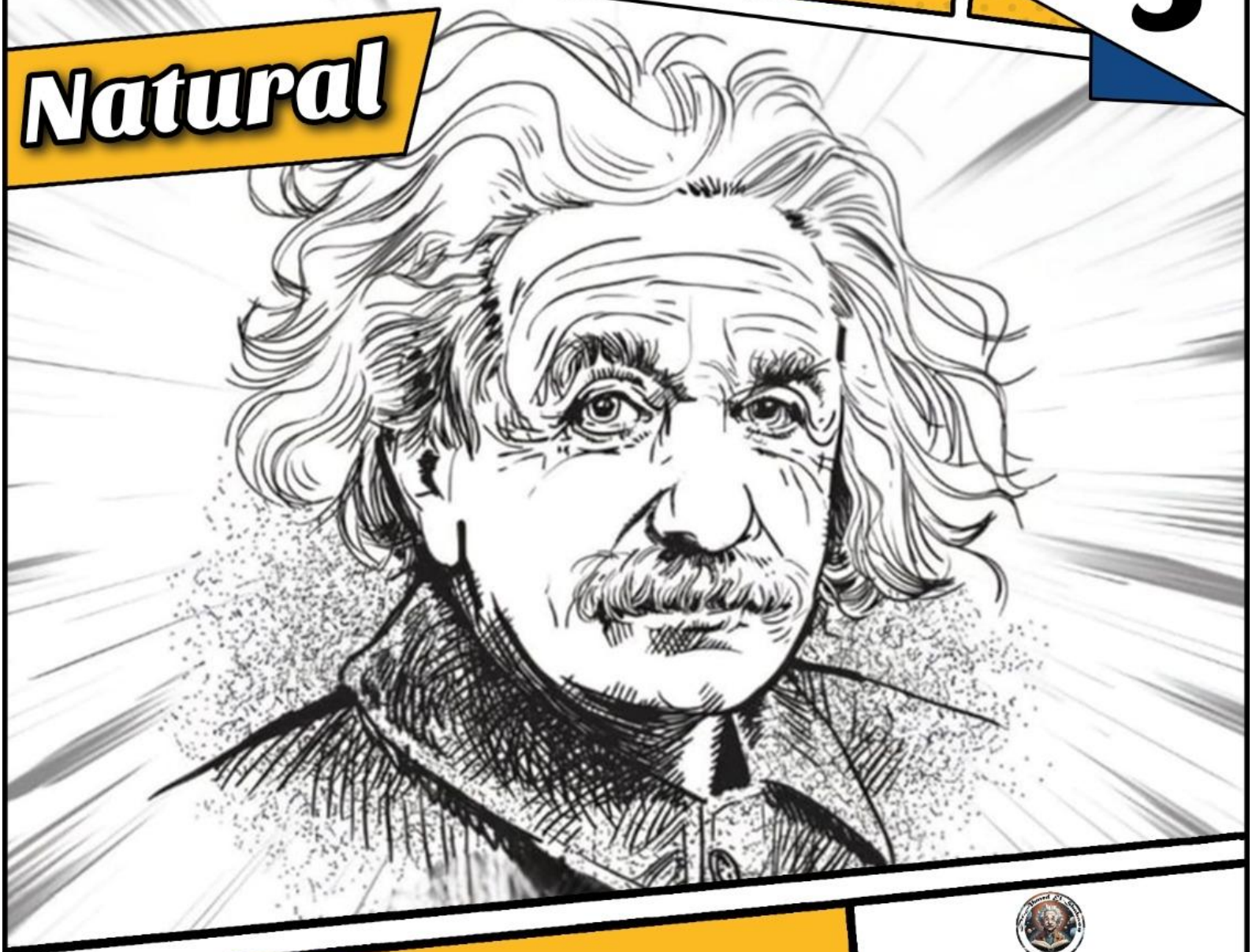
Dr/A.Elshabasy physics

2025

NO 3

Natural



Heat (Heat Transfer)

Physics 1 Dr.Elsahbasy

WhatsApp group

Heat transfer

① Conduction

② Convection

③ Radiation

1- conduction

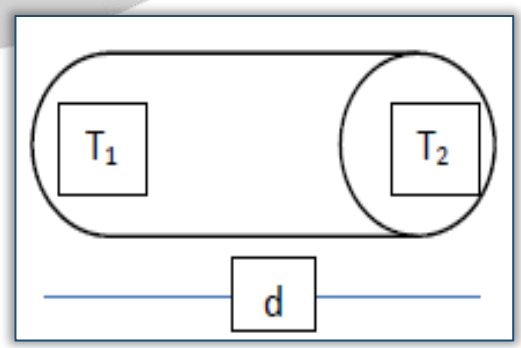
☞ heat transfer in solid due to vibration of molecules where K.E of particle proportional with temperature

☞ The heat transfer from hot to cold by the motion of free electrons (in solid)

☞ Heat transfer by conduction in the gas is through the collision gas molecules with each other.

Consider we have a bar with cross sectional area "A" and thickness "d".

