HEAT TRANSFER
UNDERGRADUATE COURSE

ENGINEERING & SCIENCE PLATFORM

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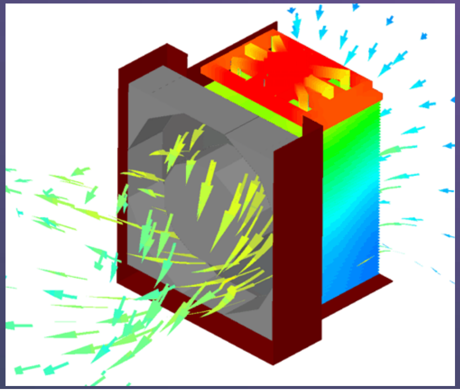
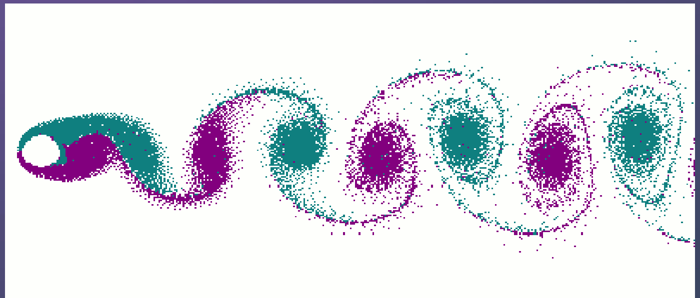
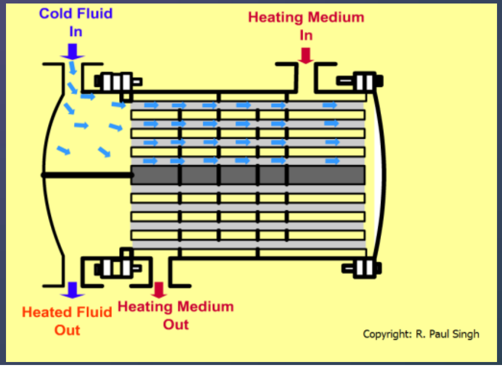
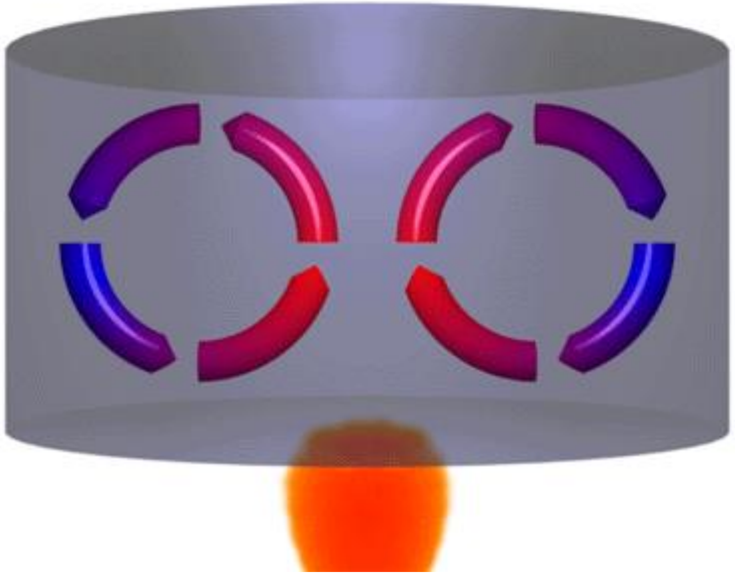
FALL 2016

