and now for something completely different....

RADIATION HEAT XFER

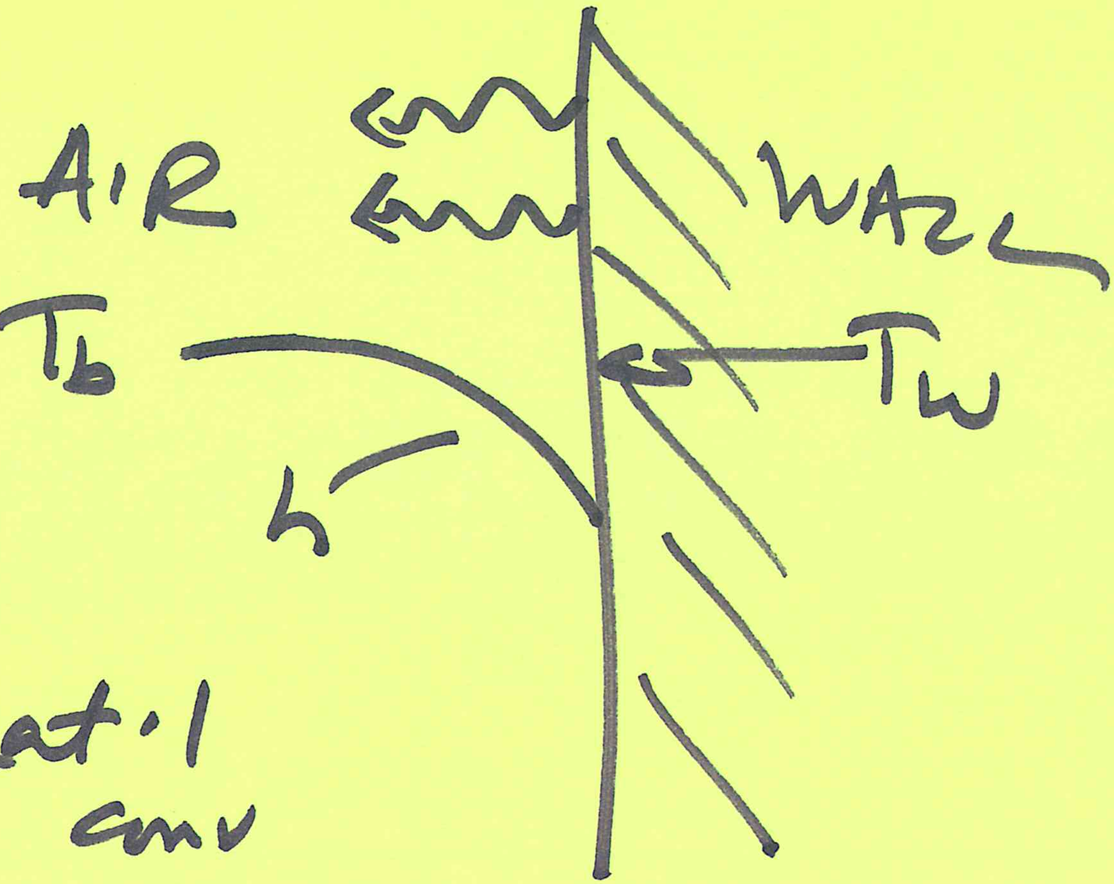
<u>conduction</u> convection

$$-k\frac{dT}{dx}=\frac{q_x}{A}$$

$$(\underline{V}\cdot\nabla T)$$

Brings in mot.

$$\mu\frac{dV_x}{dy}=\tau_{yx}$$



nat'l conv

forced conv

$$\frac{q}{A} = (h_{conv} + h_{radiation})(T_w - T_b)$$

Radiation (MODEL)

EMITTED → INCIDENT

(from hot bodies surfaces)

ABSORBED

REFLECTED

$\frac{q_{emitted}}{A} \underbrace{\propto}_{\text{"prop to"}} T^4$

$\alpha \equiv$ absorptivity

$\alpha = \frac{q_{absorbed}}{q_{incident}}$

is a function of T

grey body: α = const

blackbody: $\alpha = 1$ (all incident radiation is absorbed)

ε emissivity

$$\varepsilon = \frac{q_{emitted}}{q_{\substack{emitted \\ by\ blackbody}}}$$

How much is emitted by a black body?

$$\frac{q^{\text{black body}}}{A} = \sigma T^4$$

Stefan-Boltzman constant

$$\boxed{\begin{array}{c}\underline{\text{Kirchoff's Law}} \\ \alpha = \varepsilon\end{array}}$$

EVAPORATORS

(hot surface + gas)

Where do we get hradiation?

