INTRODUCTION TO HEAT TRANSFER

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THE ENERGY

- Energy can exit in different types (forms). They are thermal, chemical, mechanical, kinetic, potential, electrical, magnetic, nuclear and etc. There sum is being the total energy E (e, per unit mass). The microscopic energy is defined as the energy related to the molecular structure of a system and the molecular activity degree. The sum of all the microscopic forms of energy is defined as system internal energy. It is defined as U (or u per unit mass)

SPECIFIC HEAT

- **Specific heat** is defined as the energy needed to raise the temperature of a unit mass of a substance by one degree. For gases there are two famous specific heats. They are:- specific heat at constant volume (Cv) and specific heat at constant pressure (Cp). There is a relation between Cp and Cv that is:
- $Cp = Cv + R$

SPECIFIC HEAT

- In general liquids and solids are considered incompressible material. They have only one specific heat denoted by C or Cp so the change in internal energy and enthalpy of liquids and solids can be expressed as:
- $Q = mC(T_2 - T_1)$

ENERGY TRANSFER

- There are two mechanisms for energy to transfer from or to a given system. They are heat and work
- The work is studded in thermodynamics science.
- Heat transfer is denoted as $\dot{Q}$ with units J/s or W. It is represents heat transfer rate
- To calculate total heat transfer
- $Q = \int_{\tau 1}^{\tau 2} \dot{Q} d\tau$ or $Q = \int_{0}^{\tau} \dot{Q} d\tau$

MODES OF HEAT TRANSFER

- There are three different ways by which heat is transferred. They are **CONDUCTION**, **CONVECTION**, and **RADIATION**
- Conduction
- The rate of heat transfer by conduction through a medium depends on the geometry of the medium, its thickness and the material of the medium, as well as the temperature difference across the medium.
- The heat conduction rate through a plane layer is directly proportional to the temperature difference across the layer and the heat transfer area, but is inversely proportional to the thickness of the layer.

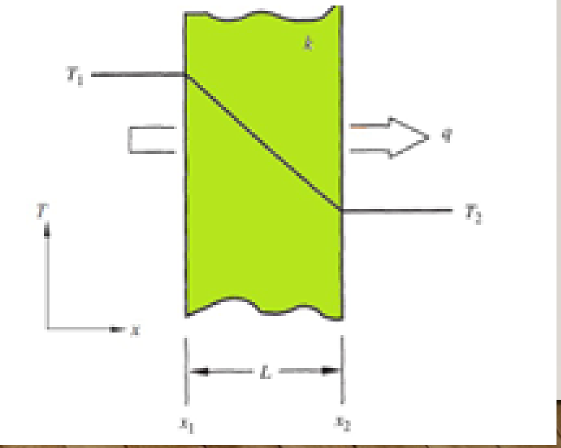
CONDUCTION

- *heat conduction*

$$\propto \left(\frac{(Area)(temperature\ differance)}{Thickness}\right)$$

$$\dot{Q}_{cond} = KA\frac{T_1 - T_2}{x_1 - x_2} = -KA\frac{T_2 - T_1}{\Delta x}$$

$$\dot{Q}_{cond} = -KA\frac{\Delta T}{\Delta x}$$



CONDUCTION

- This equation is heat conduction law. It is called Fourier's law after J. Fourier, who expressed it in his heat transfer text firstly in 1822.
- where K is the proportionality constant is called the thermal conductivity of the material

THERMAL CONDUCTIVITY

- Thermal conductivity of a material is defined as the rate of heat flow through a unity thickness of a material per unit area per temperature difference unit.
- The thermal conductivity of a material is a measure of how heat will fastly flow in that material.
- It is a property of material

THERMAL CONDUCTIVITY

Table 1.1 SOME MATERIALS THERMAL CONDUCTIVITY AT 25°C

Material	k, W/m.°C	Material	k, W/m.°C
Aluminum	237	Iron	80.2
Brick	0.78	Mercury(L)	8.54
Copper	401	Refrigerant-12	0.026
Diamond	2300	Rigid foam	0.72
Gold	317	Silver	429
Glass	0.78	Soft rubber	0.13
Glass fiber	0.043	Water(L)	0.613
Helium(g)	0.152	Wood(oak)	0.17
Human Skin	0.37	Air(g)	0.026

EXAMPLE ON CONDUCTION

- **Example 1**. The electrically heated roof of a home is (6m) long, (8m) wide and (0.25m) thick. It is made of a concrete flat layer with thermal conductivity of (0.8W/$m.^oC$). On a certain cold night, the temperature of outer and inner surface of the roof are measured to be about (4^oC) and (15^oC) respectively. For a 10 hours period, determine (a) the heat rate that lost through the roof and (b) the heat loss to the home of electricity cost if electricity cost is 120ID/kWh.

