Heat Transfer

is the means by which energy moves from

a hotter object to

a colder object

Mechanisms of Heat Transfer

Conduction

is the flow of heat by direct contact between a warmer and a cooler body.

Convection

is the flow of heat carried by moving gas or liquid.

(warm air rises, gives up heat, cools, then falls)

Radiation

is the flow of heat without need of an intervening medium.

(by infrared radiation, or light)

Conduction

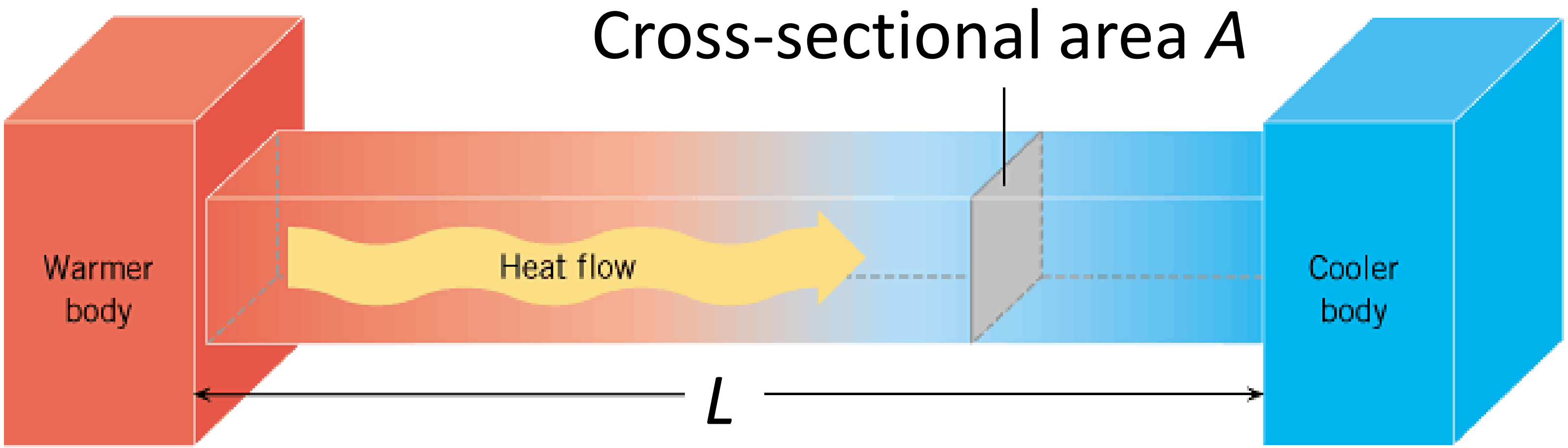
Conduction is the process whereby **heat** is transferred directly through a material, any bulk motion of the material playing no role in the transfer.

Those materials that conduct **heat** well are called ***thermal conductors***, while those that conduct heat poorly are known as ***thermal insulators***.

Most metals are excellent thermal conductors, while wood, glass, and most plastics are common thermal insulators.

The free electrons in metals are responsible for the excellent thermal conductivity of metals.

Conduction: Fourier's Law



$$Q = kA\left(\frac{\Delta T}{L}\right)t$$

What is the unit of *k*?

Q = heat transferred
k = thermal conductivity
A = cross sectional area
ΔT = temperature difference between two ends
L = length
t = duration of heat transfer