7a

(see slides)

Final $\frac{q}{A}$:

$$\frac{q_A}{A} = \varepsilon\sigma\left(T_s^4 - T_{body}^4\right)$$

$\underbrace{}$ net flux to body

Newton's Law of Cooling $\quad \frac{q_A}{A} = h_{rad}\left(T_s - T_{body}\right)$

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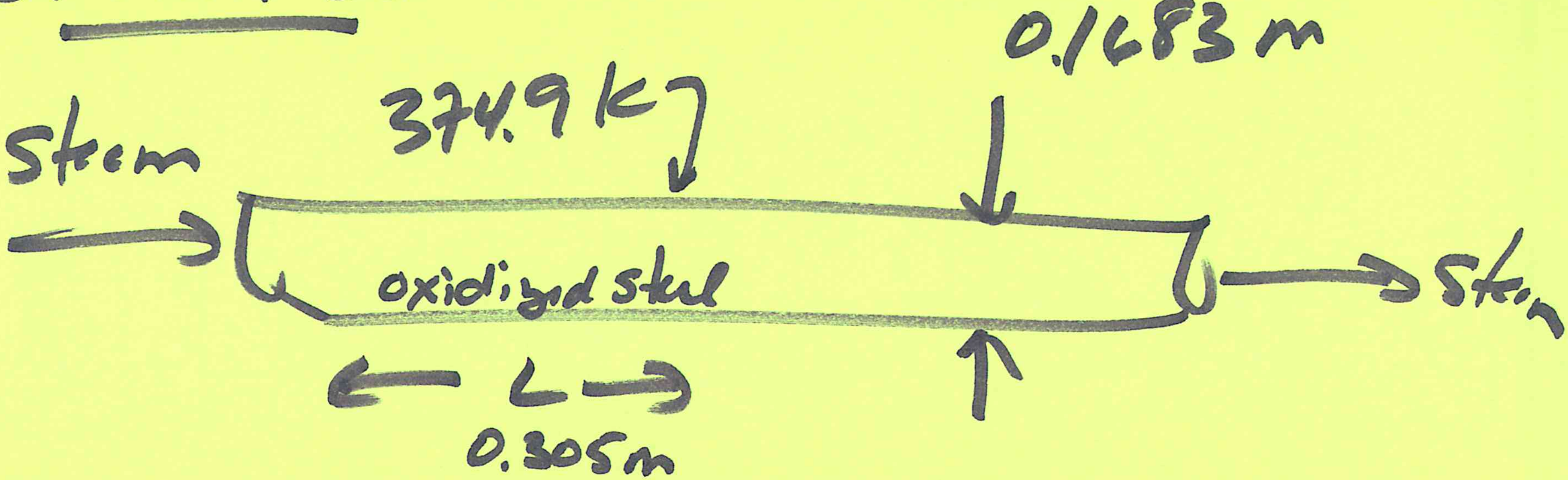
$$\frac{q}{A} = \underbrace{\left(\sigma \varepsilon \left(\frac{\left(T_s^4 - T_{body}^4\right)}{T_s - T_{body}}\right)\right)}_{\equiv h_{rad}} \left(T_s - T_{body}\right)$$

EXAMPLE



TODAY $h_{rad} + h_{nat\ conv.}$ 297.1 K = T_{bulk}

$$\frac{q_r}{A} = h\,(T_{wall} - T_{bulk})$$

YESTERDAY $h_{nat'l\ conv.}$ horizontal pipes

How to Block Radiation?

HEAT SHIELDS

PLATE 1

long

wide

T_1

PLATE 2

long

wide

T_2

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$$q_{1-2} = \varepsilon_1 \varepsilon_2 A \sigma T_1^4 \sum_{n=0}^{\infty} (1-\varepsilon_1)^n (1-\varepsilon_2)^n$$

$$(\text{Sum}) = \sum_{n=0}^{\infty} x^n = ?$$

$$(\text{sum}) = 1 + \cancel{x^1} + \cancel{x^2} + \cancel{x^3} + \ldots$$

$$x(\text{sum}) = \cancel{x} + \cancel{x^2} + \cancel{x^3} + \ldots$$

$$(\text{sum}) - x(\text{sum}) = 1$$

$$\boxed{\text{Sum} = \left(\frac{1}{1-x}\right)}$$

$$x = (1-\varepsilon_1)(1-\varepsilon_2)$$

$$q_{1\to 2} = \varepsilon_1 \varepsilon_2 A \sigma T_1^4 \left(\frac{1}{1-(1-\varepsilon_1)(1-\varepsilon_2)} \right)$$

$$\frac{\varepsilon_1 \varepsilon_2}{\cancel{1} - (\cancel{1} - \varepsilon_1 - \varepsilon_2 + \varepsilon_1 \varepsilon_2)}$$

$$= \frac{\cancel{\varepsilon_1 \varepsilon_2}}{\varepsilon_1 + \varepsilon_2 - \varepsilon_1 \varepsilon_2} \cdot \frac{\frac{1}{\cancel{\varepsilon_1 \varepsilon_2}}}{\frac{1}{\varepsilon_1 \varepsilon_2}}$$

$$= \left(\frac{1}{\frac{1}{\varepsilon_2} + \frac{1}{\varepsilon_1} - 1} \right)$$

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$$q_{1-2} = A\sigma T_1^4 \left(\frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \right)$$

$$q_{2-1} = A\sigma T_2^4 \left(\frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \right)$$

$$q_{net} = q_{1-2} - q_{2-1}$$

$$= \left(\frac{A\sigma (T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \right)$$