TOPIC:HEAT TRANSFER

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All the content material provided here is only for teaching purpose

Heat

Heat is a form of energy.

Heat travels from higher temperature(hotter) region to lower temperature(cooler) region.

Heat Transfer

Heat transfer is the **movement of heat energy** from **one substance** to **another**.

Heat **always travels** from a region of **higher temperature** to a region of **lower temperature.**

Mechanisms of heat transfer

Heat transfer from one place to another takes place by three different mechanisms and all three may occur simultaneously.

Heat Transfer Methods

1. **Conduction**
2. **Convection**
3. **Radiation**

- **Convection** is the transfer of thermal energy by the actual motion of the medium itself. The medium in motion is usually a gas or a liquid. Convection is the most important heat transfer process for liquids and gases.
- **Conduction** is the transfer of thermal energy by molecular action, without any motion of the medium. Conduction can occur in solids, liquids, and gases, but it is usually most important in solids.
- **Radiation** is a transfer of thermal energy by electromagnetic waves.

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Conduction

Conduction is the **process** by which heat is **transmitted** through **a medium** from **one particle to another.**

Heat transfer by conduction is the transfer of heat through **direct contact**.

Convection

- Convection is the **process** by which **heat** is **transmitted** from one place to another by

Conduction

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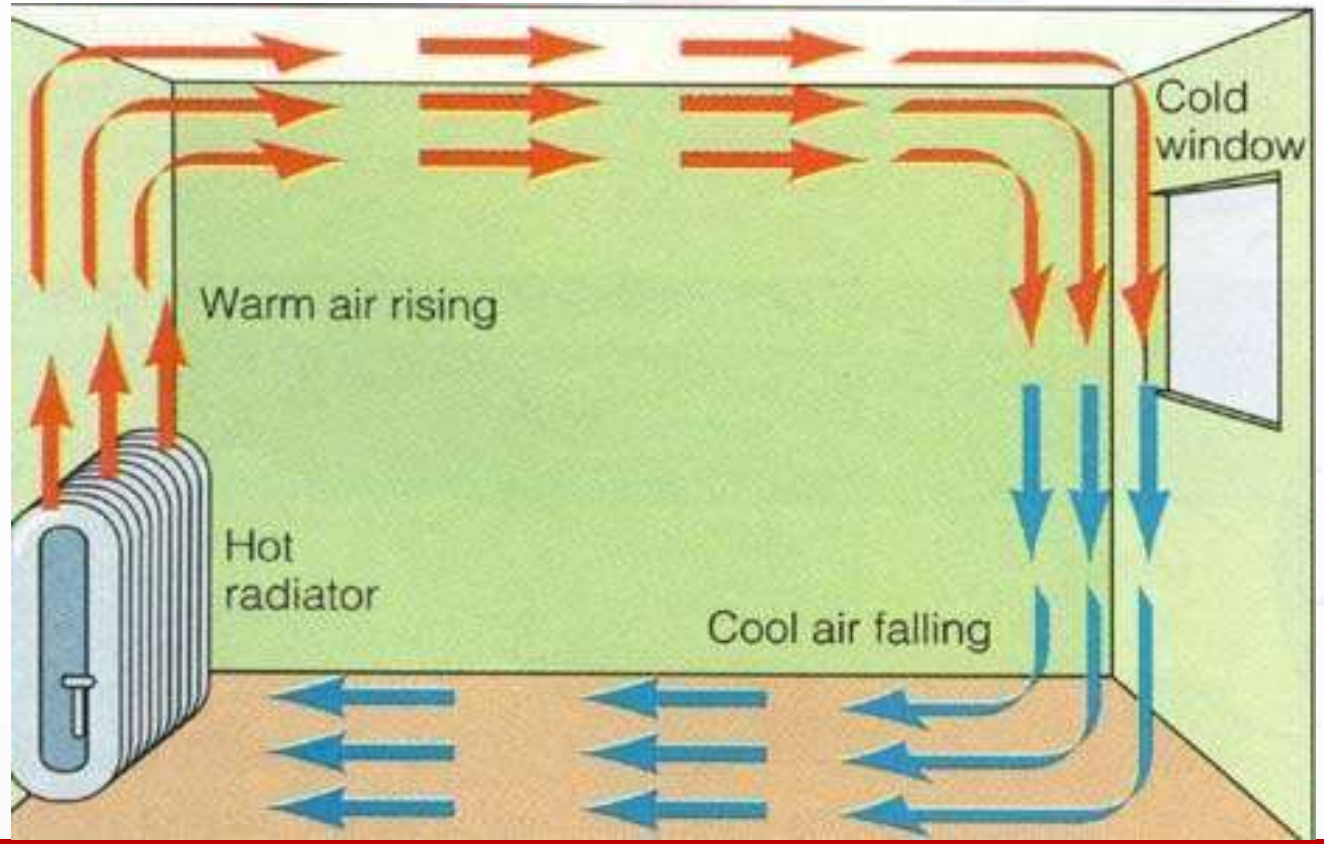
Heat transfer by conduction is the transfer of heat through **direct contact**.