EXAMPLE 1

- Solution: flat concrete roof $T_1 = 15^o$ C, $T_2 = 4^o$ C.
- Assumption : (1) steady state condition during entire night (2) properties are constant Property: The material thermal conductivity is k=0.8W/m.$^o\ C$.
- Analysis: (a) the heat transfer through the roof is by conduction. The area of the roof
- A=6m x8m =48m^2
- and thickness Δx=0.25m.

EXAMPLE 1

$$\dot{Q}_{cond} = -kA\frac{T_2 - T_1}{\Delta x} = -\left(0.8W/m.^oC\right)\left(48m^2\right)\frac{\left(4-15\right)^o C}{0.25m} = 1689.6W$$

(b) the heat lost amount through the roof during 10h period

$$Q = \dot{Q}\Delta\tau = 1.69\left(10hr\right) = 16.9kW.hr$$

and its cost are determined from the following

Cost=(amount of energy)(unit cost of energy)

=(16.9kWh)(ID120/kWh)=2028 ID

CONVECTION

- Convection is the mode by which energy transfer between a solid surface and the adjacent liquid or gas that is in motion and it involves the combined effects of fluid motion and conduction.
- Convection is of two types. They are free and forced convection. Forced convection is occurred when the fluid is flow under force over the surface by external mechanisms such as fan, pump, or the wind. Natural (or free) convection is occurred when the fluid motion is caused by forces of buoyancy that are induced due to differences of density by the temperature variation of the fluid.

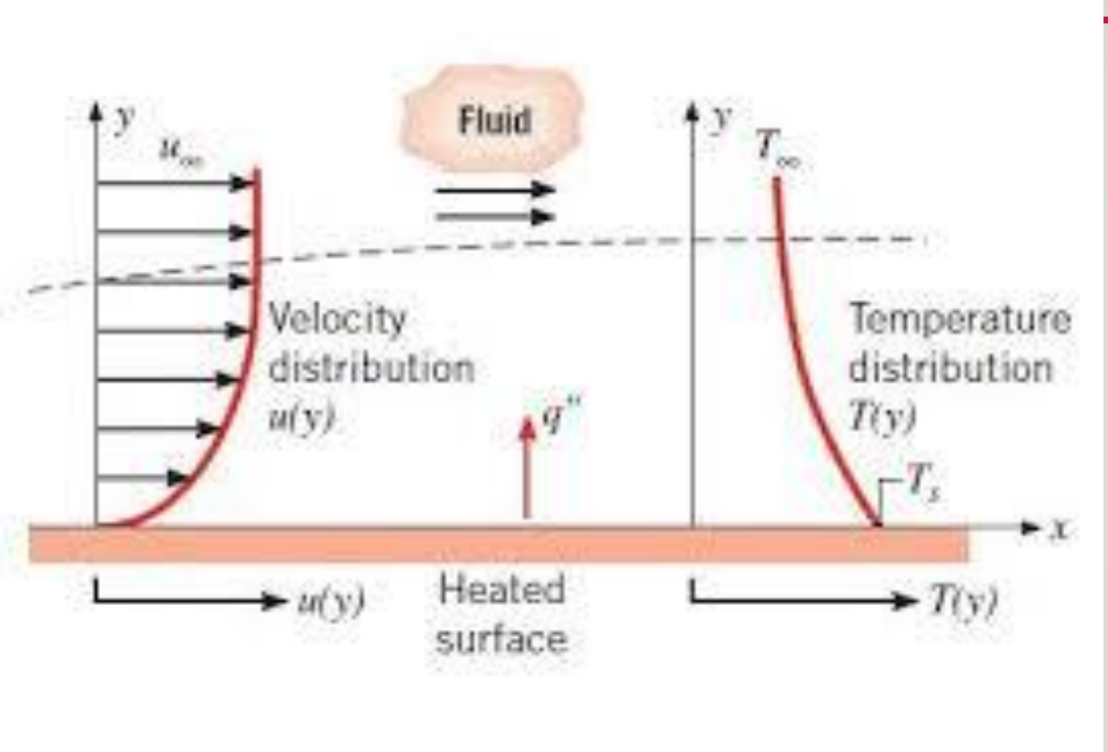
CONVECTION

- Heat transfer by convection is calculated by using Newton law of cooling
- $\dot{Q}_{conv} = hA(T_s - T_\infty)$
- Where h is convection heat transfer Coefficient. $W/m^2\,{}^oC$

