Introduction

Heat transfer is the science that seeks to predict the energy transfer that may take place between material bodies as a result of a temperature difference. The science of heat transfer seeks not merely to explain how heat energy may be transferred, but also to predict the rate at which the exchange will take place under certain specified conditions.

Modes of heat transfer

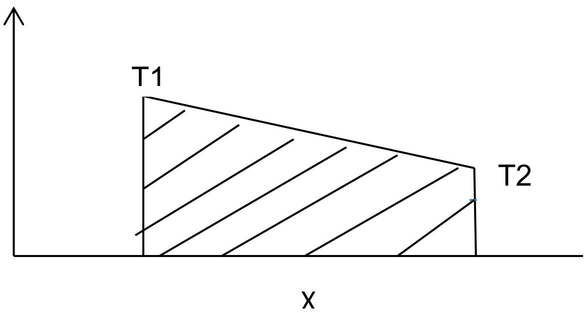
1- Conduction.

2- Convection.

3- Radiation.

Conduction heat transfer

When a temperature gradient exists in a body, there is an energy transfer from the high-temperature region to the low-temperature region.



We say that the energy is transferred by conduction and that the heat transfer rate per unit area is proportional to the normal temperature gradient:

$$\frac{q}{A} \propto \frac{\partial T}{\partial x}$$

When the proportionality constant is inserted:

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

Where:

q is the heat-transfer rate (W) or (J/Sec)

∂T/∂x is the temperature gradient in the direction of the heat flow.
k is called the thermal conductivity of the material (W/m.C°)

A is the surface area (m^2) ,
x is the thickness (m)
In one dimensional steady state system, we need only to integrate the equation ad substitute the appropriate values to solve:

$$q = -\frac{KA}{\Delta X}(T_2 - T_1)$$

Example: A temperature difference of 85◦ C is impressed across a fiberglass layer of 13 cm thickness. The thermal conductivity (K) of the fiberglass is 0.035 W/m · ◦C. Compute the heat transferred rate through the fiberglass material per unit area.
Solution

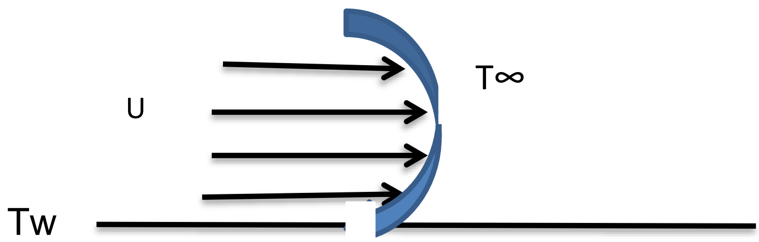
$$\frac{q}{A} = -K\frac{\Delta T}{\Delta X}$$

ΔT= - 85 C° , K= 0.035 W/m.C° , Δx = 0.13 m

$$\frac{q}{A} = -0.035\ \frac{-85}{0.13} = 22.88\ W/m^2$$

Convection heat transfer

It is well known that a hot plate of metal will cool faster when placed in front of a fan than when exposed to still air. We call the process convection heat transfer



Convection heat transfer

Natural convection — Forced convection

Newton's law used to express the overall effects of convection.

$q = h\,A(T_w - T_\infty)$

Where:

q = is the heat transfer rate (w)

A = is the surface area (m^2)

Tw = wall temperature

T_∞ = fluid temperature

h = heat transfer coefficient ($W/m^2.C°$)

Example: Air at 20◦C blows over a hot plate 50 by 75 cm maintained at 250◦C. The convection heat-transfer coefficient is 25 W/m^2.◦C. Calculate the heat transfer.

Solution:

h= 25 W/m^2.◦C , Tw = 250 ◦C , T_∞= 20.◦C

A = 0.5*0.75 = 0.375 m^2

$q = h\,A\,(T_w - T_\infty) \longrightarrow$
25* 0.375(250-20) = 2156 W

Radiation heat transfer

Heat may also be transferred through regions where a perfect vacuum exists. The mechanism in this case is electromagnetic radiation. Thermodynamic considerations show∗ that an ideal thermal radiator, or blackbody, will emitted energy at a rate proportional to the fourth power of the absolute temperature of the body and directly proportional to its surface area. Thus

$q = \sigma A T^4$

Where σ is the proportionality constant and called the Stefan-Boltzmann constant with the value of $5.669 \times 10^{-8}\ W/m^2 \cdot K^4$

But the radiation exchange between two surfaces will be

$q = \varepsilon\,\sigma\,A\,(T_1^{\,4} - T_2^{\,4})$

ε is called emissivity , also ε for black body is 1.

Example: Two perfectly black surfaces are constructed so that all the radiant energy leaving a surface at 800° C reaches the other surface. The temperature of the other surface is maintained at 250° C. Calculate the heat transfer between the surfaces per unit area.

Solution:

T1= 800+ 273= 1073 K

T2= 250+ 273= 523 k

ε = 1 (black body)

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

$q/A = 1 * 5.669 \times 10^{-8} \{ (1073^4) - (523^4) \} = 70.9 \text{ kw/m}^2$

Note: Temperature conversions are performed with the familiar formulas:

°F=1.8 °C +32

°R= °F +459.69

K= °C+273.16

°R= 1.8 K