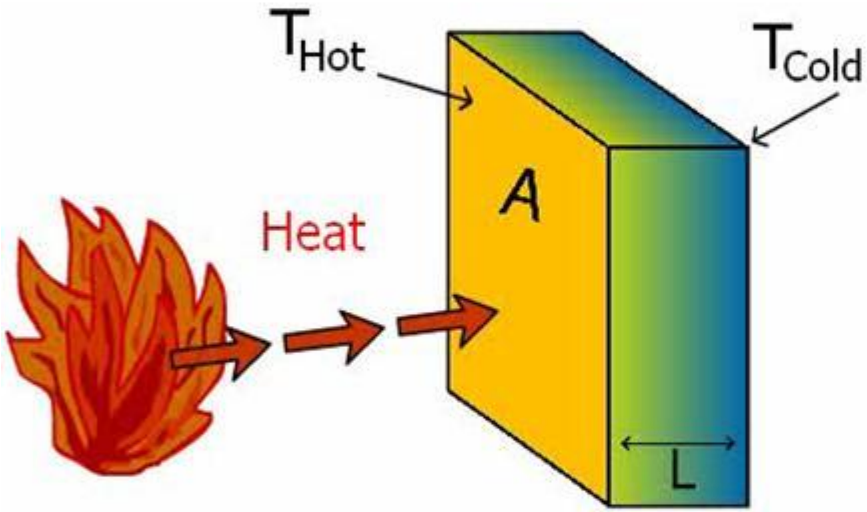


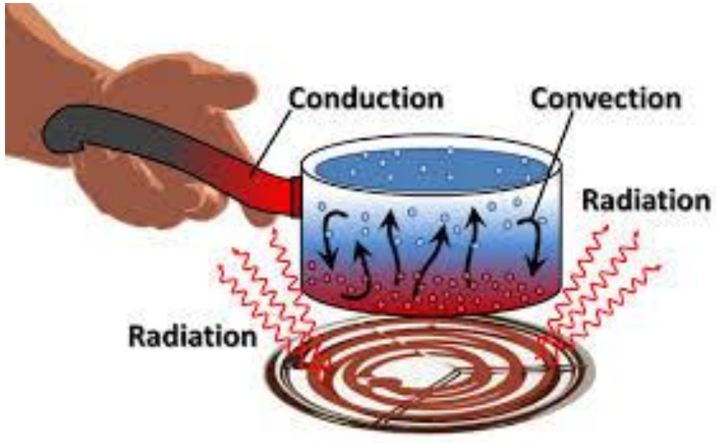




HEAT TRANSFER DEFINITIONS AND MODES



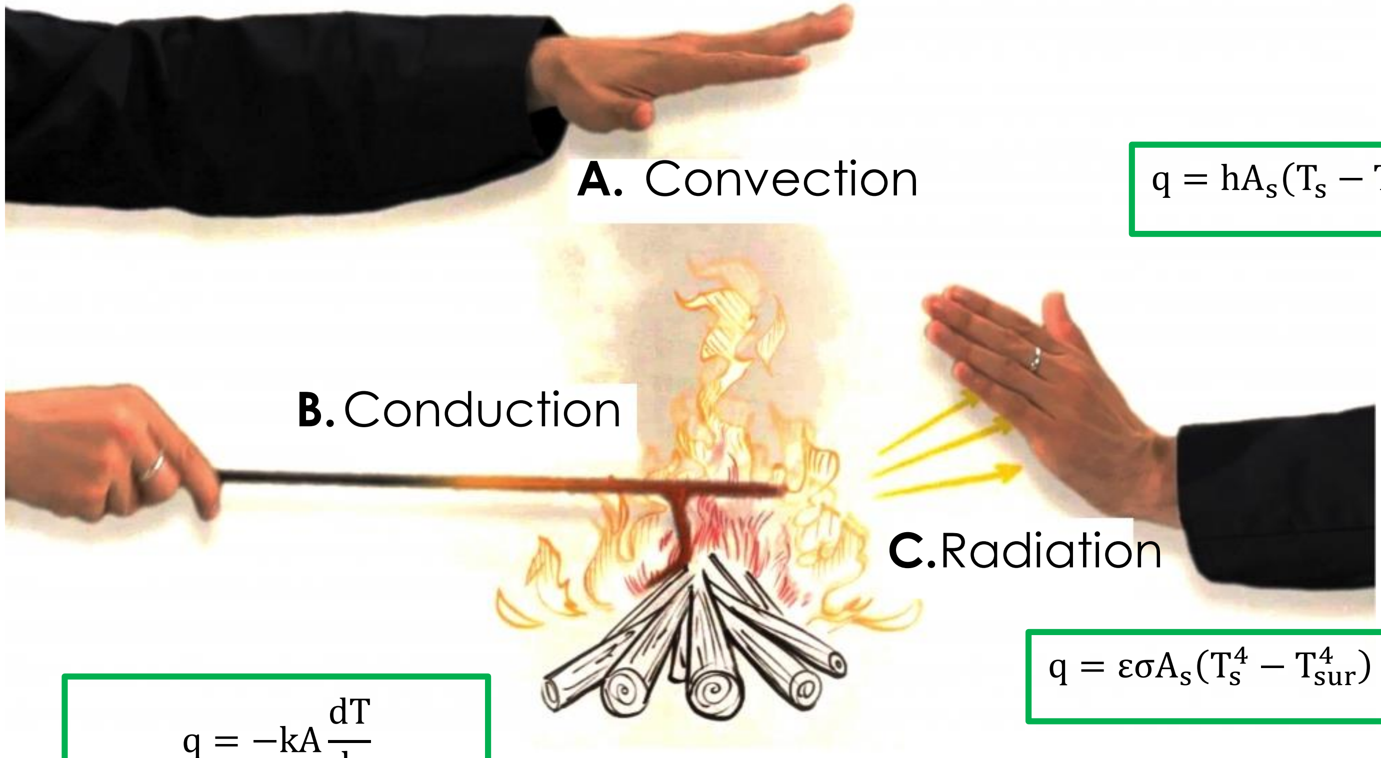




Convection Mode

Conduction Mode

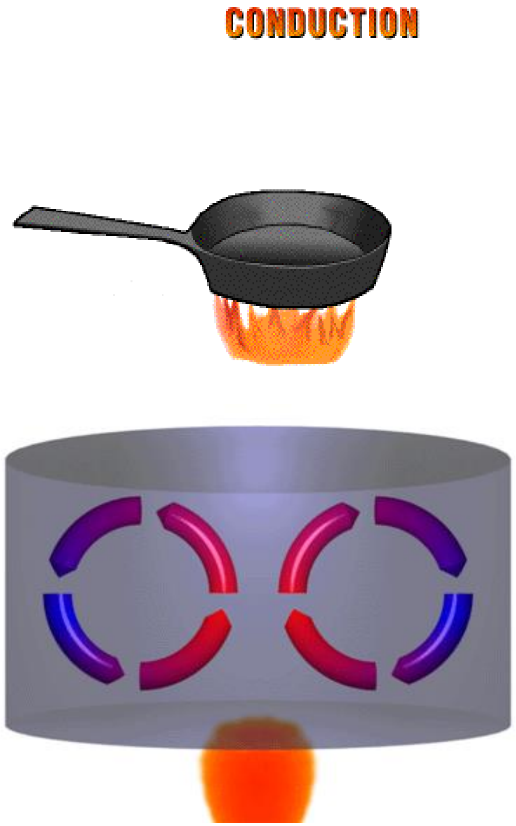
HEAT TRANSFER DEFINITIONS AND MODES