Convection

- Convection is the **process** by which **heat** is **transmitted** from one place to another by the **movement of heated particles** of a **gas or liquid.**
- **Occurs** primarily in **liquids and gases**(fluids)

Convection

Warm fluids rise, cool down, sink, and then are warmed again.



Radiation

- Heat is transferred by **electromagnetic waves**
- There is **no direct contact** between the substances.
- Radiation is a **method** of **heat transfer** that does **not require** any **medium**
- It can take place in a vacuum.

Application of Radiation

White paint for houses

- **In hot countries, houses are painted in white to reduce absorption of heat energy from the Sun**

Tea pot :-

- Has **smooth, shiny** and **silvery surface.**
- Smooth, shiny and silvery surface is a **bad radiator of heat.**
- This **reduces** rate of **heat loss.** Tea or coffee can be **kept warm** in the teapot.

Heat transfer applications

1. **Evaporation:** heat is supplied in order to convert a liquid into a vapor.
2. **Distillation:** heat is supplied to the liquid mixture for separation of individual vapor component.
3. **Drying:** for drying the wet granules.
4. **Crystallization:** saturated solution is heated to bring out super saturation, which promotes crystallization of drugs.
5. **Sterilization:** Autoclaves are used with stream as a heating medium.
6. Heat transfer is required for refrigeration.

Fourier's law: Fourier's law can be applied to a metal wall trough which the conduction of heat is taking place. The characteristics are as follows.

Fourier's law states that the negative gradient of temperature and the time rate of heat transfer is proportional to the area at right angles of that gradient through which the heat flows. Fourier's law is the other name of the law of heat conduction.

$Areaofwall = A, m^2$

Thickness of the wall=L, m

Face of the wall is maintained at a uniform, Definite and higher

temperature=t1, K

Face of the wall is maintained at a lower, But uniform temperature=t2, K

The heat flow will be at right angles to the plane A and is assumed to be in a steady state. Consider a thin section.

An empirical relationship between the conduction rate in a material and the temperature gradient in the direction of energy flow, first formulated by Fourier in 1822.who concluded that "the heat flux resulting from thermal conduction is proportional to the magnitude of the temperature gradient and opposite to it in sign". For a unidirectional conduction process this observation may be expressed as:

$$q_x = -\lambda \frac{dT}{dx}$$

.where the vector is the heat flux (W/m^2) in the positive x-direction, dT/dx is the (negative) temperature gradient (K/m) in the direction of heat flow (i.e., conduction occurs in the direction of decreasing temperature and the minus sign confirms this thermodynamic axiom) and the proportionality constant λ is the **Thermal Conductivity** of the material (W/mK).

Fourier's Law thus provides the definition of thermal conductivity and forms the basis of many methods of determining its value. Fourier's Law, as the basic rate equation of the conduction process, when combined with the principle of conservation of energy, also forms the basis for the analysis of most **Conduction** problems.

EQUEIPMENT

HEAT EXCHANGERS AND HEAT INTERCHANGERS

Most of the chemical and pharmaceutical industries employ a variety of heat transfer equipment. The materials to be heated may be liquids or gases and occasionally solids (which is a separate case by itself). The heating media is a hot fluid or condensed steam. Some of the processes, which involve the heat transfer encountered in pharmacy, are:

- Preparation of starch paste (Seam jacketed kettles) for granulation
- Crystallization
- Evaporation
- Distillation

In industrial processes, heat energy is transferred by various methods. The principles, construction and working of equipment used for the transfer of heat energy are as follows:

Heat exchangers: *Heat exchangers* are the devices used for transferring heat from one fluid (hot gas or steam) to another fluid (liquid) through a metal wall.