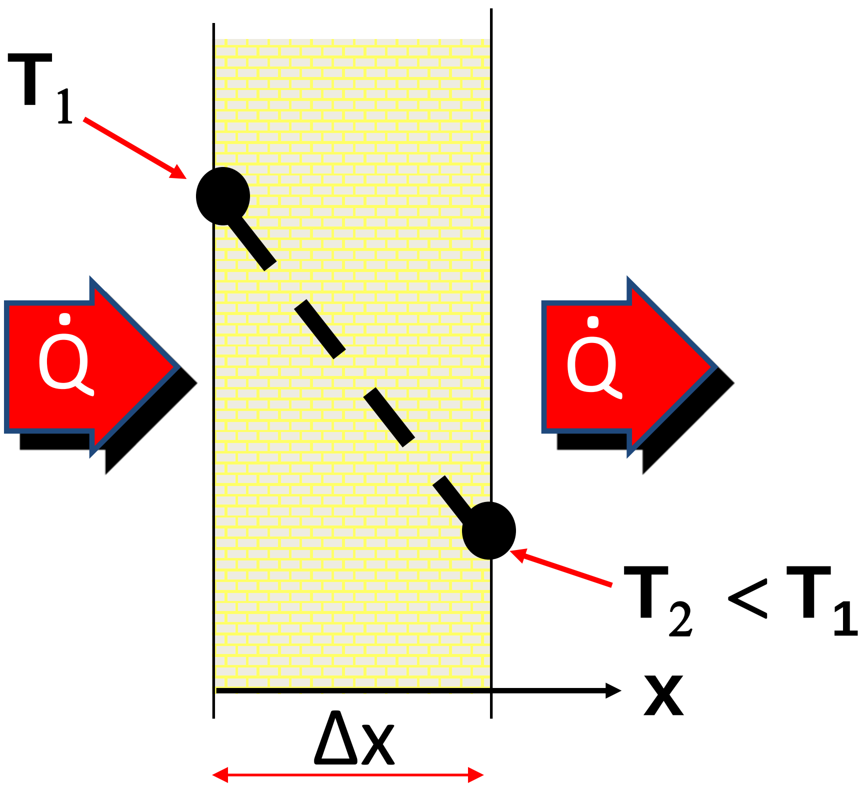
Thermal Conductivities

Substance	Thermal Conductivity k [W/m.K]
Syrofoam	0.010
Air	0.026
Wool	0.040
Wood	0.15
Body fat	0.20
Water	0.60

Substance	Thermal Conductivity k [W/m.K]
Glass	0.80
Concrete	1.1
Iron	79
Aluminum	240
Silver	420
Diamond	2450

Conduction through Single Wall

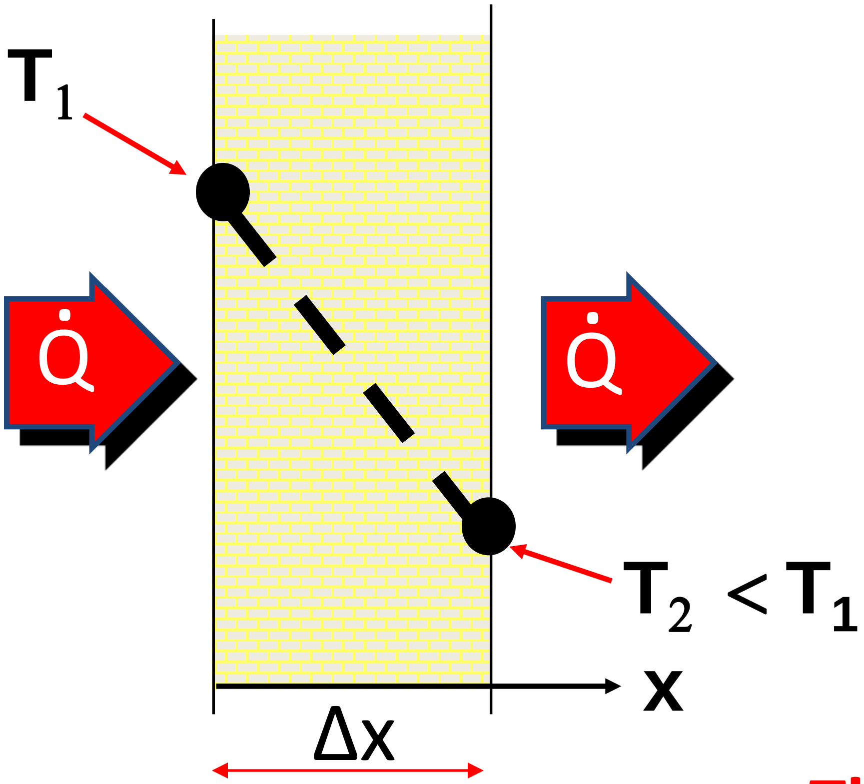
Use Fourier's Law:



$$Q = kA\left(\frac{\Delta T}{L}\right)t$$

$$\dot{Q} = \frac{k\,A\,(T_1 - T_2)}{\Delta x}$$

Conduction through Single Wall

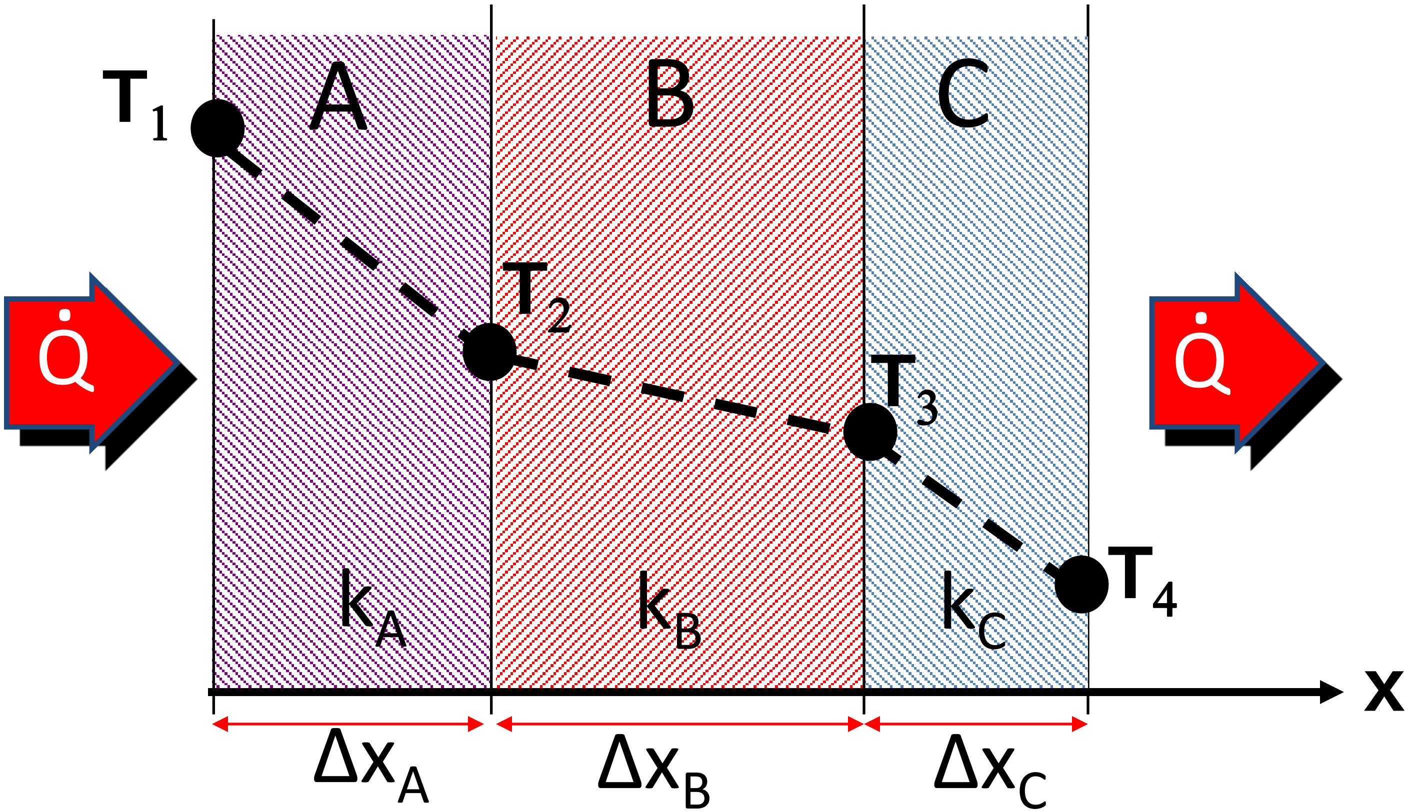


$$\dot{Q} = \frac{k\,A\,(T_1 - T_2)}{\Delta x}$$

$$= \frac{T_1 - T_2}{\Delta x/(kA)}$$

Thermal resistance (in k/W)
(opposing heat flow)

Conduction through Composite Wall



$$\dot{Q} = \frac{T_1 - T_2}{(\Delta x/kA)_A} = \frac{T_2 - T_3}{(\Delta x/kA)_B} = \frac{T_3 - T_4}{(\Delta x/kA)_C}$$

Conduction through Composite Wall

$$\dot{Q} = \frac{T_1 - T_2}{(\Delta x/kA)_A} = \frac{T_2 - T_3}{(\Delta x/kA)_B} = \frac{T_3 - T_4}{(\Delta x/kA)_C}$$

$$\dot{Q}\left[(\Delta x/kA)_A + (\Delta x/kA)_B + (\Delta x/kA)_C\right]$$

$$= T_1 - T_2 + T_2 - T_3 + T_3 - T_4$$

$$\dot{Q} = \frac{T_1 - T_4}{(\Delta x/kA)_A + (\Delta x/kA)_B + (\Delta x/kA)_C}$$

Example 1

An industrial furnace wall is constructed of 21 cm thick fireclay brick having k = 1.04 W/m.K. This is covered on the outer surface with 3 cm layer of insulating material having k = 0.07 W/m.K. The innermost surface is at 1000^{o}C and the outermost surface is at 40^{o}C. Calculate the steady state heat transfer per area.

Solution: We start with the equation

$$\dot{Q} = \frac{T_{in} - T_{out}}{(\Delta x/kA)_{fireclay} + (\Delta x/kA)_{insulation}}$$

Example 1 continued

$$\dot{Q} = \frac{(1000 - 40)\ A}{(0.21/1.04) + (0.03/0.07)}$$

$$\frac{\dot{Q}}{A} = 1522.6 \quad W/m^2$$