UNIT – 1

Heat Transfer:

Objectives:

1. **Temperature Equalization:**
    - Transfer heat from regions of higher temperature to lower temperature until thermal equilibrium is reached.
2. **Energy Conservation:**
    - Efficiently transport and distribute thermal energy for various applications.
3. **Control of Processes:**
    - Maintain specific temperature conditions for industrial processes, heating, and cooling.

Applications:

1. **Thermal Comfort:**
    - HVAC systems for maintaining comfortable indoor temperatures.
2. **Industrial Processes:**
    - Heat transfer in chemical reactions, manufacturing, and material processing.
3. **Power Generation:**
    - Cooling systems in power plants, heat exchange in turbines.
4. **Electronics Cooling:**
    - Heat dissipation in electronic devices to prevent overheating.
5. **Transportation:**
    - Radiators in vehicles, cooling systems in airplanes.

Heat Transfer Mechanisms:

1. **Conduction:**
    - Transfer of heat through a material without the material itself moving.
    - Occurs in solids and stagnant fluids.
    - Governing law: Fourier's Law.
2. **Convection:**
    - Transfer of heat through a fluid (liquid or gas) involving the actual movement of the fluid.
    - Can be natural (due to density differences) or forced (induced by external means).

3. **Radiation:**
    - Transfer of heat through electromagnetic waves.
    - Doesn't require a medium and can occur in a vacuum.

Fourier's Law:

- **Description:**
    - Governs heat conduction.
    - Mathematically expressed as �=−��Δ��$Q=-kAd\Delta T$, where:
        - �Q is the heat transferred,
        - �k is the thermal conductivity of the material,
        - �A is the cross-sectional area,
        - Δ�ΔT is the temperature difference,
        - �d is the thickness of the material.

Heat Transfer by Conduction:

- **Process:**
    - Heat flows through a material from higher to lower temperature regions.
- **Factors Influencing Conduction:**
    - Thermal conductivity of the material.
    - Cross-sectional area.
    - Temperature gradient.

Heat Transfer by Convection:

- **Natural Convection:**
    - Heat transfer due to density differences in a fluid.
    - Hot fluid rises, and cold fluid descends, creating a circulation pattern.
- **Forced Convection:**
    - External force (fan, pump) induces fluid motion, enhancing heat transfer.

Heat Transfer by Radiation:

- **Mechanism:**
    - Heat transfer through electromagnetic waves.
    - Doesn't require a medium.
- **Factors Affecting Radiation:**

- Emissivity of surfaces.
- Temperature difference.
- Surface area and orientation.

Heat Exchangers:

- **Purpose:**
  - Transfer heat between two or more fluids.
  - Commonly used in industrial processes, HVAC systems, and power plants.

Types of Heat Exchangers:

1. **Shell and Tube Heat Exchanger:**
   - Consists of a shell with multiple tubes.
   - Fluids flow through the shell and tubes, facilitating heat exchange.
2. **Plate Heat Exchanger:**
   - Uses a series of plates to separate hot and cold fluids.
   - Efficient and compact design.
3. **Double Pipe Heat Exchanger:**
   - Simplest design with one pipe inside another.
   - Suitable for small-scale applications.
4. **Finned Tube Heat Exchanger:**
   - Enhances heat transfer by adding fins to the tube surface.
   - Increases surface area for better efficiency.

Heat Interchangers:

- **Definition:**
  - Devices designed to transfer heat between two or more fluids without mixing them.
- **Applications:**
  - Used in various industrial processes and systems to optimize heat transfer.

Summary:

Heat transfer is essential for temperature equalization, energy conservation, and control of processes. Conduction, convection, and radiation are the primary mechanisms governing heat transfer. Fourier's Law describes heat conduction, considering factors like thermal conductivity, area, temperature gradient, and material thickness. Heat exchangers, such as shell and tube, plate, double pipe, and finned tube heat exchangers, facilitate efficient heat transfer between fluids. Heat interchangers optimize heat transfer without fluid mixing, finding applications in industrial processes and systems.

Evaporation:

Objectives:

1. **Concentration:**
    - Increase the concentration of a solute in a liquid by removing the solvent.
2. **Separation:**
    - Separate a volatile component from a non-volatile component.
3. **Product Recovery:**
    - Recover valuable products from solutions or suspensions.

