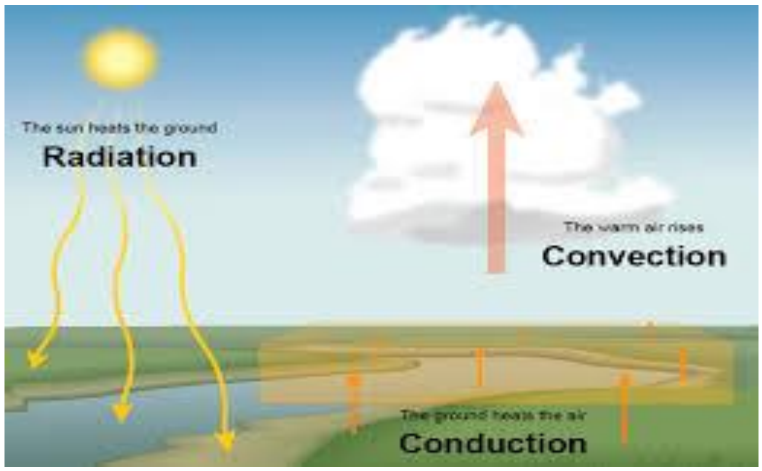
University of Science and Technology

Faculty of Engineering

First Year - Semester One - Academic Year:2025-2026

Physics (1) - Lec (10)

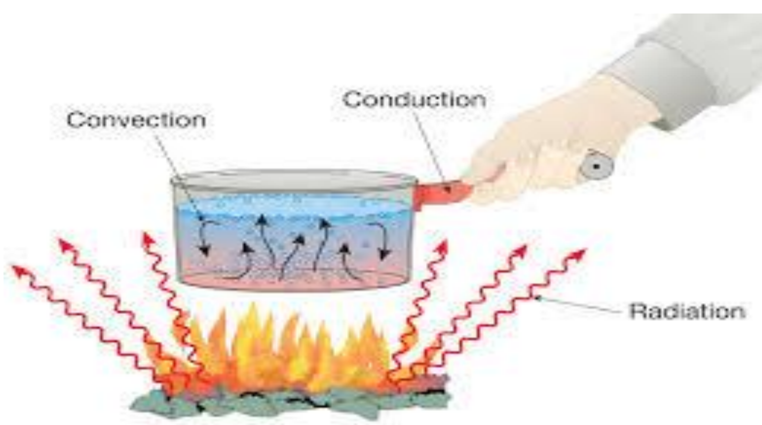
Heat Transfer



1. Definition of Heat Transfer : **Heat transfer** is the movement of thermal energy from a body at a higher temperature to a body at a lower temperature.

- Transfer continues until **thermal equilibrium** is reached.
- There are **three main methods of heat transfer**: **Conduction, Convection, and Radiation**.

2. Methods of Heat Transfer



Dr.moawia Ibrahim hamedelnil – moawiaibrahim73@gmail.com

A) Conduction

- **Definition:** Heat transfer through a **solid material** from a hotter region to a cooler region **without the material itself moving**.
- Occurs due to **collisions of particles and transfer of kinetic energy**.

Formula: $Q = k \cdot A \cdot [\Delta T / L] \cdot t$

Where:

- Q = heat transferred (Joules)
- k = thermal conductivity of the material (W/m·°C)
- A = cross-sectional area (m^2)
- ΔT = temperature difference (°C)
- L = thickness of the material (m)
- t = time (s)

Numeric Example:

- Copper plate:
  - Area: $A=0.01m^2$
  - Thickness: $L=0.02m$
  - Temperature difference: $\Delta T=50°C$
  - Thermal conductivity: $k=385W/m\cdot°C$
  - Time: $t=10s$

$Q=385 x 0.01 x [50/0.02] x 10=9625$ J

Interpretation: 9625 J of heat transfers through the plate in 10 seconds.

B) Convection

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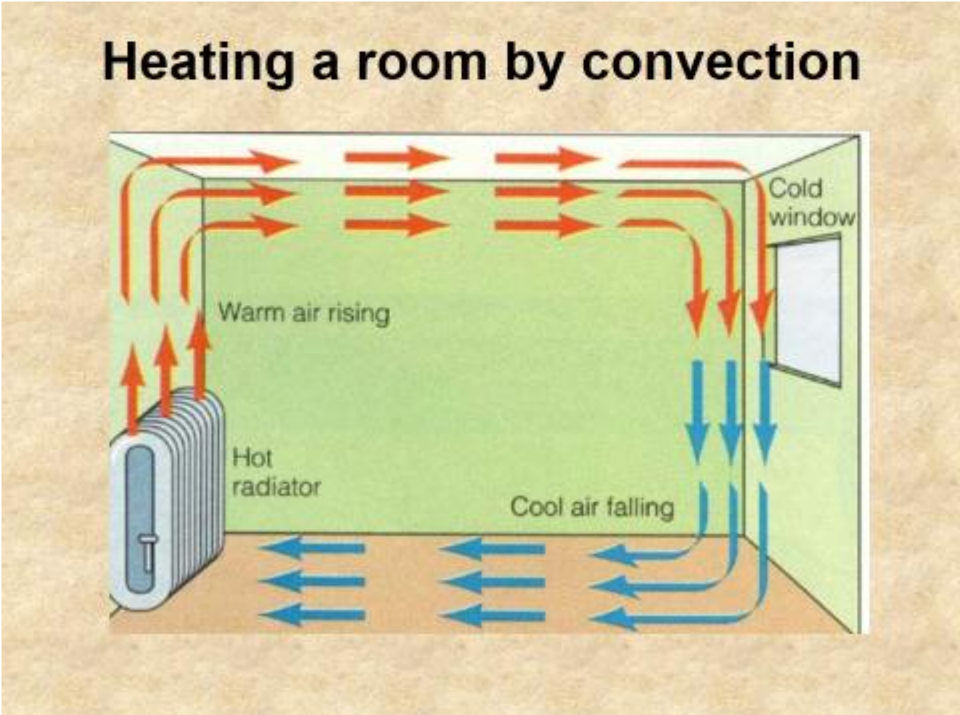

