2800.3$ KJ/kg

$h_2 = 1814.5326$

$W_T = 2800.3 - 1814.5326$

$\boxed{W_T = 985.77 \text{ KJ/kg}}$

$W_P = h_4 - h_3 \rightarrow ②$

For h_4 put $x = 0$

$h_4 = h_f$ at $P = 40$ bar table #2

$h_4 = 1057.4$ KJ/kg

For $h_3 = ?$ First find $x = ?$

As; $S_4 = S_3 = S_f$ at 40 bar & Table #2

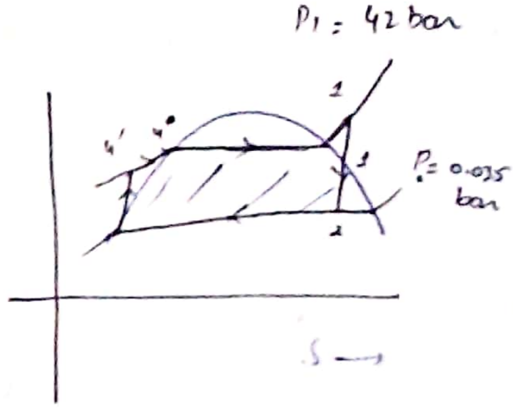
$S_3 = S_4 = 2.797$ KJ/kg K

As; $S_3 = (1-x)S_f + xS_g$ at $P = 0.075$ bar Table #2

$2.797 = (1-x)(0.2581) + x(8.573)$

Example # 8.2

Compare the Rankine cycle performance of exp # 8.1 with that obtained when steam is superheated to 500°C. Neglect feed pump work.



Solution:-

As for Rankine Cycle;

$$\text{Efficiency} = \eta = \frac{h_1 - h_2}{h_1 - h_3} \longrightarrow (1).$$

To find $h_1 = ?$

From table # 4 at $P = 42$ bar

& temp $= 500°C$

$$h_1 = 3442.7 \text{ kJ/kg}$$

For $h_2 = ?$

First find $x = ?$

As; $s = (1-x) s_f + x s_g$.

From table # 5 $P = 42$ bar & temp $= 500°C$

$$s_1 = 7.066 \text{ kJ/kg K}.$$

Since; $s_1 = s_2$ so,

$$s_2 = (1-x) s_f + x s_g.$$

$$7.066 = (1-x)(0.391) + x(8.523)$$ From table # 2 $P = 0.035$ bar

$$6.675 = 8.132\, x$$

$$\boxed{x = 0.821}$$

So,

$h_2 = (1-x)h_f + x h_g$

From Table #2
$P = 0.035$ bar

$h_2 = (1-0.821)(111.8) + (0.821)(2550.4)$

$h_2 = 20.0122 + 2093.87$

$$\boxed{h_2 = 2113.89 \text{ KJ/kg}}$$

To find $h_3 = ?$

Put $x = 0$

So; $h_3 = h_f$

$P = 0.035$ bar
& Table #2

$$\boxed{h_3 = 111.8 \text{ KJ/kg}}$$

By Putting values in eq ①

eq ① $\Rightarrow$ $$\eta = \frac{h_1 - h_2}{h_1 - h_3}$$

$$\eta = \frac{3442.7 - 2113.89}{3442.7 - 111.8}$$

$$\eta = \frac{1328.8}{3330.9}$$

$$\eta = 0.398$$

or

$$\boxed{\eta = 39.8\ \%}$$

Ex 5.3

Repeat Problem 5.1(a) for steam supply condition of 40 bar & 350°C & same condenser pressure of 0.035 bar.

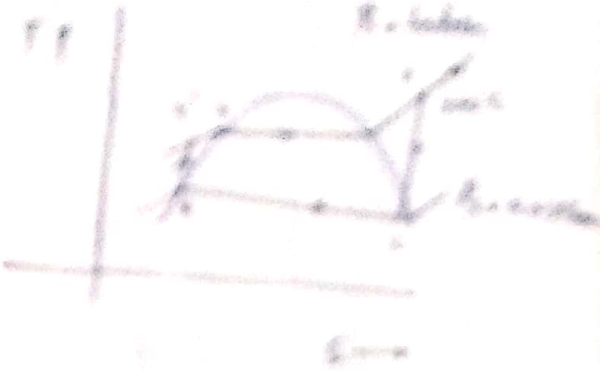
Find

(i) Work output neglecting feed pump work

(ii) Rankine efficiency

(iii) Specific steam consumption

(iv) For same steam condition calculate efficiency & specific steam consumption for Carnot cycle operating with wet steam.



Solution:-

(i) For ~~Carnot~~ Rankine cycle

(ii) Efficiency:-

$$\eta = \frac{h_1 - h_2}{h_1 - h_3} \quad \text{--- (1)}$$

$h_1 = ?$ at $P_1 = 40$ bar & Temp = 350°C

From table [illegible]

$h_1 = 3092.5$ kJ/kg

For $h_2 = ?$

$s_1 = s_2$ [illegible]

Since from table [illegible] $P_1 = 40$ bar & Temp = 350°C

$s_1 = 6.583$ kJ/kg K

Now;

$$S.S.C = \frac{1}{\Sigma W} \longrightarrow (A).$$

But $\Sigma W = W_T + \cancel{W_P}^{\,0}$.

$\Sigma W = W_T$.

$\Sigma W = W_T = h_1 - h_2$.

By putting values.

$= 3442.7 - 2113.89$.

$\Sigma W = 1328.81$ KJ/Kg

Put in eq (1).

$$= \frac{1}{1328.81}$$

$$\boxed{S.S.C = 0.000753}$$ Kg/KW S. Ans

or

$$\boxed{S.S.C = 2.71 \text{ Kg/kWh}}$$

Ans

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As $S_1 = S_2 = 6.[illegible]$

$S_2 = (1-x) S_f + x S_g$

From table at $P = 0.15$ bar

$6.[illegible] = (1-x)([illegible]) + x([illegible])$

$\therefore x = [illegible]$

$\boxed{x = 0.762}$

Sol. $h_2 = (1-x) h_f + x h_g$ — from table at $P = 0.15$ bar

$h_2 = (1 - 0.762)([illegible]) + (0.762)([illegible])$

$h_2 = [illegible] + [illegible]$

$h_2 = [illegible]\ kJ/kg$

For $h_3 = ?$

Put $x = 0$

$h_3 = (1-x) h_f + x h_g$

$h_3 = h_f$ — from table at $P = 0.15$ bar

$h_3 = [illegible]\ kJ/kg$

By putting values in eq ①

$\eta = \frac{[illegible] - [illegible]}{[illegible] - [illegible]} \Rightarrow \eta = \frac{[illegible]}{[illegible]}$

$\eta = 0.377$

or

$$\boxed{\eta = 37.7\ \%}$$

(ii) Work output –

As Work output $= \Sigma W$

$$\Sigma W = W_T + \cancel{W_P}^{\,0}$$

$$\Sigma W = W_T = h_1 - h_2$$

By putting values

$$\Sigma W = W_T = 2095 \cdot 1 - 1978$$

$$\boxed{W_{output} = W_T = 117.5 \cdot 1\ kJ/kg}$$

or

$$\boxed{W_{output} = 117.5\ 1\ kJ/kg}\ \text{Ans}$$

(iii) Specific Steam Consumption –

$$S.S.C = 1/\Sigma W \quad \text{or} \quad 1/W_T + \cancel{W_P}^{\,0}$$

$$= \frac{1}{W_T} \qquad \text{By putting values}$$

$$S.S.C = \frac{1}{117.5\ 1}$$

$$\boxed{S.S.C = 0.00851\ kg/kJ}\ \text{Ans}$$

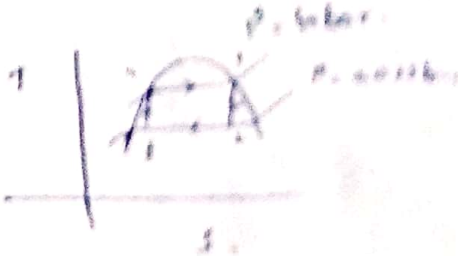
(d) For Carnot Cycle.

(i) Efficiency = ?

