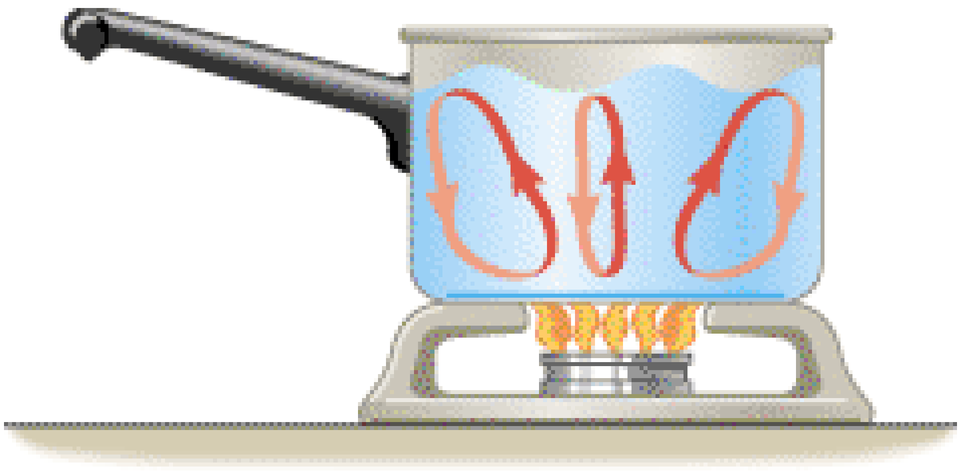
Convection

Convection is the process in which **heat** is carried from place to place by the bulk movement of a **fluid** (gas or liquid).

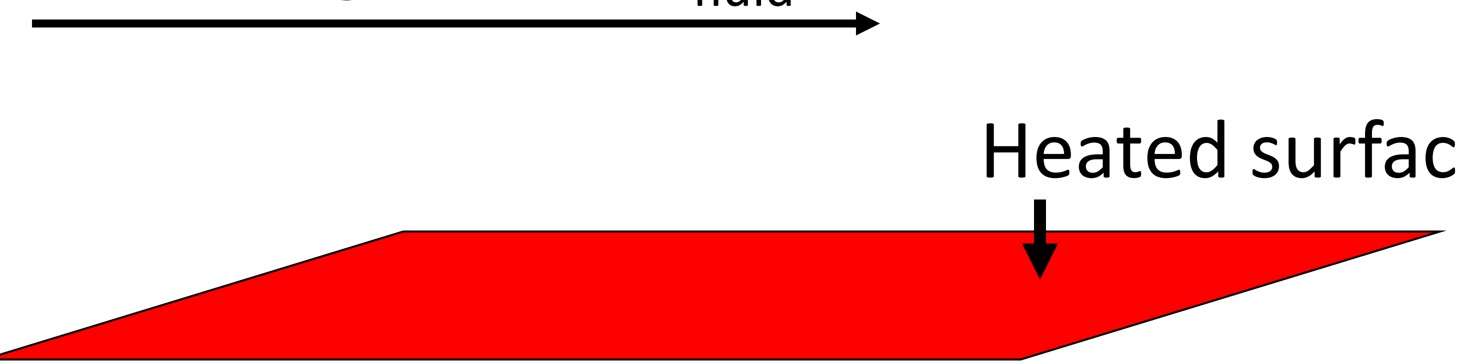


Convection currents are set up when a pan of water is heated.

Convection: Newton's Law of Cooling

Flowing fluid at T_{fluid}

Heated surface at $T_{surface}$

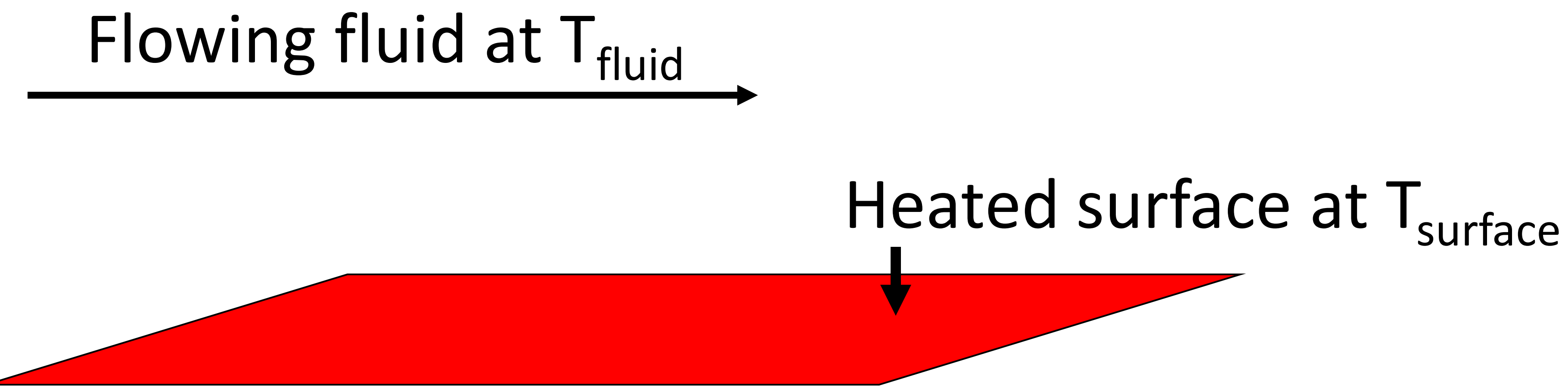


$$\dot{Q}_{conv.} = h\,A\,(T_{surface} - T_{fluid})$$

Area exposed

Heat transfer coefficient (in $W/m^2.K$)