$$q = hA_s(T_s - T_\infty)$$

$$q = -kA\frac{dT}{dx}$$

$$q = \varepsilon\sigma A_s(T_s^4 - T_{sur}^4)$$



STEADY HEAT CONDUCTION IN PLANE WALLS

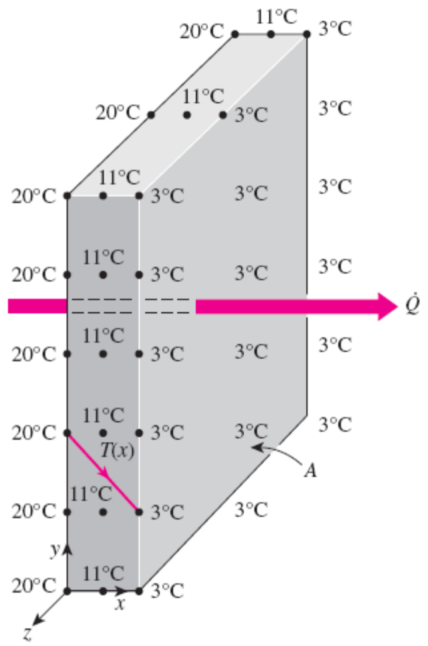


FIGURE 3–1
Heat transfer through a wall is one-dimensional when the temperature of the wall varies in one direction only.