Since for Carnot Cycle

$$\eta = 1 - \frac{T_2}{T_1}$$

Note for Carnot we not Superheated steam. So,



$T_1 = 250.3\ °C$

$T_1 = 250.3 + 273\ K$

$T_1 = 523.3\ K$

$t_2 = 26.69$

$T_2 = 26.69 + 273\ K$

$T_2 = 299.69\ K$

$$\eta = 1 - \frac{299.69}{523.3} \Rightarrow \boxed{\eta = 0.427} \text{ or } \boxed{\eta = 42.7\%}$$

(ii) Specific Steam Consumption:-

$$S.S.C = \frac{1}{\Sigma W} \quad \text{—— (A)}$$

already find in Q.No.3

$\Sigma W = W_T + W_P$ —— (1)

$W_T = h_1 - h_2 = 985.77\ kJ/kg$

$W_P = h_4 - h_3 = 288.74\ kJ/kg$

Put in eq (1).

$\cancel{S.S.C = \frac{1}{\ldots}}$

$\Sigma W = 985.77 + 288.74$

$\Sigma W = 1074.5\ kJ/kg$

Using values in eq (A).

$$S.S.C = \frac{1}{\Sigma W}.$$

$$= \frac{1}{1074.5}$$

$$\boxed{S.S.C = 0.000931\ kg/kWs}$$

Ans

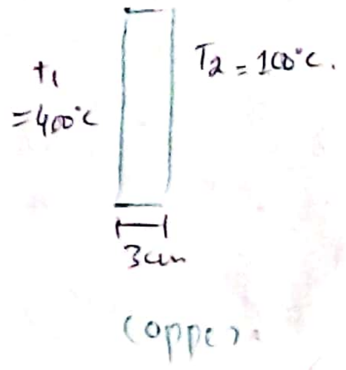
Example # 1.1

Given data;

Thickness $= \Delta x = 3cm$

$T_1 = 400°c$

$T_2 = 100°c$



Required data;

Heat transfer = ?

Solution:-

As

$$q = -\frac{K\Delta T}{\Delta x/A} \Rightarrow -\frac{KA\Delta T}{\Delta x}$$

$$\frac{q}{A} = \frac{-K\Delta T}{\Delta x}$$

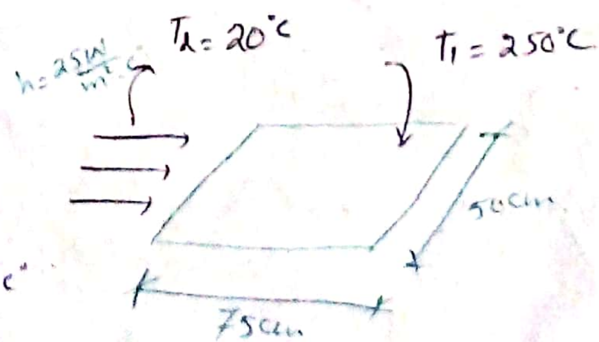
∴ as area is not given so shift to other side

$$= -\frac{370(100-400)}{3\times10^{-2}}$$

∴ $K = 370 \frac{W}{m°c}$.

$$q/A = 3700000 \Rightarrow \boxed{3.7\ MW/m^2 = q/A}$$

Example # 1.2



Sol:- Given data;

h = Convection heat transfer Co-efficient $= 25\frac{W}{m^2c}$.

$T_1 = 250°c$

$T_2 = 20°c$

$A = 75 \times 50$.

$A = 3750\ cm^2$.

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Required

heat transfer = ?

Sol:-

As

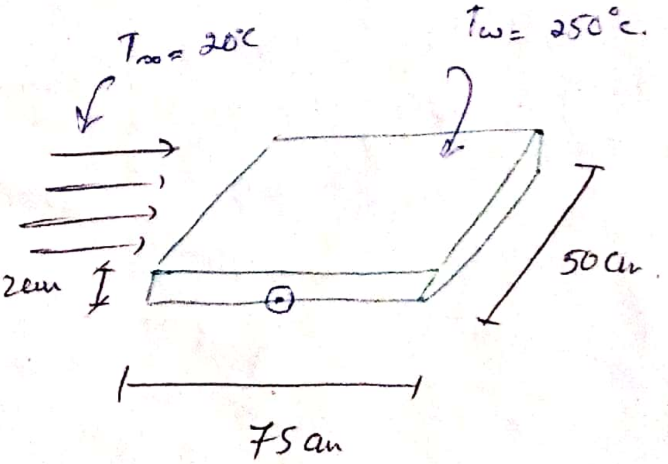
$\cancel{q = -KA\frac{\Delta T}{\Delta x}}$

~~By putting values.~~

$$q_{conv} = hA(T_w - T_\infty)$$

$$= 25(3750\times10^{-4})(250^\circ - 20^\circ)$$

$\boxed{q_{con} = 2156.25\,W.}$ or $\boxed{q_{conv} = 2.156\,kW}$



Example # 1.3

Given data;

$A = 75 \times 50\ cm^2$

$= 3750\ cm^2.$

$T_\infty = 20^\circ C$

$T_w = 250^\circ C$

$\Delta x = 2cm.$

$q_{rad} = 300W.$

Required

T_1 = Inside plate temperature = ?

Solution:-

As;

$$q_{cond} = q_{conv} + q_{rad} \quad \text{①}$$

As plate is at high temp so heat will transfer from plate bcz of both convection to air & radiation.

$q_{conv} = 2156.25\,W$

$q_{rad} = 300\,W$

$\{ \quad q_{cond} = \dfrac{-KA\Delta T}{\Delta x}$

eq ① $\Rightarrow$

$$\frac{-KA\Delta T}{\Delta x} = 2156.25 + 300$$

From table 1.1 K value for Carbon steel is 43

$$-\frac{43(3750\times10^{-4})\Delta T}{2\times10^{-2}} = 2456.25$$

$$-16.125\,\Delta T = 49.125$$

$$\Delta T = -3.0465^\circ$$

So, As $\Delta T = T_2 - T_1$

As here temp (inside) of steel plate is req. That why we take $T_2 = 250^\circ$

$$T_1 = \Delta T + T_2$$

$$T_1 = 3.0465 + 250^\circ$$

$$\boxed{T_1 = 253.0465^\circ}$$

Example # 1.4

Given data;

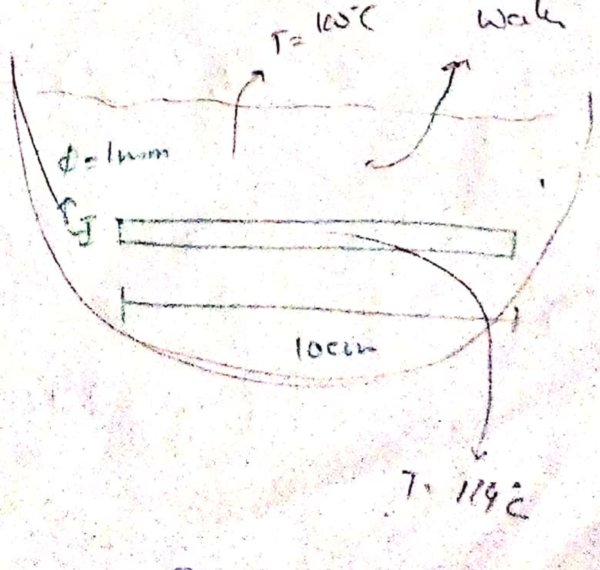
$d = 1mm$

$l = 10cm$

$h = 5000\,W/m^2.^\circ C$

$T_w = 100^\circ C$

$T = 114^\circ C$



Required: q = electric power = ?

Sol:- As we know that;

$q = hA(T - T_w)$ (in this case)

∴ As here no direct transfer of heat from wall to that wire. So heat will transfer through Convection.

$q = (5000)(2\pi r l)(114 - 100)$

$= 5000\,(2(3.14)(\frac{1}{2}\times10^{-3})(1\times10^{-2})(14))$

$\boxed{q = 21.98\ W}$

$A = 2\pi r l$

$r = \frac{1}{2}\times10^{-3}$

That is equal to power that must be applied.

