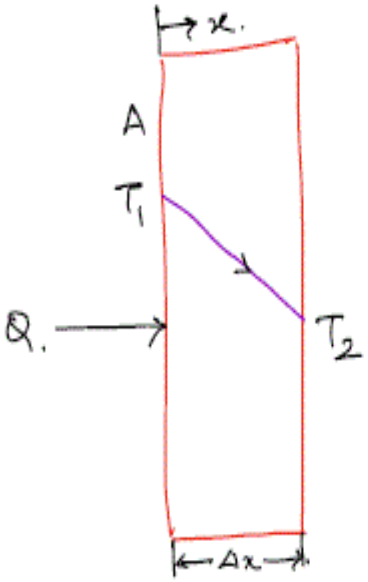
Modes of Heat Transfer:

Conduction: An energy transfer across a system boundary due to temperature difference by the mechanism of inter-molecular interactions.

a) Conduction needs matter.

b) Conduction rate equation is governed by Fourier law.

$$q = -K.A_{c/s}.\nabla T.$$



∇T = Gradient of temp (K/m)

$$\nabla T = \frac{\partial T}{\partial x}\hat{i} + \frac{\partial T}{\partial y}\hat{j} + \frac{\partial T}{\partial z}k.$$ } Vector Eqn.

Cartesian Coordinates:

$$X \rightarrow q_x = -k A_{x} \frac{dT}{dx}.$$
$$Y \rightarrow q_y = -k A_{y} \frac{dT}{dy}$$
$$Z \rightarrow q_z = -k A_{z} \frac{dT}{dz}.$$

Circular Coordinates:

$$q_r = -kA_r \frac{dT}{dr}$$

$$q = \frac{Q}{A_{c/s}} \left[W/m^2\right]$$

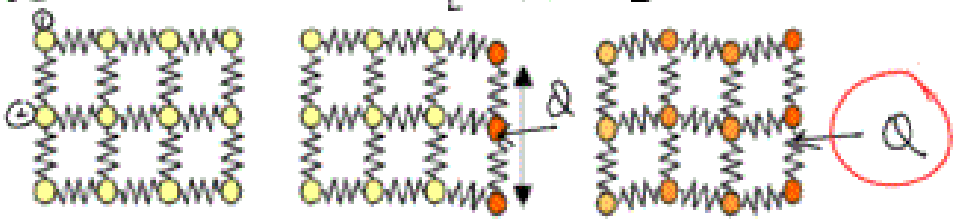
Fourier law of heat conduction:

a) Heat flux 'q' is defined as the rate of heat transfer unit area, normal to the direction.

b) Fourier law states that the heat flux is proportional to the temperature gradient.

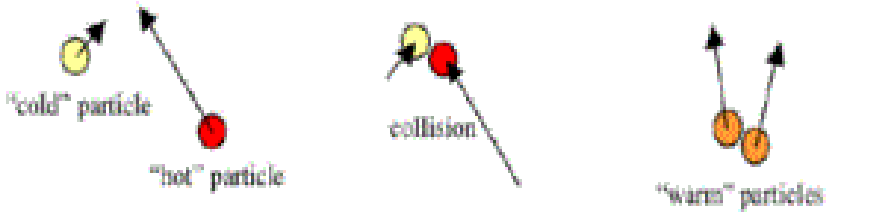
$$q_x \propto \frac{\partial T}{\partial x}. \qquad \frac{\partial T}{\partial x} = \text{Temperature gradient.}$$

Conduction mode of Heat Transfer → It is driven by the temp. gradient in the medium. [substance].



1) network of atoms 2) vibrate "hot" side 3) whole structure vibrating

Conduction by lattice vibration



1) particle from hot side migrates to the cold side 2) hot particle collides with cold particle 3) two particles have similar energy levels, both are warm

Conduction by particle collision

Convection: An energy transfer across the system boundary due to temperature difference by the combined mechanisms of intermolecular interactions and bulk transport. Convection need fluid matter Liquid, Gas.

moving fluid →

① $T_s > T_\infty$ → Heat will flow from surface to fluid.

② $T_\infty > T_s$ → Heat is given by the fluid to surface.

Newton's law of cooling:

$$Q = h \cdot A_s \Delta T.$$

where, Q = Heat flow from the surface (scalar)

h = Heat transfer coefficient (W/m^2K).

A_s = Surface area. [Fluid in contact].

ΔT = Temperature diff b/n surface & fluid.

Convection

- Free (or) Natural. (Buoyancy forced)
- Forced. (External forces).

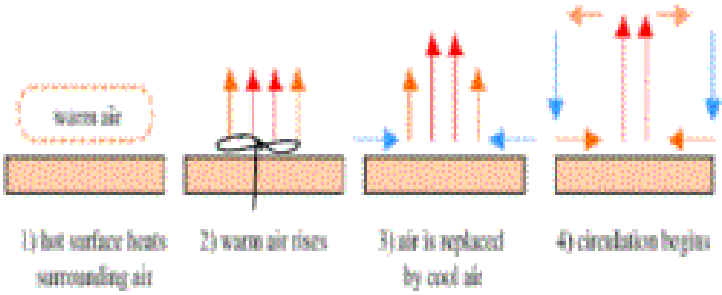


Table 1: Typical values of the convective heat transfer coefficient h

Type of flow	h ,$W/(m^2K)$
Free convection	
Gases	2-25
Liquids	50-1000
Forced convection	
Gases	25-250
Liquids	50-20000
Convection with phase change	
Boiling or Condensation	2500-100000

Radiation: Radiation heat transfer involves transfer of heat by electromagnetic radiation that arises due to the temperature of the body. Radiation doesn't need matter (not mandatory).

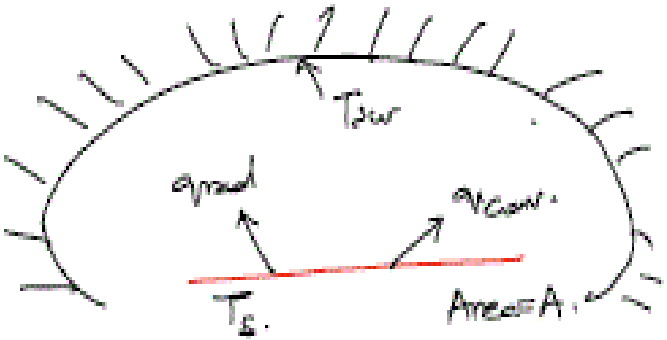
$$E = \sigma \epsilon T_s^4$$

where,

E = Emissive power of a surface.

σ = Stefan Boltzman constant $[5.67 \times 10^{-8}\ W/m^2K^4]$

T_s = Absolute surface temp $[K]$.



Net heat transfer between 2 surfaces

$$q = \frac{Q}{A} = \sigma \epsilon (T_s^4 - T_{sur}^4$$

Table 2: Emissivity values of different materials

Material	Emissivity value
Aluminium foil	0.07
Anodized aluminium	0.82
Polished copper	0.03
Polished gold	0.03
Polished silver	0.02
Polished stainless steel	0.17
Black paint	0.98
White paint	0.90

Material	Emissivity value
White paper	0.92-97
Asphalt pavement	0.85-0.93
Red brick	0.93-0.96
Human skin	0.95
Wood	0.82-0.92
Soil	0.93-0.96
Water	0.96
Vegetation	0.92-0.96