Heat transfer through the wall of a house can be modeled as *steady* and *one-dimensional.*

The temperature of the wall in this case depends on one direction only (say the *x*-direction) and can be expressed as $T(x)$.

$$\begin{pmatrix}\text{Rate of} \\ \text{heat transfer} \\ \text{into the wall}\end{pmatrix} - \begin{pmatrix}\text{Rate of} \\ \text{heat transfer} \\ \text{out of the wall}\end{pmatrix} = \begin{pmatrix}\text{Rate of change} \\ \text{of the energy} \\ \text{of the wall}\end{pmatrix}$$

$$\dot{Q}_{\text{in}} - \dot{Q}_{\text{out}} = \frac{dE_{\text{wall}}}{dt}$$

$$dE_{\text{wall}}/dt = 0$$

for *steady* operation

In steady operation, the rate of heat transfer through the wall is constant.

$$\dot{Q}_{\text{cond, wall}} = -kA\frac{dT}{dx} \qquad \text{(W)}$$

Fourier's law of heat conduction

THERMAL RESISTANCE CONCEPT IN A PLANAR COORDINATE

$$R_{wall} = \frac{L}{kA} \qquad (°C/W)$$

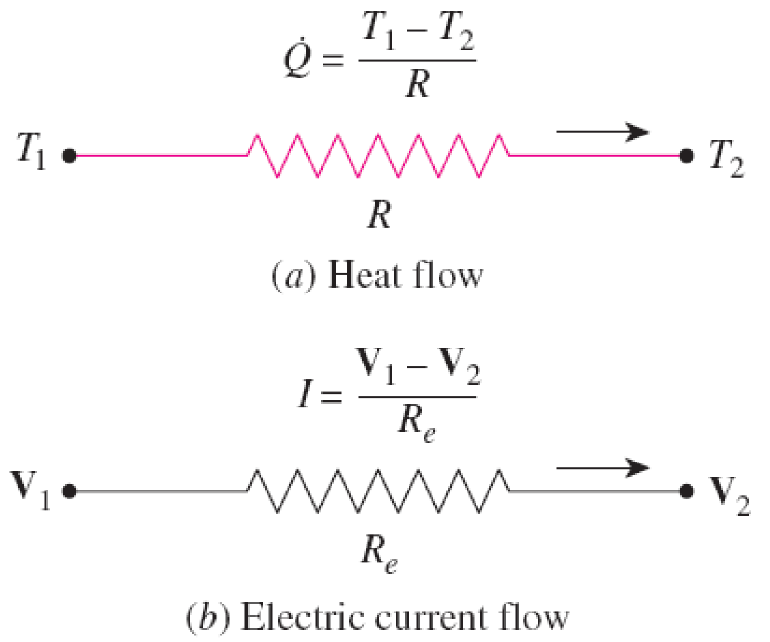
Conduction resistance of the wall: *Thermal resistance* of the wall against heat conduction.

Thermal resistance of a medium depends on the *geometry* and the *thermal properties* of the medium.

$$\dot{Q}_{cond,\ wall} = \frac{T_1 - T_2}{R_{wall}} \qquad (W)$$

$$\dot{Q}_{cond,\ wall} = kA\frac{T_1 - T_2}{L}$$

Analogy between thermal and electrical resistance concepts.



$$I = \frac{V_1 - V_2}{R_e} \qquad R_e = L/\sigma_e A$$

Electrical resistance

rate of heat transfer → electric current
thermal resistance → electrical resistance
temperature difference → voltage difference