Example # 1.5

Given data;

$t_1 = 800°C \Rightarrow T_1 = 800+273 = 1073K$

$t_2 = 300°C \Rightarrow T_2 = 300+273 = 573K$

Required data;

heat transfer $= q = ?$

Sol:- As we know that,

$q = \sigma A(T_1^4 - T_2^4)$

∴ For heat transfer in case of radiation temp should be in Kelvin

$\frac{q}{A} = 5.669\times10^{-8}((1073)^4 - (573)^4)$

$\sigma = 5.669\times10^{-8}$

$q/A = 5.669\times10^{-8}(1.2177\times10^{12})$

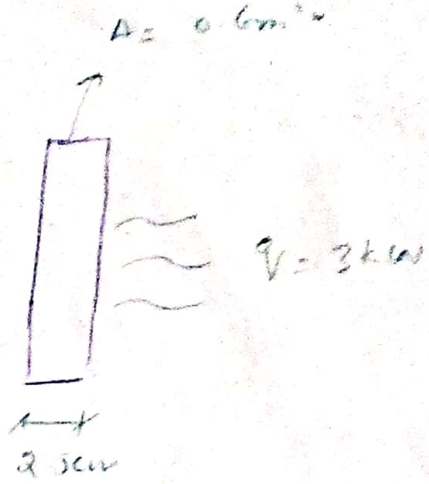
∴ As area is not given so shift to other side.

$q/A = 69031.41\ W$

$\boxed{q/A = 69.031\ KW}$ Ans

Pb # 1.1

Given data;



$A = 0.6 m^2$

$q = 3KW$

$\Delta x = 2.5cm = 2.5\times10^{-2} m$

K = Thermal Conductivity $= 0.2 W/m°C$

Required data;

$\Delta T = ?$

Solution:-

As we know

$$q = -KA\frac{\Delta T}{\Delta x}$$

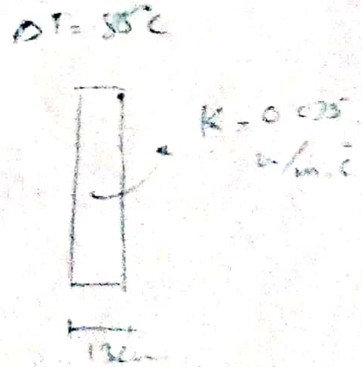
$$\Delta T = \frac{-q\,\Delta x}{KA}$$

∴ By putting values.

$$\Delta T = \frac{-3\times10^3(2.5\times10^{-2})}{(0.6)(0.2)} \Rightarrow \boxed{\Delta T = 625°}\ \text{Ans}$$

Pb # 1.2

Given data;



$\Delta T = 85°C$

$\Delta x = 13cm$

$K = 0.035 W/m.°C$

$q = ?$ heat transfer per unit hour?

Solution:- As we know That;

$$q = -\frac{KA\,\Delta T}{\Delta x} \longrightarrow ①$$

∴ By putting values

$$\frac{q}{A} = \frac{-(0.035)(55^\circ)}{(13\times10^{-2})}$$

∵ As area not given so shift to other side.

$$\frac{q}{A} = -22.88 \ W/m^2$$

$$= -22.88 \ J/s\,m^2$$

$$= -22.88 \frac{J}{(1/3600)\,hr\,m^2}$$

$$= -\frac{22.88\times3600 \ J}{hr\,m^2}$$

$$\boxed{q/A = -82384.61 \ J/hr\,m^2}$$ Ans.

Pb # 1.4

Given data

$k = 0.75 \ W/m\,^\circ C$

$\Delta x = 15cm$

$T_1 = 375^\circ$

$T_2 = 85^\circ$

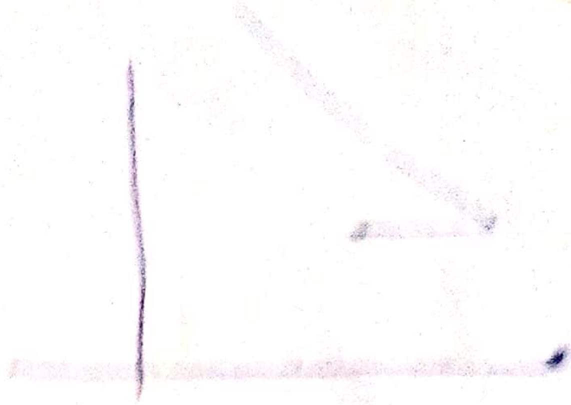
$q = ?$

Note :- When area is not given than shift to other side

Sol. As $q = -KA\frac{\Delta T}{\Delta x} \Rightarrow \frac{-0.78(85^\circ - 375^\circ)}{15\times10^{-2}} = q/A$

$$\boxed{q/A = 1508 \ W/m^2}$$

Heat flow at steady state condition



Example # 1.6

Given data,

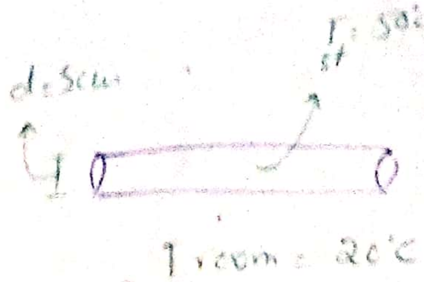
$d = 5cm$

$T_{st} = 50°C$

$T_r = 20°C$

$F_\epsilon = 0.8$

$F_G = 1$



Required:

$q = ?$

Sol:- As it is placed in room. So total heat loss is due to convection & radiation.

$$q_{total} = q_{conv} + q_{rad} \rightarrow ①$$

$$q_{conv} = hA(T_w - T_\infty)$$

From table 1.3

$h = 6.5\ W/m^2\,°C$

$A = 2\pi r L$

$$= (6.5)(2\pi r L)(50° - 20°C)$$

$$= (6.5)(2(3.14)(5/2 \times 10^{-2})(L)(30°C)$$

∴ shift L to other side.

$$\left(\frac{q}{L}\right)_{conv} = 30.615\ W/m \rightarrow ②$$

$$q_{rad} = F_\epsilon F_G \sigma A(T_1^4 - T_2^4)$$

For steel.

$\sigma = 5.669 \times 10^{-8}$

$$q_{rad} = (0.8)(1)(5.669 \times 10^{-8})(\pi LD)((323)^4 - (293)^4)$$

(5×10^{-2})

$$\left(\frac{q}{L}\right)_{rad} = 25.12\ W/m \rightarrow ③$$

Put eq ② & ③ in ①

6250000

= 16000

$t_1 = 50°C \rightarrow 50+273$

$= 323K$

$t_2 = 20 \rightarrow 20+273$

$293K$

$$q_{Total} = 25.12 + 30.615$$

$$\boxed{q_{TOT} = 55.73\ W/m}$$ Ans

Scanned with CamScanner

Example # 2.1

Given data

$\Delta x_1 = 6''$

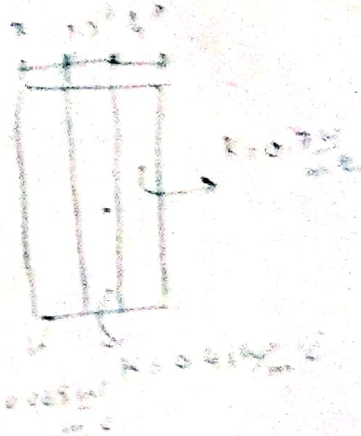
$k_1 = 0.7\ W/m.^{\circ}C$

$\Delta x_2 = 1.5''$

$k_2 = 0.065\ W/m.^{\circ}C$

$\Delta x_3 = ?$

$k_3 = 0.065\ W/m.^{\circ}C$



Thermal Circuit

Required

How much thickness insulation induce that heat loss reduce by 80%.

