Modes of Heat Transfer

OBJECTIVES:
-- To study different modes of heat transfer.
-- To determine rate of heat transfer in food and non-food materials

Why study heat transfer?

-- to examine how foods are heated and cooled

-- to assess the performance of existing heat exchange equipment

CONDUCTION
-- Energy transfer at a molecular level

-- Heating/Cooling of the solid material

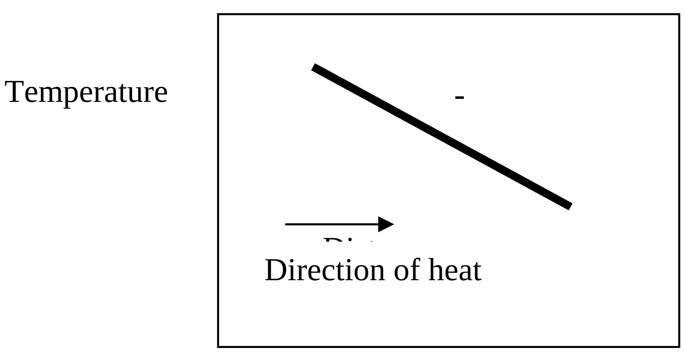
The rate of heat flux (rate of heat transfer per unit area) in a solid object is proportional to the temperature gradient, this can be stated mathematically as,

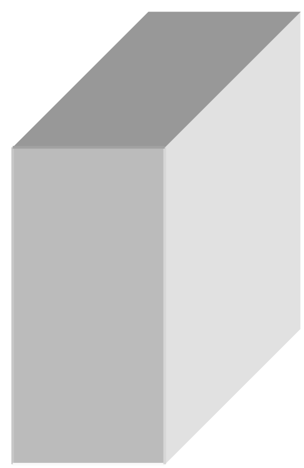
We may remove the proportionality by using a constant 'k', to obtain, Fourier's Law

where

q_x = rate of heat transfer in the x direction by conduction, W
k = thermal conductivity, W/mC
A = area (normal to x-direction) through which heat flows, m^2
T = temperature, C
x = length, variable, m

SIGN CONVENTION





Thermal Conductivity, k   unit: W/mC

Water: k = 0.597 W/mC

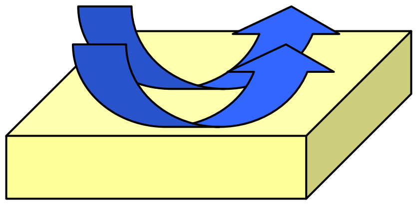
Insulating materials: k = 0.035 - 0.173 W/mC

For foods
$k = 0.25\ m_c + 0.155\ m_p + 0.16\ m_f + 0.135\ m_a + 0.58\ m_m$

Where m is mass fraction and subscripts c: carbohydrate, p: protein, f: fat, a: ash, m: moisture.

CONVECTION

Fluid flow over a solid body -- heat transfer between a solid and a fluid.



Newton's Law of Cooling:

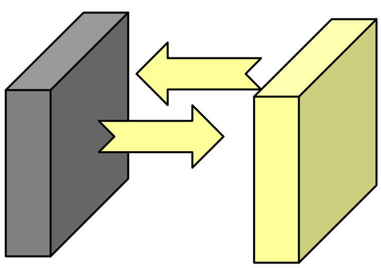
where: h is convective heat transfer coefficient (W/m^2C), A is area (m^2), T_p is plate surface temperature (°C), T_α is surrounding fluid temperature (°C).

Forced Convection –
Free (Natural) Convection –

Fluid condition	h (W/m^2C)
Air, free convection	5-25
Water, free convection	20-100
Water, forced convection	50-10,000
Condensing water vapor	5,000-100,000

RADIATION

Heat transfer between two surfaces by emission and later absorption of electromagnetic radiation



requires no physical medium

- Stefen-Boltzmann Equation:

where σ = Stefen-Boltzmann's constant, 5.669×10^{-8} W/m^2K^4
ε = emissivity, (varies from 0 to 1) dimensionless
A = area, m^2
T_1 = temperature of surface 1, Absolute
T_2 = temperature of surface 2, Absolute