Convection: Newton's Law of Cooling



$$\dot{Q}_{conv.} = \frac{T_{surface} - T_{fluid}}{1/(hA)}$$

Convective heat resistance (in k/W)

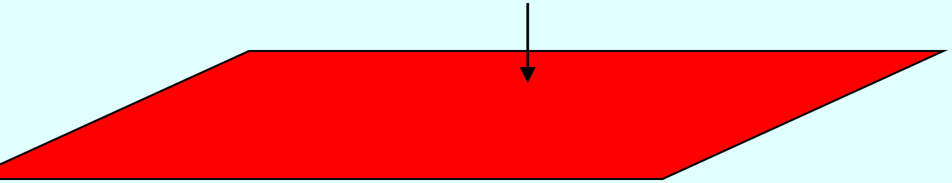
Example 3

The convection heat transfer coefficient between a surface at 50^oC and ambient air at 30^oC is 20 $W/m^2.K$. Calculate the heat flux leaving the surface by convection.

Solution:

Flowing fluid at T_{fluid} = 30^oC

Heated surface at $T_{surface}$ = 50^oC



$h = 20\ W/m^2.K$

Use Newton's Law of cooling :

$$\dot{Q}_{conv.} = h\,A\,(T_{surface} - T_{fluid})$$

$$= (20\ W/m^2.K) \times A \times (50-30)^oC$$

Heat flux leaving the surface:

$$\frac{\dot{Q}_{conv.}}{A} = 20 \times 20 = 400\ W/m^2$$

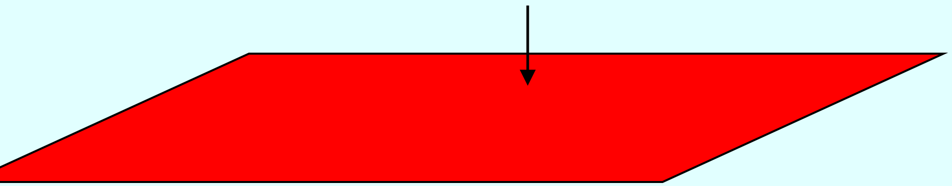
Example 4

Air at 300°C flows over a flat plate of dimensions 0.50 m by 0.25 m. If the convection heat transfer coefficient is 250 $W/m^2.K$, determine the heat transfer rate from the air to one side of the plate when the plate is maintained at 40°C.

Solution:

Flowing fluid at $T_{fluid} = 300^oC$

Heated surface at $T_{surface} = 40^oC$



$h = 250\ W/m^2.K$

$A = 0.50x0.25\ m^2$

Use Newton's Law of cooling :

$$\dot{Q}_{conv.} = h A (T_{surface} - T_{fluid})$$

$$= 250\ W/m^2.K \times 0.125\ m^2 \times (40 - 300)^oC$$

$$= -8125\ W/m^2$$

Heat is transferred from the air to the plate.

Radiation

Radiation is the process in which energy is transferred by means of electromagnetic waves of wavelength band between 0.1 and 100 micrometers solely as a result of the temperature of a surface.

Heat transfer by radiation can take place through vacuum. This is because electromagnetic waves can propagate through empty space.

The Stefan–Boltzmann Law of Radiation

$$\frac{Q}{t} = \varepsilon \sigma A T^4$$

ε = emissivity, which takes a value between 0 (for an ideal reflector) and 1 (for a black body).

σ = $5.668 \times 10^{-8}\ W/m^2.K^4$ is the Stefan-Boltzmann constant

A = surface area of the radiator

T = temperature of the radiator in Kelvin.

If object at temperature T is surrounded by an environment at temperature T_0, the net radioactive heat flow is:

$$\frac{Q}{t} = \varepsilon \sigma A (T^4 - T_o^4)$$

T^4 → Temperature of the radiating surface

T_o^4 → Temperature of the environment

Example 5

What is the rate at which radiation is emitted by a surface of area 0.5 m^2, emissivity 0.8, and temperature 150°C?

Solution:

$$\frac{Q}{t} = \varepsilon \sigma A T^4$$

- ε → 0.8
- σ → 5.67×10^{-8} $W/m^2.K^4$
- A → 0.5 m^2
- T^4 → $[(273+150)\ K]^4$

$$\frac{Q}{t} = (0.8)(5.67 \times 10^{-8}\ W/m^2.K^4)(0.5\ m^2)(423\ K)^4$$

= 726 W