Sol:- As we can write

$$q_{with} = (q_{without})(1-.80)$$

$$q_{with} = 0.2(q_{without}) \longrightarrow ①$$

$$q_{with} = \frac{\Delta T}{\left(\frac{\Delta x_1}{k_1 A}\right) + \left(\frac{\Delta x_2}{k_2 A}\right) + \left(\frac{\Delta x_3}{k_3 A}\right)}$$

or

$$q_{with} = \frac{\Delta T A}{\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3}} \longrightarrow ②$$

$$q_{without} = \frac{\Delta T A}{\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2}} \longrightarrow ③$$

Put values in eq ①.

$$\frac{0.2\,x}{\frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}+\frac{\Delta x_3}{K_3}} = \left(\frac{\Delta x}{\frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}}\right)0.2$$

$$\left(\frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}+\frac{\Delta x_3}{K_3}\right)0.2 = \frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}$$

$$0.2\frac{\Delta x_3}{K_3} = \frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2} - \frac{0.2\,\Delta x_1}{K_1} - \frac{0.2\,\Delta x_2}{K_2}$$

$$0.2\frac{\Delta x_3}{K_3} = 0.8\left(\frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}\right)$$

$$\Delta x_3 = \frac{K_3(0.8)}{0.2}\left(\frac{\Delta x_1}{K_1}+\frac{\Delta x_2}{K_2}\right)$$

$$= 4(0.065)\left(\frac{[illegible]}{0.7}+\frac{[illegible]}{0.48}\right)$$

$$= 0.26\,(\,[illegible] + [illegible]\,)$$

$$\boxed{\Delta x_3 = 0.0553\ [illegible]}$$

In [illegible]

$$\Delta x_3 = 0.055 \times 10^{[illegible]} \times [illegible]$$

$$\boxed{\Delta x_3 = [illegible]}$$

Pb # 2.1

Given data;

$\Delta x_1 = 2 cm$

$K_1 = 1.3$

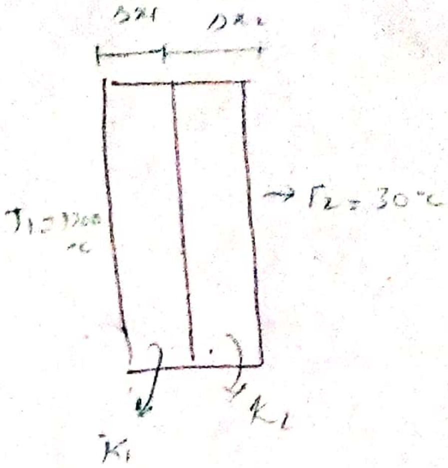
$K_2 = 0.35$

$q = 1830 W/$

$T_1 = 1300 °c.$

$T_2 = 30°c.$

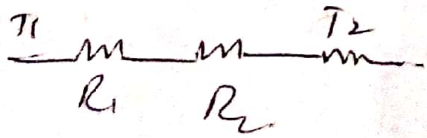
$\Delta x_2 = ?$



Sol:-

As;

Thermal Circuit



$$q = \frac{-\Delta T A}{\left(\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2}\right)}$$

$$q/A = \frac{-\Delta T}{\left(\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2}\right)}$$

$$1830 = \frac{-(130 - 1300)}{\frac{2\times 10^{-2}}{1.3} + \frac{\Delta x_2}{0.35}}$$

$$1830 = \frac{1270}{0.01538 + \frac{\Delta x_2}{0.35}} \Rightarrow 1830\left(0.01538 + \frac{\Delta x_2}{0.35}\right) = 1270$$

$$28.154 + 5228.57 \Delta x_2 = 1270.$$

$$5228.57 \Delta x_2 = 1241.846$$

$$\boxed{\Delta x_2 = 0.237 m}$$

$$\boxed{\Delta x_2 = 23.75 cm}$$

Pb# 2.3

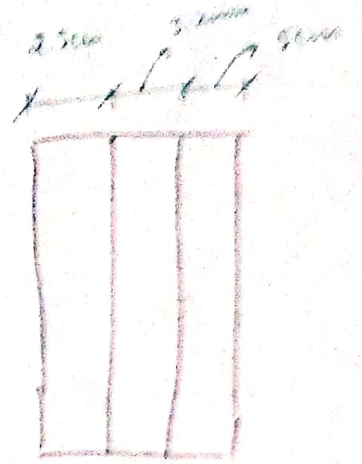
Given data;

$\Delta x_1 = 2.5\,cm$

$\Delta x_2 = 3.2\,mm = 0.32\,cm.$

$\Delta x_3 = 5\,cm.$

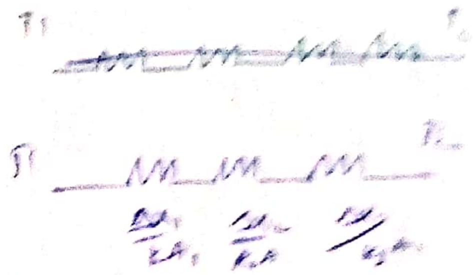
$\Delta T = 560\,^\circ C$



Req.

heat flow per unit area

Thermal circuit



Sol:

As we know;

$$q = \frac{k\,\Delta T\,A}{\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2} + \frac{\Delta x_3}{K_3}}$$

$$q/A = \frac{\Delta T}{\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2} + \frac{\Delta x_3}{K_3}}$$

For copper.

$K_1 = 386$

For Asbestos

$K_2 = 0.149$

For fibreglass

$K_3 = 0.038$

$$= \frac{560}{\left(\frac{2.5\times10^{-2}}{386}\right) + \left(\frac{0.32\times10^{-2}}{0.149}\right) + \left(\frac{5\times10^{-2}}{0.038}\right)}$$

$$= \frac{560}{6.4767\times10^{-5} + 0.02147 + 1.31578}$$

$$\boxed{q/A = 418.7466\,W/m^2}$$

Pb #2.5

Given data:

$\Delta x_1 = 5\,cm$

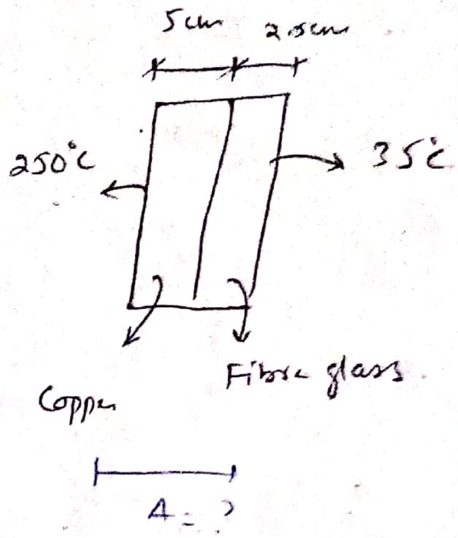
$\Delta x_2 = 2.5\,cm$

$T_1 = 250\,°C$

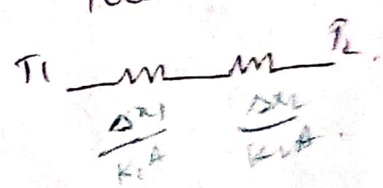
$T_2 = 35\,°C$

$q = 52\,kW$

Area = ?



Thermal circuit



Solution:-

As we know that,

$$q = \frac{A\,\Delta T}{\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2}}$$

$$A = \frac{q\left(\frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2}\right)}{\Delta T}$$

For copper

$K_1 = 386$

For Fibre glass

$K_2 = 0.038$

By putting values.

$$A = \frac{52\times10^3\left(\frac{5\times10^{-2}}{386} + \frac{2.5\times10^{-2}}{0.038}\right)}{(-250° + 35°)}$$

$$A = \frac{52\times10^3(1.29\times10^{-4} + 0.65789)}{-215°}$$

$$\boxed{A = 159.1\,m^2}$$ Ans

Pb # 2.6

Given data:

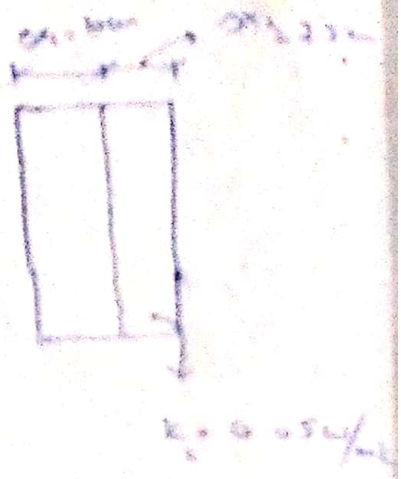
$\Delta x_1 =$ [redacted] 10cm

$\Delta x_2 = 2.5cm$

$k_2 = 0.05 \, W/m \cdot C$

$q = ?$

$\Delta T = 25°C$



Solution:-

$k_1 = 0.69$

As we know that

Thermal Circuit

$$T_1 \xrightarrow{\frac{\Delta x_1}{k_1 A}} \xrightarrow{\frac{\Delta x_2}{k_2 A}} T_2$$

$$q = \frac{\Delta T A}{\left(\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2}\right)}$$

$$q/A = \frac{(20)}{\frac{0.69}{(10\times10^{-2})} + \frac{0.05}{(2.5\times10^{-2})}}$$

$$q/A = \frac{25}{6.9+2} \Rightarrow \boxed{q/A = 2.808 \, W/m^2}$$

Ans

Pb # 2.7

Given data,

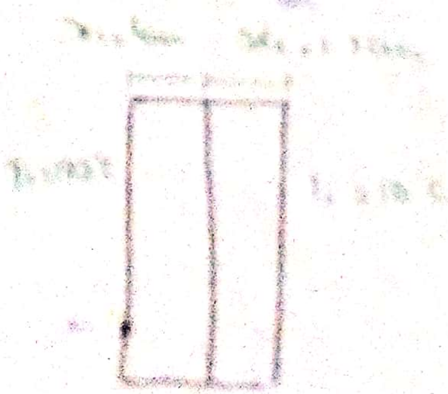
$\Delta x_1 = 6cm$

$\Delta x_2 = 1.5cm$

$T_1 = 135°C$

$T_2 = 80°C$

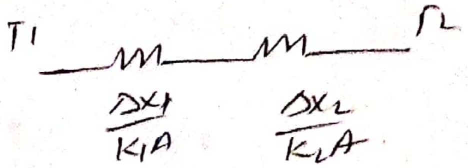
$q/A = 9765 \, W/m^2$



Solution:-

$\therefore$ As we know; Thermal Circuit.