THERMAL RESISTANCE CONCEPT IN A PLANAR COORDIANTE

$$\dot{Q}_{conv} = \frac{T_s - T_\infty}{R_{conv}} \qquad \text{(W)}$$

$$R_{conv} = \frac{1}{hA_s} \qquad (°\text{C/W})$$

Newton's law of cooling

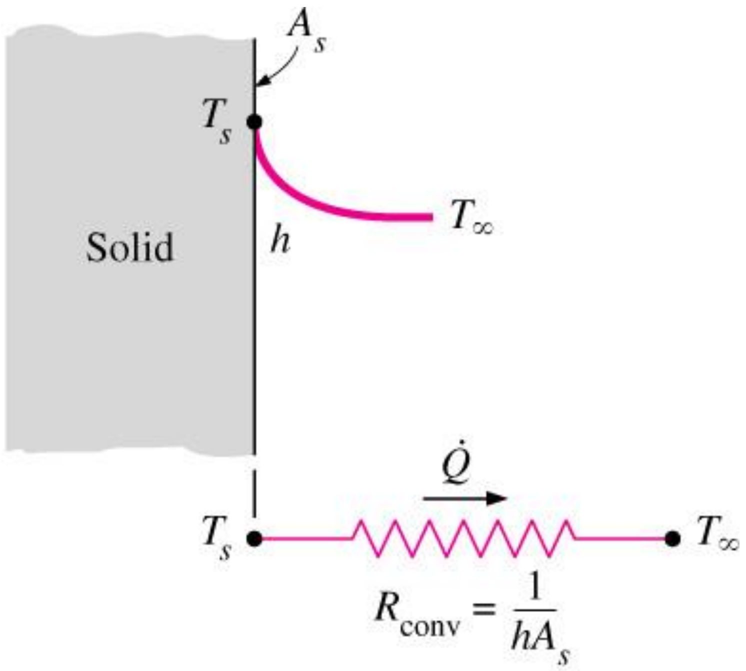
$$\dot{Q}_{conv} = hA_s(T_s - T_\infty)$$

Convection resistance of the surface: Thermal resistance of the surface against heat convection.

When the convection heat transfer coefficient is very large ($h \to \infty$), the convection resistance becomes *zero* and $T_s \approx T$.

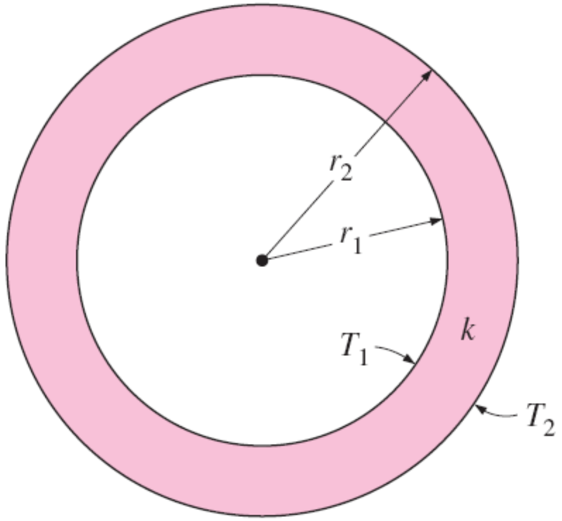
That is, the surface offers *no resistance to convection*, and thus it does not slow down the heat transfer process.

This situation is approached in practice at surfaces where boiling and condensation occur.



Schematic for convection resistance at a surface.

THERMAL RESISTANCE CONCEPT IN A SPHERICAL COORDINATE



$$\dot{Q}_{\text{cond, sph}} = \frac{T_1 - T_2}{R_{\text{sph}}}$$

A spherical shell with specified inner and outer surface temperatures T_1 and T_2.

$$R_{\text{sph}} = \frac{r_2 - r_1}{4\pi r_1 r_2 k} = \frac{\text{Outer radius} - \text{Inner radius}}{4\pi(\text{Outer radius})(\text{Inner radius})(\text{Thermal conductivity})}$$

R_{sph} is conduction resistance of the spherical layer.

REFERENCES

1. Heat and Mass Transfer: Fundamentals & Applications Fourth Edition, Yunus A. Cengel, Afshin J. Ghajar, McGraw-Hill, 2011

2. HEAT TRANSFER (GREGORY F.NELLIS, SANFORD A.KLEIN, 2009) - BOOK