- **Definition:** Heat transfer by the **movement of fluids or gases**.
- Caused by **density differences** in the fluid due to temperature variations.
- Two types:
    1. **Natural convection:** Caused by density differences.
    2. **Forced convection:** Assisted by pumps or fans.

Formula: $Q = h \cdot A \cdot \Delta T \cdot t$

Where:

- h = convective heat transfer coefficient ($W/m^2 \cdot °C$)
- A = surface area (m^2)
- ΔT = temperature difference (°C)
- t = time (s)

Numeric Example:

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- Water in a container:
    - Surface area: $A=0.05m^2$
    - Temperature difference: $\Delta T=30°C$
    - Convective coefficient: $h=100W/m^2\cdot°C$
    - Time: $t=60s$

$Q=100x0.05x30x60=9000$ J

Interpretation: 9000 J of heat is transferred to the water in 1 minute by convection.

C) Radiation

- **Definition:** Heat transfer via **electromagnetic waves**, without a material medium.
- Every body with a temperature above absolute zero emits thermal radiation.

Formula (Stefan–Boltzmann Law): **$Q=\epsilon\cdot\sigma\cdot A\cdot(T^4-Ts^4)\cdot t$**

Where:

- ϵ = emissivity of the surface ($0 < \varepsilon \leq 1$)
- $\sigma=5.67\times10^{-8}W/m^2\cdot K^4$ (Stefan–Boltzmann constant)
- A = surface area (m^2)
- T = object temperature (K)
- Ts = surrounding temperature (K)
- t = time (s)

Numeric Example:

- Metallic surface:
    - Area: $A=0.1m^2$
    - Object temperature: $T=373K$ (100°C)

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- Surrounding temperature: $T_s=293K$ (20°C)
- Emissivity: $\epsilon=0.9$
- Time: $t=60s$

$Q=0.9x5.67x10^{-8}\cdot0.1x(373^4-293^4)x60\approx460$

Interpretation: The object loses approximately 460 J of heat in 1 minute through radiation.

3. Important Notes

- **Conduction:** Important in metals and solid materials.
- **Convection:** Dominates in fluids and gases, e.g., heating water or air.
- **Radiation:** Can occur in vacuum, e.g., heat from the Sun reaches Earth.

First Law of Thermodynamics

1. Definition of the First Law of Thermodynamics

The **First Law of Thermodynamics** is a statement of **the principle of conservation of energy** for thermodynamic systems.

- It states that **energy cannot be created or destroyed; it can only be transformed from one form to another**.
- In thermal systems, energy can be converted from **heat** into **work** or stored as **internal energy** in the system.

2. Mathematical Formulation $\Delta U=Q-W$

Where:

- ΔU = change in **internal energy** of the system (J)
- Q = heat absorbed by the system from the surroundings (J)

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- W = work done by the system on the surroundings (J)

Notes:

- **$Q>0$** → heat is absorbed by the system.
- **$W>0$** → the system performs work on its surroundings.

3. Types of Thermodynamic Processes

1. **Isochoric Process (Constant Volume)**
   - Volume is constant ($\Delta V=0$) → no work is done $W=P\Delta V=0$
   - First law simplifies to: $\Delta U=Q$
   - **Example:** Heating gas in a rigid, sealed container.
2. **Isobaric Process (Constant Pressure)**
   - Pressure is constant → work: $W=P\Delta V$
   - First law: $\Delta U=Q-P\Delta V$
   - **Example:** Heating air in an open cylinder at constant pressure.
3. **Isothermal Process (Constant Temperature)**
   - Temperature is constant → $\Delta U=0$
   - All absorbed heat is converted to work: $Q=W$
   - **Example:** Expansion of an ideal gas at constant temperature.
4. **Adiabatic Process (No Heat Exchange)**
   - No heat transfer $Q=0$
   - First law: $\Delta U=-W$
   - **Example:** Compression of gas in a thermally insulated piston.

4. Numeric Example

- Heat absorbed by a gas: $Q=500$ J
- Work done by the gas: $W=200$ J

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$\Delta U = Q - W = 500 - 200 = 300$ J

Interpretation: The internal energy of the system increases by 300 J.

5. Important Notes

- The first law **does not specify the direction of thermal processes**, only energy conservation.
- To understand the direction of heat flow, the **Second Law of Thermodynamics (entropy)** is needed.
- The first law is widely used in **thermodynamic engines, compressors, heat exchangers, and power cycles**.

Dr.moawia Ibrahim hamedelnil – moawiaibrahim73@gmail.com