$$q = \frac{\Delta T\, A}{\left(\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2}\right)}$$



$$A = q\left(\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2}\right) \Big/ \Delta T$$

For Copper $k_1 = 386$

For fibre glass $k_2 = 0.038$

$$= 300\left(\frac{4\times10^{-2}}{386} + \frac{1.5\times10^{-2}}{0.038}\right) \Big/ 80$$

$$= 300\left(1.036\times10^{-4} + 0.3947\right) \Big/ 80$$

$$\boxed{A = \cancel{148.45}\ 1.48\,m^2}$$ Ans

Pb # 2.12

Given data;

$\Delta x_1 = 2$ cm

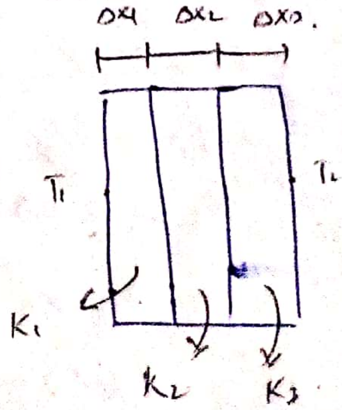
$\Delta x_2 = 3$ cm

$k_2 = 0.166$ W/m.°C.

$\Delta x_3 = 6$ cm

$\Delta T = 500$°C.

$q = ?$



Sol:- As we know that;

$$q = \frac{\Delta T}{\left(\frac{\Delta x_1}{k_1 A}\right) + \left(\frac{\Delta x_2}{k_2 A}\right) + \left(\frac{\Delta x_3}{k_3 A}\right)} \Rightarrow \frac{\Delta T\, A}{\left(\frac{\Delta x_1}{k_1}\right) + \left(\frac{\Delta x_2}{k_2}\right) + \left(\frac{\Delta x_3}{k_3}\right)}$$

Scanned with CamScanner

By Putting values

Right area the other side.

Circuit diagram:

$$q/A = \frac{-560}{\left(\frac{2\times10^{-2}}{385}\right)+\left(\frac{3\times10^{-2}}{0.166}\right)+\frac{(6\times10^{-2})}{30}}$$

For Copper, Table 1-1

$k_1 = 385$

$k_3 = 30$

$$q/A = \frac{-560}{0.0000051948 + 0.18072 + 0.002}$$

$$\boxed{q/A = -3063.9275\ W/m^2}$$

Pb # 2.13

Givendata;

$\Delta x_1 = 6$ in. (m).

$k_1 = 1.9\ W/m\,°C$

$k_2 = 30\ W/m\,K$

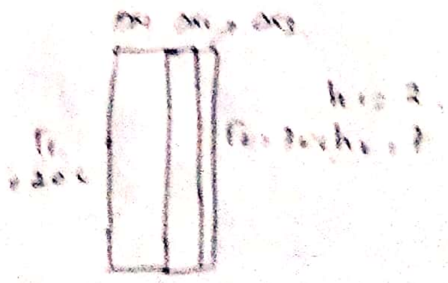
$\Delta x_2 = 2''$ (fiber glass)

$\Delta x_3 = 3/8''$ (gypsum)

$k_3 = 0.05\ W/m\,°C$.

$T_1 = 20°C$

$T_2 = 72°C$.



Sol:- (a) Heat transfer co-efficient.

$U = ?$

As $$U = \frac{1}{\frac{1}{h_2 A} + \frac{\Delta x_1}{k_1 A} + \frac{\Delta x_2}{k_2 A} + \frac{\Delta x_3}{k_3 A} + \frac{1}{h_1 A}}$$

By Putting values

$$U = \frac{1}{\frac{1}{7(A)} + \frac{6}{(1.2)A} + \frac{2}{30A} + \frac{3}{8(0.05)} + \frac{1}{2(A)}}$$

$$\frac{U}{A} = \frac{1}{\frac{1}{7} + \frac{6}{1.2} + \frac{2}{30} + \frac{3}{8(0.05)} + \frac{1}{2}}$$

$$U/A = \frac{1}{10.7095}$$

$$\boxed{U/A = 0.0934}$$

(b) R value.

As R value.

$$R = \frac{\Delta x_1}{K_1} + \frac{\Delta x_2}{K_2} + \frac{\Delta x_3}{K_3}.$$

$$R = \frac{6}{1.2} + \frac{2}{30} + \frac{3}{8(0.05)}$$

$$\boxed{R = 108.833}$$

(c) Heat loss per unit area

As

$$q = \frac{-\Delta T}{\frac{1}{h_2 A} + \frac{\Delta x_1}{K_1 A} + \frac{\Delta x_2}{K_2 A} + \frac{\Delta x_3}{K_3 A} + \frac{1}{h_1 A}}$$

$$\frac{q}{A} = \frac{-\Delta T}{\frac{1}{h_1} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_3}}$$

$$= \frac{-(+20-72)}{1/7 + \frac{6}{1.2} + \frac{2}{30} + \frac{3}{5(0.05)} + \frac{1}{2}}$$

$$= \frac{+52}{10.7095}$$

$$\boxed{q/A = 4.855 \ W/m^2}$$ Ans.

Example 3.1 Given data;

Height of wall = 3m

Width = 5m (length).

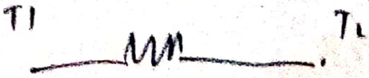
Thickness = 0.3m

$K = 0.9\ W/m\cdot{}^\circ C$

$T_1 = 16^\circ C$

$T_2 = 2^\circ C$

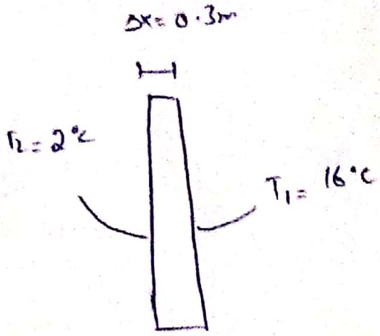
Circuit diagram.



Required data;

Rate of heat loss through wall on day.

Solution:-



As we know that there will conduction occur through so wall.

So amount of heat loss through wall will be;

$$q = \frac{KA\Delta T}{\Delta x} \quad \text{--- (1)}$$

$K = 0.9$

$A = H \times L$

$= 3 \times 5 = 15 m^2$

$\Delta T = 16 - 2$

$= 14^\circ C$

$\Delta x = 0.3m$

By putting values.

$$q = \frac{0.9(15)(14)}{0.3}$$

$$\boxed{q = 630 W} \text{ Ans}$$

$$= \frac{W/m\cdot{}^\circ C\,(m^2)(^\circ C)}{m}$$

$= W$

Example # 3-2

Given data;

Height of window = 0.8 m

Length = 1.5 m

thickness = Δx = 8 mm

$k = 0.78\ W/m\,°C$

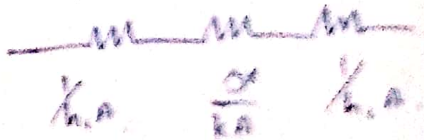
$T_1 = 20°C$

$T_2 = -10°C$

$h_1 = 10\ W/m^2\,°C$

$h_2 = 40\ W/m^2\,°C$

Circuit diagram



Solution:-

Since we know that;

$$q = \frac{\Delta T}{\frac{1}{h_1 A} + \frac{\Delta x}{kA} + \frac{1}{h_2 A}} \longrightarrow ①$$