Heat interchangers: *Heat interchangers*are the devices used for transferring heat from one liquid to another or from

one gas to another gas through a metal wall.

The classification given above is vague and may time used interchangeably. Therefore, it is appropriate to call them as heat

transfer equipment.

Some of them are discussed in the following sections.

14.2 Heaters or Heat Exchangers

Heat exchangers are the devices used for transferring heat from one fluid (hot gas or steam) to another fluid (liquid) through a metal wall.

In heat exchangers, the film coefficients on the steam side are usually much larger than the film coefficients on the cold liquid side. Therefore, the overall heat transfer coefficients will be nearer to the cold liquid side (because it is smaller of the two coefficients). Hence, heat transfer becomes less. The efficiency can be improved by passing the liquid at a high velocity. As a result, the thickness and resistance of the liquid film decrease. Normally, the space outside the tubes is large, but steam velocity is low. Still heat exchangers are useful, because of the high values of the steam film coefficients.

Tubular heater (Shell-and-tube heater):

Shell-and-tube heater is the simplest form of a tubular heater. It is a single-pass tubular heater.

Construction: *The* construction of a simple tubular heater is shown in Figure 5-11. Tubular heater consists of a bundle of parallel tubes, which are relatively thin walled. The ends of these tubes are expanded into two tube sheets, B1and B2. The bundle of tubes is enclosed in a cylindrical shell or casting, C, to which the tube-sheets are fitted. Many heaters have a cast iron shell.

Tubular heaters or heat exchangers

- It is the simplest form of heater. It is single pass tubular heater.
- **Working:**

1. Steam is introduced and it flows down the tubes
2. In this process tubes get heated, the condensate vapor drained.
3. Non condensate gases escape through vent
4. The fluid to be heated is pumped into the left distribution chamber
5. The fluid flows through the tube and steam and fluid are separated physically.
6. The total heat transfer is affected by the single pass of the fluid
7. Thus the fluid reaches the right distribution chamber and leaves through the exit point.

Advantages:

- Large heating surface can be packed into volume.

Disadvantages:

1. Velocity of fluid is low because of large cross section area.
2. Due to high temperature loosening and leakage take place.

1. **Cutting (Slicing): -**

- The material is cut into pieces.
- It may be effected by a sharp pen knife, a pair of scissors, or a root cutter.
- Equipment: - Cutter mill

2. **Compression (Bruising): -**

- Material is crushed by application of a pressure.
- Particle disintegration by two rigid forces.
- Equipment: - Mortar and Pestle (Laboratory) and Roller mill (Industry)

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Impact: -

- The material is stationary and is hit by an object moving at high speed or Moving particles strikes a stationary surface.
- Size reduction occurs by a single rigid force.
- Equipment: - Mortar and Pestle (Laboratory) and Hammer mill & Disintegrator (Industry)

4. Attrition: -

- Arising from particles scraping against one another or against a rigid surface.
- Here, the material is subjected to pressure as in compression, but the surfaces are moving relative to each other.
- Equipment: - Roller mill

5. **Impact and Attrition: -**

- Here, both impact and attrition are combined.
- Equipment: - Ball mill and Fluid energy mill

ENERGY LAWS

- **Rittinger's Law: -**
- *"Energy required (consumed) is proportional to the fresh surface produced (sheared)".*

if p=-2

$$E = C\left(\frac{1}{L_2} - \frac{1}{L_1}\right)$$

$C = K_R f_c$, fc is the crushing strength of the material

energy required for size reduction is directly proportional to the increase in surface

More applicable to fine powders

- **Kick's Law: -**
- *"Energy necessary for crushing material is proportional to the logarithm of the ratio between initial and final diameters".*

if p=- 1

$$E = C \ln \frac{L_1}{L_2}$$

$C = K_k f_c$, fc is the crushing strength of the material

$$E = K_K f_c \ln \frac{L_1}{L_2}$$

energy required to crush a given amount of material from 50 mm to 25mm in size is same as that required to reduce 12 mm to 6mm

- **Bond's Law: -** (Intermediate between Rittinger's & Kick's law)
- *"The useful work is directly proportional to the new surface area, & since the crack length is proportional to the square root of the new surface area produced, the useful energy or work in inversely proportional to the square root of the product diameter minus the feed diameter".*

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