Marwari college Darbhanga

Subject---physics (Hons)

Class--- B.Sc. Part 1

Paper 2 : Group – A

Topic—Thermal physics (Fourier's heat conduction)

Lecture series—43

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Fourier's Law

Fourier's law states that the negative gradient of temperature and the time rate of heat transfer are 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.

Newton's law of cooling and Ohm's law are a discrete and electrical analogue of Fourier's law.

Differential Form Of Fourier's Law

Fourier's law differential form is as follows:

$$q = -k \nabla T$$

Where,

- q is the local heat flux density in $W.m^2$
- k is the conductivity of the material in $W.m^{-1}.K^{-1}$
- ∇T is the temperature gradient in $K.m^{-1}$

In one-dimensional form:

$$q_x = -k \, dT/dx$$

Integral form

$$\frac{\partial Q}{\partial t} = -k \oiint_S \nabla T \cdot dS$$

Where,

- $\partial Q/\partial t$ is the amount of heat transferred per unit time
- dS is the surface area element

When the same equation is given in the differential form, which is the basis of heat equation derivation:

$$Q/\Delta t = -kA(\Delta T/\Delta x)$$

Where,

- A is the area of the cross-sectional surface
- ΔT is the temperature difference between the endpoints

- Δx is the distance between two ends

Fourier's law in terms of conductance

$$\Delta Q \Delta t = UA(-\Delta T)$$

Where,

- U is the conductance

Fourier's Law Derivation

The derivation of Fourier's law was explained with the help of an experiment which explained the *Rate of heat transfer through a plane layer is proportional to the temperature gradient across the layer and heat transfer area.*

Rate of heat conduction

$$\propto \frac{(area)(temperature\ difference)}{thickness}$$

Let T_1 and T_2 be the temperature difference across a small distance Δx of area A. k is the conductivity of the material. Therefore, in one dimensional, the following is the equation used:

$$Q_{cond} = kA\frac{T_1-T_2}{\Delta x} = -kA\frac{\Delta T}{\Delta x}$$

When Δx → 0, following is the equation in a reduced form to a differential form:

$$Q_{cond} = -kA\frac{\Delta T}{\Delta x}$$

The three-dimensional form the Fourier's law is given as:

$$\vec{q} = -k \bigtriangledown T$$