$\Delta T = 20 - (-10) = 30°C$

$$\frac{1}{h_1 A} = \frac{1}{10(0.8)(1.5)} = 0.08333\ °C/W$$

$$\frac{\Delta x}{kA} = \frac{8\times10^{-3}}{0.78(0.8)(1.5)} = 0.00555\ °C/W$$

$$\frac{1}{h_2 A} = \frac{1}{40(0.8)(1.5)} = 0.02083\ °C/W$$

By putting values in eq ①.

$$q = \frac{30\ °C}{0.08333\ °C/W + 0.00555\ °C/W + 0.02083\ °C/W}$$

$\boxed{q = 266\ W}$ Ans

Example 3.1 Given data;

Height of wall = 3m

Width = 5m (length)

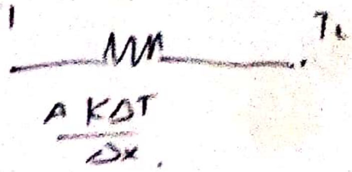
Thickness = 0.3m

$K = 0.9\ W/m\cdot{}^{\circ}C$

$T_1 = 16^{\circ}C$

$T_2 = 2^{\circ}C$

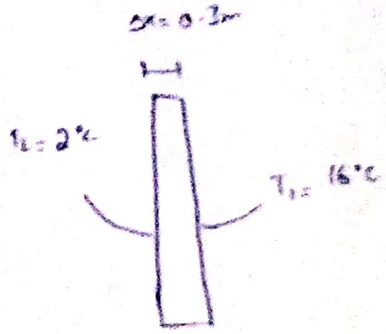
Circuit diagram.



Required data;

Rate of heat loss through wall on day

Solution:-



As we know that there will conduction occur through so wall

So amount of heat loss through wall will be;

$$q = \frac{KA\Delta T}{\Delta x} \quad \longrightarrow (1)$$

$K = 0.9$

$A = H \times L$

$= 3 \times 5 = 15m^2$

$\Delta T = 16 - 2^{\circ}$

$= 14^{\circ}C$

$\Delta x = 0.3m$

By putting values

$$q = \frac{0.9(15)(14)}{0.3}$$

$$\boxed{q = 630\ W} \quad \text{Ans}$$

$$= \frac{W/m\cdot{}^{\circ}C\,(m^2)({}^{\circ}C)}{m}$$

$= W$

Exp # 3.3

Double Pan Window

Given data;

Height $= 0.8m$

length $= 1.5m$

$k_g = 0.78 \; W/m\,°C$

$\Delta X_1 = \Delta X_3 = 4mm$

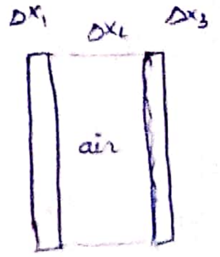
$\Delta X_2 = 10mm$

$K_{air} = 0.026 \; W/m\,°C$

$h_1 = 10 \; W/m^2\,°C$

$h_2 = 40 \; W/m^2\,°C$

Req:- $q = ?$

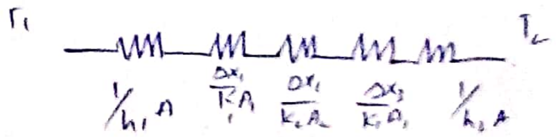


Two pan window;

Circuit diagram.

$T_1 = -10°C \quad T_2 = 20°C$

Solution:-



$$\frac{1}{h_1 A} \quad \frac{\Delta X_1}{K_1 A_1} \quad \frac{\Delta X_2}{K_2 A_2} \quad \frac{\Delta X_3}{K_1 A_1} \quad \frac{1}{h_2 A}$$

As we know that;

$$q = \frac{\Delta T}{\frac{1}{h_1 A} + \frac{\Delta X_1}{k_1 A_1} + \frac{\Delta X_2}{k_2 A_2} + \frac{\Delta X_3}{k_1 A_1} + \frac{1}{h_2 A}} \longrightarrow (A)$$

$A = (0.8)(1.5)$

$A = 1.2 m^2$

$\Delta T = 20 - (-10)$

$= 30°C$

$$\frac{1}{h_1 A} = \frac{1}{10(1.2)} = 0.08333 \; °C/W$$

$$\frac{\Delta X_1}{k_1 A_1} = \frac{4 \times 10^{-3}}{(0.78)(1.2)} = 0.00427 \; °C/W$$

$$\frac{\Delta X_2}{k_2 A_2} = \frac{10 \times 10^{-3}}{0.026(1.2)} = 0.3205 \; °C/W$$

$$\frac{\Delta X_3}{KA} = 0.00427 \; °C/W$$

$$\frac{1}{h_2 A} = \frac{1}{40(1.2)} = 0.02083 \; °C/W$$

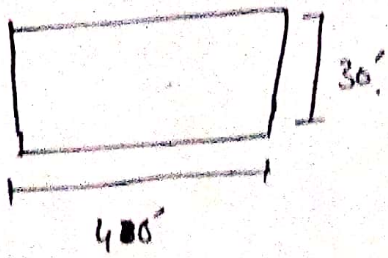
By putting all values in eq (A)

$$q = \frac{30}{0.08333 + 0.00427 + 0.3205 + 0.00427 + 0.02083} \Rightarrow \boxed{q = 69.2W}$$

~~Pb #~~ Example # 3-15 (House)

Given data;

Height = 9' (wall)



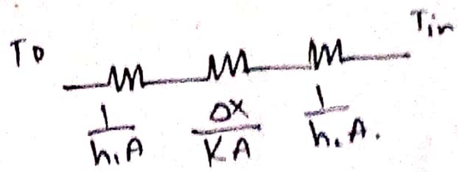
Length of two of wall = 40'

Length of other two wall = 30'.

$T_1 = 75°F$.

$T_2 = 45°F$

Circuit diagram



Electricity Cost = 0.075 /kWh.

$h_i = 1.46 \ Btu/h \cdot ft^2 \cdot °F$

$h_o = 4 \ Btu/h \, ft^2 \cdot °F$.

R-value $= L/K = 13 h \cdot ft^2 \cdot °F/Btu$.

Solution:-

As we know that;

$$q = \frac{\Delta T}{R_{conv} + R_{cond} + R_{conv}} \longrightarrow (A).$$

$$A = (2\times30 + 2\times40)\times 9$$
$$= 1260 \ ft^2.$$

$$R_{conv} = \frac{1}{h_i A} = \frac{1}{(1.46)(1260)} = 0.00054 \ h\,°F/Btu.$$

$$R_{cond} = \frac{\Delta x}{KA} = \frac{\Delta x}{K}\left(\frac{1}{A}\right) = \frac{R_{value}}{A} = \frac{13}{1260} = 0.01032 \ h\,°F/Btu$$

$$R_{conv} = \frac{1}{h_o A} = \frac{1}{4(1260)} = 0.0001984 \ h\,°F/Btu.$$

By putting values in eq (A)

$$q = \frac{(75-45)}{0.00054 + 0.01032 + 0.0001984}$$

$$q = 2712.86 \ Btu/hr.$$

The amount of heat loss during 24 hr.

$$q = 2712.86 \ \tfrac{Btu}{hr} \times 24 \ hr/day$$

$q = 65105.58$ Btu/day

as $1\,kWh = 3412$ Btu

So in kWh it is,

$$q = 65105.58\left(\frac{1}{3412}\right) kWh$$

$$q = 19.08\, kWh \longrightarrow (B)$$

Heating cost = (Energy lost) × (cost of energy)

$$= \left(19.08\, \frac{kWh}{day}\right) \times (\$0.075/kWh)$$

$\boxed{\text{Cost heat} = \$1.43/day}$ Ans 2.

Pb # 3-17

Given data;

Height of wall = 4m

Length = 6m

thickness = $\Delta x = 0.3m$

$k = 0.8\ W/m°C$

$T_1 = 14°C$

$T_2 = 6°C$

$q = ?$

Circuit diagram

Sol: as we know that,

$$q = \frac{k A \Delta T}{\Delta x}$$

Since $\Delta T = 14 - 6 = 8\,^\circ C$

$\Delta x = 0.3 m$.

$A = 4 \times 6 = 24 m^2$

$K = 0.8\ W/m^\circ C$.