A is the area of the surface through which convection of heat transfer take place.

T_s,T_∞ are the surface temperature and the fluid temperature that far from the surface with sufficient distance

CONVECTION



Fluid
y
u_∞
Velocity
distribution
$u(y)$
q''
y
T_∞
Temperature
distribution
$T(y)$
T_s
x
$u(y)$
Heated
surface
$T(y)$

CONVECTION

Typical Coefficient Of Convection Heat Transfer Values

Type of Convection	h[W/m^2.K
Gases Free Convection	2-25
Liquids Free Convection	10-1000
Gases Forced Convection	25-250
Liquids Forced Convection	50-20000
Condensation and Boiling	2500-100000

CONVECTION

- **Example**
- **Determine the convection heat transfer from a surface with area of ($2m^2$) and the temperature of (100^oC) to the air of temperature (25^oC), if the coefficient of heat transfer by convection is ($20W/m^2.K$).**

CONVECTION

- **Solution**: determination of heat transfer by convection between hot surface and air.
- Surface area: $A=2m^2$, surface Temp $T_s=100°C$, air Temp. $T_\infty=25°C$.
- **Assumption**: (1) steady state heat transfer with convection only
- **Property:** The heat transfer coefficient $h=20W/m^2.K$
- **Analysis**: by using the Newton's law of cooling

CONVECTION

$$\dot{Q}_{conv} = hA(T_s - T_\infty)$$

$$\dot{Q}_{conv} = 20 \times 2(100 - 25) = 3000W$$

RADIATION

- **Radiation** is the energy that emitted by a matter in the form of electromagnetic waves (photons) as a result of the change in the electronic configuration of the atoms or molecules. Not same as that in conduction and convection, the energy transfer by radiation does not require the existence of medium. In fact, energy transfer by radiation is more fast (its speed is the light speed) and it doesn't effect by a vacuum. This is exactly how the energy transfers from the sun to reach the earth.

RADIATION

- The mechanism rate of radiation that emitted from a surface at an absolute temperature (in K) is given by the Stefan-Boltzmann Law as
- $$\dot{Q}_{rad} = A\epsilon\sigma(T_{s1}^4 - T_{s2}^4)$$
- Where temperatures are in K
- A: the heat transfer area
- σ =5.67x$10^{-8} W/m^2K^4$ Stefan-Boltzmann constant
- ε; emissivity of surface

RADIATION

- Radiation Heat Transfer Coefficient Radiation Heat Transfer Coefficient
- $\dot{Q}_{rad} = A\varepsilon\sigma(T_1^4 - T_2^4) = A\varepsilon\sigma(T_1^2 + T_2^2)(T_1 + T_2)(T_1$

RADIATION

- Example: A plate at temperature of (127C) with area of (1.2m^2) and emissivity of (0.92) exchange heat by radiation with a wall of a room at (27C). Find the heat transfer coefficient of radiation between the plate and the wall, and the rate of heat transfer by radiation.
- Solution: there is heat transfer by radiation between a plate and a wall of a room containing the plate. Plate Temp. T_1=127^oC=400K, wall Temp. T_2=27^oC=300K, A=$1.2m^2$, ε=0.92. and we know that σ=5.67x$10^{-8}W/m^2k^4$.

RADIATION

- to calculate the heat transfer coefficient of radiation,
- $h_r = \varepsilon\sigma(T_1^2 + T_2^2)(T_1 + T_2)$
- $h_r = 0.92 \times 5.67 \times 10^{-8}\left((400)^2 + (300)^2\right)(400 + 300)$
  $= 9.1287W/m^2K$
- $\dot{Q}_{rad} = Ah_r(T_1 - T_2) = 1.2m^2(9.13W/m^2K)(400$