Applications:

1. **Food and Beverage Industry:**
    - Concentration of fruit juices, milk, and other liquid products.
2. **Chemical Industry:**
    - Separation of chemicals, recovery of solvents, and concentration of solutions.
3. **Water Treatment:**
    - Desalination and concentration of brine.
4. **Pharmaceutical Industry:**
    - Concentration of drug solutions and recovery of pharmaceutical products.

Factors Influencing Evaporation:

1. **Temperature:**
    - Higher temperatures increase the rate of evaporation.
2. **Surface Area:**
    - Larger surface area facilitates faster evaporation.
3. **Humidity:**
    - Lower humidity enhances evaporation.
4. **Airflow:**
    - Air movement aids in carrying away vapor, promoting evaporation.

Differences Between Evaporation and Other Heat Processes:

1. **Evaporation vs. Boiling:**

- Evaporation occurs at the liquid's surface, while boiling occurs throughout the liquid.

2. **Evaporation vs. Condensation:**
   - Evaporation involves the conversion of liquid to vapor, while condensation is the reverse process.
3. **Evaporation vs. Sublimation:**
   - Evaporation involves the conversion of a liquid to a gas, while sublimation is the direct transition from a solid to a gas.

Evaporator Types:

1. **Steam Jacketed Kettle:**

- **Principle:** Heating the liquid using steam in a jacket surrounding the kettle.
- **Applications:** Cooking, processing of food, pharmaceuticals, and chemicals.

2. **Horizontal Tube Evaporator:**

- **Principle:** Liquid flows through horizontal tubes, and steam passes through the shell.
- **Applications:** Concentration of juices, milk, and chemicals.

3. **Climbing Film Evaporator:**

- **Principle:** Liquid forms a thin film on vertical tubes, and evaporation occurs as the film climbs.
- **Applications:** Concentration of heat-sensitive liquids.

4. **Forced Circulation Evaporator:**

- **Principle:** Pump circulates liquid through the heat exchanger.
- **Applications:** Concentration of viscous liquids, waste treatment.

5. **Multiple Effect Evaporator:**

- **Principle:** Uses multiple evaporator units with decreasing pressure.
- **Applications:** Efficient concentration of solutions, reducing energy consumption.

6. **Economy of Multiple Effect Evaporator:**

- **Principle:** Recycles vapor from one effect to another to save energy.
- **Applications:** Large-scale concentration of solutions.

Distillation:

Basic Principles:

- **Distillation:** Separation of components in a liquid mixture based on differences in their boiling points.

Methodology of Different Distillation Processes:

1. **Simple Distillation:**
    - **Principle:** Separation based on differences in boiling points.
    - **Applications:** Purification of liquids, separation of components.
2. **Flash Distillation:**
    - **Principle:** Rapid vaporization of a liquid at reduced pressure.
    - **Applications:** Used in the petrochemical industry for separation.
3. **Fractional Distillation:**
    - **Principle:** Repeated vaporization and condensation for better separation.
    - **Applications:** Separation of components in complex mixtures.
4. **Distillation Under Reduced Pressure:**
    - **Principle:** Reducing pressure lowers the boiling point of the liquid.
    - **Applications:** Used in laboratories and industries for heat-sensitive compounds.
5. **Steam Distillation:**
    - **Principle:** Vaporization of volatile compounds by steam.
    - **Applications:** Extraction of essential oils from plants.
6. **Molecular Distillation:**
    - **Principle:** Distillation under high vacuum to reduce boiling points.
    - **Applications:** Separation of high-boiling-point compounds.

Summary:

Evaporation is used for concentration, separation, and product recovery in various industries. Factors influencing evaporation include temperature, surface area, humidity, and airflow. Different evaporation systems include steam jacketed kettles, horizontal tube evaporators, climbing film evaporators, forced circulation evaporators, multiple effect evaporators, and the economy of multiple effect evaporators. Distillation involves the separation of components based on boiling points, with methods like simple distillation, flash distillation, fractional distillation, distillation under reduced pressure, steam distillation, and molecular distillation. Each method has specific applications in different industries.