By putting values.

$$q = \frac{8(24)(0.8)}{0.3}$$

$$\boxed{q = 512 W} \quad \text{Ans}$$

Pb #3.15

Given data

Height of window = 1.2m.

length = 2m.

thickness = 6mm

$k = 0.78\ W/m^\circ C$

$T_1 = 24^\circ C$

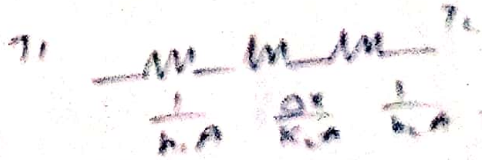
$T_2 = -5^\circ C$

$h_1 = 10 W/m^2 {}^\circ C$.

$h_2 = 25 W/m^2 {}^\circ C$.

$q = ?$

Circuit diagram



Solution:-

Since;

$$q = \frac{1}{R_1 + R_2 + R_3} \longrightarrow ①$$

$$R_1 = \frac{1}{h_1 A} = \frac{1}{10(1.2 \times 2)} = 0.04167\ ^\circ C/W$$

$$R_2 = \frac{\Delta x}{K_1 A} = \frac{6 \times 10^{-3} m}{(0.78)(1.2)(2)} = 0.003205\ ^\circ C/W$$

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$$R_3 = \frac{1}{h_2 A} = \frac{1}{[illegible]}$$

$R_3 = 0.0167\ °C/W$

By putting values in eq (i)

$$q = \frac{(24 - (-5))}{(0.01 + [illegible] + 0.385 + 0.0167)}\ \text{[illegible]}$$

$$\boxed{q = [illegible]\ W}\ \text{Ans}$$

Pb # 3.7 (Double Pane Window)

Given data

Height of window = 1.2 m

Length = 2 m

$\Delta x_1 = \Delta x_2 = 3\ mm$ (thickness of glass)

$k_{glass} = 0.78\ W/m°C$

$\Delta x_2 = 12\ mm$ (thickness of air)

$k_{air} = 0.026\ W/m°C$

$h_1 = 10\ W/m^2°C$

$h_2 = 25\ W/m^2°C$

$T_1 = 24°C$

$T_2 = -5°C$

$q = ?$

Circuit diagram

T_1 —— $\frac{1}{h_1 A}$ —— $\frac{\Delta x_1}{k_1 A}$ —— $\frac{\Delta x_2}{k_2 A}$ —— $\frac{\Delta x_3}{k_3 A}$ —— $\frac{1}{h_2 A}$ —— T_2

Solution:

As we know that:

$$q = \frac{\Delta T}{R_1 + R_2 + R_3 + R_4 + R_5} \longrightarrow (i)$$

$$R_1 = \frac{1}{h_1 A} = \frac{1}{10(2.4)}$$

$A = 2(1.2)$
$= 2.4\ m^2$

$$R_1 = 0.04167\ °C/W$$

$$R_2 = R_4 = \frac{\Delta x}{k_2 A}$$

$$= \frac{3 \times 10^{-3}\ m}{(0.78\ W/m°C)(2.4)}$$

$$R_2 = R_4 = 0.001602\ °C/W$$

$$R_3 = \frac{\Delta x}{k_3 A} = \frac{12 \times 10^{-3}}{(0.026)(2.4)}$$

$$R_3 = 0.19231\ °C/W$$

$$R_5 = \frac{1}{h_2 A} = \frac{1}{25(2.4)}$$

$$0.0167\ °C/W$$

By putting values in eq (a)

$$q = \frac{(25-(-5))\ °C}{(0.04167 + 0.00[illegible] + [illegible])\ °C/W}$$

$$q = \frac{29.[illegible]\ °C}{0.2538\ °C/W}$$

$$\boxed{q = 116.24\ W}$$ Ans

Pb# 3.22 (House)

Given data;

Height of wall = 9'

Thickness = 1'

K = 0.40 Btu / h ft °F

Two walls of house = 40'

Other two walls = 30'

~~$T_1 = 70°F$~~

$T_2 = 55°F$

For day:

$T_1 = 55°F$ For 10 hours.

$T_2 = 45°F$.

For night:- Price = \$0.08/kWh

$T_1 = 55°F$ For 14 hours

$T_2 = 35°F$

Required data:

① Amount of heat lost from house that day.

② Cost of heat lost

Solution:-

For day:

Amount of heat lost is,

$$q = \frac{\Delta T K A}{\Delta x} \longrightarrow ①.$$

$A = 2 \times (30 \times 9 + 40 \times 9)\ ft^2$

$A = 1260\ ft^2 \longrightarrow ②$.

$\Delta T = 55 - 45 = 10°F$

$K = 0.40$ Btu/h ft °F. $\Delta x = 1'$

By putting values in q (1)

$$q = \frac{10°F\,(1260\,ft^2)\,(0.40\,Btu/h\,ft^2\,°F)}{1\,ft}$$

$q = 5040\ Btu/h$

For night:

$$q = \frac{\Delta T\, A\, k}{\Delta x}$$

$$= \frac{(55-35)(1260)(0.40)}{1}$$

$= 10080\ Btu/hr$

$Q = 10 \times q_{day} + 14 \times q_{night}$

$= 10\,hr\,(5040\ Btu/hr) + 14\,hr\,(10080)\,Btu/hr$

$= 50400 + 141120$

$\boxed{Q = 191520\ Btu}$

Consumption:

Annual loss = $191520 \times \$0.09/Btu$

$\boxed{Amount = 17236.8\ \$\ /\ day}$

Pb # 3-26

Given data;

Area = $1.7 m^2$

$T_1 = 37°C$

$K = 0.3 W/m°C$

$q = 150 W$

$\Delta x = 0.5 cm$

$T_2 = ?$

$T_1 \xrightarrow[\frac{\Delta x}{K \cdot A}]{} T_2$

Solution:-

As we know that;

$$q = \frac{\Delta T A K}{\Delta x}$$

$$\frac{q \Delta x}{A K} = \Delta T$$

By putting values $\Delta T = T_1 - T_2$

$$T_1 - T_2 = \frac{150 W (0.5 \times 10^{-2} m)}{1.7 m^2 (0.3 W/m°C)}$$

$$37°C - T_2 = \frac{0.75}{0.51}$$

$$T_2 = 37°C - 1.47°C$$

$$\boxed{T_2 = 35.52°C}$$ Ans

Pb # 3.34

Given data:

Size of house = 10m × 20m

Height of wall = 4m

All walls R-value = 2.31 m²·°C/W

Two 10m × 4m wall has no windows.

Third wall has four windows of glass

Thickness = 0.5cm.

$k = 0.78$ W/m·°C b/h = (1.2m × 1.8m)

Fourth wall has same no of windows but

double pan space i.e. air = 1.5cm.

$k = 0.026$ W/m·°C b/w glass layers

$T_1 = 22°C$ $h_i = 7$ W/m²·°C

$T_2 = 8°C$ $h_o = 10$ W/m²·°C

Req: Heat transfer through each wall

Solution:

Heat calculation:

- Walls without windows

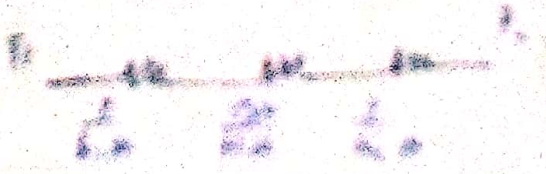
$$\dot{Q} = \frac{\Delta T}{R_1 + R_2 + R_3} \longrightarrow ①$$

$$R_1 = \frac{1}{h_i A} = \frac{1}{7(40m^2)}$$

$R_1 = 0.00357$ °C/W

$$R_2 = \frac{R}{A} = \frac{2.31}{40m^2}$$

$R_2 = 0.0578$ °C/W



Circuit diagram

$\dot{Q} = 2.R$

$$R_3 = \frac{1}{h_2 A} = \frac{1}{15(10\times 4)}$$

$$R_3 = 0.00167\ W$$

Putting all values.