☞ While $T_2 > T_1$ then the heat will transfer from hot to cold



The rate of heat energy which conducted through a material depends on

1) Thermal conductivity coefficient of material k

$$\frac{dQ}{dt} \propto K$$

2) Area through which heat is conducted A

$$\frac{dQ}{dt} \propto A$$

3) Difference in temperature across the material dT

$$\frac{dQ}{dt} \propto dT$$

4) Thickness of material through which heat travels dx

$$\frac{dQ}{dt} \propto \frac{1}{dx}$$

$$dQ = -KA \frac{T_h - T_c}{dx} dt$$

☞ The amount of heat energy transmitted through the slice distance two surface 1 m and the area of each surface $1\,m^2$ when the difference in degree of the two-surface heat 1 k during a period of 1 sec.

Unit: $J.m^{-1}K^{-1}sec^{-1}$ // $W.m^{-1}K^{-1}$

Example

the temperature of a room is maintained at 20℃ above the outside temperature. if all the heat losses occur through a plate glass window of area $2\,m^2$ and thickness 3 mm, calculate the rate of heat flow out through the glass.

Thermal conductivity coefficient of glass $1.1\,W.m^{-1}K^{-1}$

Answer

$\frac{dQ}{dt} = ?$, $A = 2m^2$, $dx = 3mm = 3\times10^{-3}\,m$, $\Delta T = 20K$

$$\frac{dQ}{dt} = -KA\frac{dT}{dx} = 1.1\times2\times\frac{20}{0.003} = 14666\,J/s$$

Example

A room is maintained at $25°C$, while the outside temperature is $0°C$. The heat loss occurs through a wooden wall of area $5\ m^2$ and thickness 4 cm. The thermal conductivity of wood is $0.12\ W/mK$. Calculate the rate of heat loss through the wall

Answer

2- Convection (pregnancy)

- This happens on gases and liquids.
- If we heat gas or liquid, the part of it near to heater will low density then it will move and replaced by cold layer, this process is called '' convection ''

Types of convection

1. Free pregnancy
2. Forced pregnancy.

Rate of heat energy transfer from surface to fluid

$$\frac{dQ}{dt} = -h_c A\, dT$$

- h_c: represents convection coefficient.
- Negative signal means decreasing temperature with the passage of time.

Definition of convection coefficient

- The amount of heat energy transmitted through an area of 1 m^2 with a time of 1 sec, when the difference between the surface and the degree of fluid 1K

Units: $J.m^{-2}\,K^{-1}\,sec^{-1}$ // $W.m^{-2}\,K^{-1}$

The convection coefficient (h_c) depends on several factors

1) Position of fluid surface
2) The type of fluid
3) The fluid density
4) The speed of the fluid

Example

Calculate the rate of heat transfer from a metal plate with an area of $2\ m^2$ and a surface temperature of $100°C$ to the surrounding air at $25°C$. The convective heat transfer coefficient for air is $10\ W/m^2.K$.

Answer

Example

A spherical object with a radius of $0.5\ m$ is submerged in water. The object's surface temperature is $80°C$, while the water temperature is $20°C$. The convective heat transfer coefficient for water is $500\ W/m^2\ K$. Calculate the rate of heat loss from the object.

Answer

3 - Radiation

- This **does not** need a medium to transfer.
- This heat transfer as electromagnetic radiation like light
- Thermal radiation from a hot object of any kind **depends on temperature.**
- Good absorbers are also good emitters.
- Good reflectors (poor absorbers) are poor emitters.
- Radiation emitted from solid, and liquid is different from that emitted from gases.

Properties of thermal radiation

1) Travels through the vacuum speed of light
2) Is like light and move in straight lines
3) Applies inverse – square law
4) Is reflected and refracted in accordance with the laws of light
5) Have interference phenomena such as diffraction and polarization

Stefan – Boltzmann law of radiation

$$Q = \varepsilon \ \sigma A \left(T_1^4 - T_2^4\right)$$

T: the absolute temperature

ε: emissivity = 1 **for black body**

σ : stefan constant ($\sigma = 5.67 \times 10^{-8}\ W\,.m^{-2}\,K^{-4}$)

A: cross section area

Example

A radiator has a surface area of $1.8\,m^2$ and a surface temperature, when hot of 60℃ , determine the rate at which heat is radiated by the radiator if it behaves as a blackbody

Answer

$$\frac{Q}{t} = \varepsilon\ \sigma\ AT^4$$

$$\sigma = 5.67 \times 10^{-8}\ W\,.m^{-2}\,K^{-4}\ , \qquad A = 1.8\,m^2 \qquad \varepsilon = 1$$

$$T = 60 + 273 = 333\,K$$

$$\frac{Q}{t} = (1)(5.67 \times 10^{-8})(1.8)(333^4) = 1254\,W$$

Example

A metal plate has a surface area of $2.5\,m^2$ and is maintained at a temperature of $400°\,C$. Determine the rate at which heat is radiated by the plate if it behaves as a blackbody

Answer