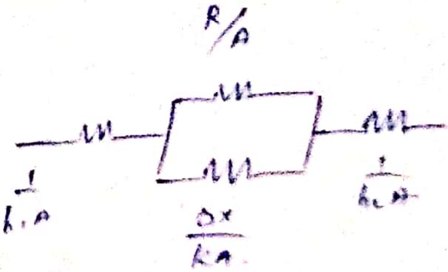
$$q = \frac{22-8}{0.00357 + 0.05775 + 0.00167}$$

$$\boxed{q = 222.2\ W}$$

Wall with Single Pane Window:-

Since heat transfer is;

Circuit diagram



$$q = \frac{\Delta T}{R_1 + R_{eq} + R_2} \longrightarrow (2)$$

$$\frac{1}{R_{eq}} = \frac{1}{R_{wall}} + \frac{1}{R_{glass}}$$

$$= \frac{1}{R/A} + \frac{1}{\frac{\Delta x}{kA}}$$

$$= \frac{1}{2.31/(10\times 4)} + (5)\frac{1}{\frac{0.5\times 10^{-2}}{(0.78)(1.8\times 1.2)}}$$

$$\frac{1}{R_{eq}} = 34.63 + 1684.8$$

$$1/R_{eq} = 1719.43$$

$$R_{eq} = 0.0005816\ °C/W$$

$$R_1 = \frac{1}{h_1 A} = \frac{1}{7(20\times4)}$$

$$R_1 = 0.001786\ °c/w$$

$$R_2 = \frac{1}{h_2 A} = \frac{1}{15(20\times4)}.$$

$$R_2 = 0.000833\ °c/w.$$

By putting values in eq ②.

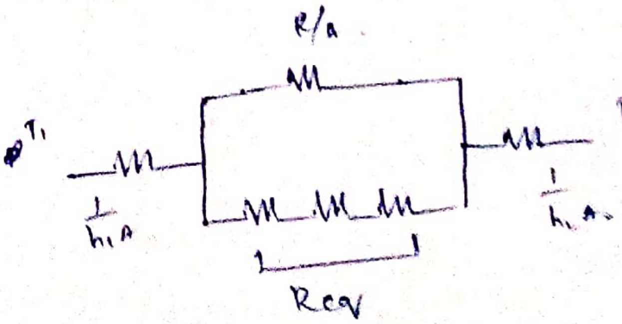
$$q = \frac{(22-8)\ °c}{(0.001786 + \underset{0.0005816}{[\text{struck out}]} + 0.000833)\ °c/w}$$

$$\boxed{q = 4373.8\ W}$$

(4) Wall with Double Pan Windows.

The heat transfer;

Circuit diagram.



$$q = \frac{\Delta T}{R_1 + R_{eq} + R_2} \longrightarrow ③.$$

$$\Delta T = 22 - 8$$
$$= 14\ °c.$$

$$R_1 = \frac{1}{h_1 A} = \frac{1}{7(20\times4)} = 0.001786\ °c/w.$$

$$R_2 = \frac{1}{h_2 A} = \frac{1}{15(20\times4)} = 0.000833\ °c/w.$$

$$1/R_{eq} = \frac{1}{R_{eq}'} + \frac{1}{R/A}$$

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$R_{eq}' = R_{glass} + R_{air} + R_{glass}$

$\therefore R_{eq}' = 2R_{glass} + R_{air}$

$$R_{eq}' = 2\frac{\Delta x}{KA} + \frac{\Delta x}{KA}$$

$$= \frac{2(0.005)}{0.78(1.2)(1.6)} + \frac{0.015}{(0.026)(1.2)(1.6)}$$

$$= 0.005935 + 0.267.$$

$R_{eq}' = 0.27303 \ °C/\omega$

$$\frac{1}{R_{eq}} = \frac{1}{R_{wall}} + 5\left(\frac{1}{R_{eq}'}\right)$$

$$= \frac{1}{R/A} + 5\left(\frac{1}{0.27303}\right)$$

$$= \frac{1}{2.31/(80.1)} + \frac{5}{0.27303}$$

$1/R_{eq} = 34.63 + 18.31$

$R_{eq} = 0.01889 \ °C/\omega$

By putting values in eq (2)

$$q = \frac{14}{0.001786 + 0.01889 + 0.000833}$$

$\boxed{q = 650.9 \, W}$

Amount Save;

Price of electricity = 0.08 $/kwh.

So the price save if single pan windows are replaced by double Pan;

$\Delta Q = 4373.8 - 650.9$

$\Delta Q = 3722.86\ W$.

∴ For Seven months;

$\Delta Q = 3722.86 \times 7 \times 30 \times 24\ W\,hr$.

$\Delta Q = 18763241.49\ W\,hr$.

$\Delta Q = 18763.241\ kWhr$.

Now money Saving is;

$= 18763.241\ \cancel{kwh} (0.08\ \$/\cancel{kwh})$

$\boxed{\text{Money Save} = 1501.1\ \$}$ Ans 2

Analysis;

Heat through wall, having no window.

$\boxed{q = 222.3\ W}$

Through wall with single Windows.

$\boxed{q = 4373.8\ W}$

Through wall with double Pan Window;

$\boxed{q = 650.9\ W}$

Prob 7-12 ([illegible])

Given data;

Height of wall = 12'

Length = 40'

Two wall has no window

other two has four windows of

Δx_{glass} = 0.25 in

k = 0.45 Btu/h ft °F

Size = 3' × 5'

R value of wall = 19 h ft² °F/Btu

h_i = 2 Btu/h ft² °F

h_o = 4 Btu/h ft² °F

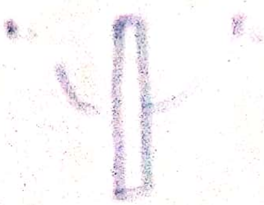
Required:

Rate of heat transfer through walls with & without window

Solution:

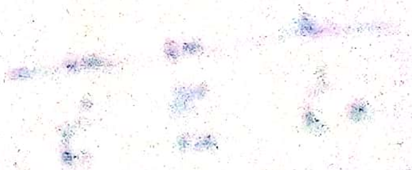
Heat transfer through wall without window

Since we know,



$$\dot{Q} = \frac{\Delta T}{R_i + R_w + R_o} \quad \text{---(1)}$$

Circuit diagram



ΔT = ΔT

$$R_i = \frac{1}{h_i A} = \frac{1}{2([illegible])}$$

R_i = 0.00[illegible] °F/Btu

$R_4 = \frac{1}{h_o A} = \frac{1}{4(40)(12)} = 0.000521\ h\,°F/Btu$

$R_3 = \frac{L}{kA} = \frac{19}{40 \times 12} = 0.03958\ h\,°F/Btu$

By putting values

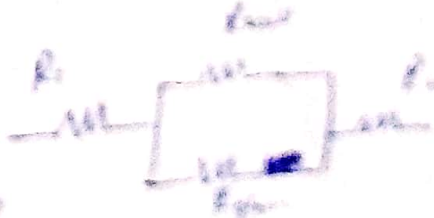
$$q = \frac{\Delta T}{0.00104 + 0.000521 + 0.03958}$$

$$\underline{q} = \frac{\Delta T}{0.04114\ h\,°F/Btu} \rightarrow ①$$

(2) Heat transfer with windows

As we know that,

Circuit diagram



$$q = \frac{\Delta T}{R_i + R_{eq} + R_o} \rightarrow ①$$

$R_i = \frac{1}{h_i A} = 0.00104\ h\,°F/Btu$

$R_o = \frac{1}{h_o A} = 0.000521\ h\,°F/Btu$

$$R_{eq} = \frac{1}{R_{wall}} + 4\left(\frac{1}{R_{window}}\right)$$

$$= \frac{1}{R/A} + 4\left(\frac{1}{\Delta x / kA}\right)$$

$$= \frac{1}{19/(40 \times 12)} + 4\left(\frac{1}{(0.125/12)/(0.45 \times 3 \times 4.5)}\right)$$

$$\frac{1}{R_{eq}} = 25.26 + 1296$$

$$R_{eq} = 0.000772 \ h°F/Btu$$

By putting values

$$q = \frac{\Delta T}{0.00104 + 0.000521 + 0.000772}$$

$$q_{with} = \frac{\Delta T}{0.002333} \longrightarrow (2)$$

Ratio of heat transfer through wall with & without window.

$$\frac{q_{with}}{q_{without}} = \frac{\Delta T / 0.002333 \ h°F/Btu}{\Delta T / 0.041141 \ h°F/Btu}$$

$$\boxed{\frac{q_{with}}{q_{without}} = 17.63}$$ Ans 2.

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Pb#3-29

Given data;

Thickness of roof $= \Delta x = 3cm$

$K = 2 W/m\,°C$.

Length $= 20m$.

Width $= 15m$

$h_1 = 5 W/m^2\,°C$.

$h_2 = 12 W/m^2\,°C$.

Not included as there is confusion in taking temperature, Also radiation heat transfer included.