Heat Transfer: Conduction

Introduction to the topic of convection and advective heat transfer

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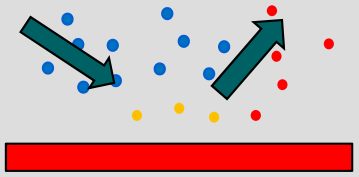
Learning goals

Introduction to convection:

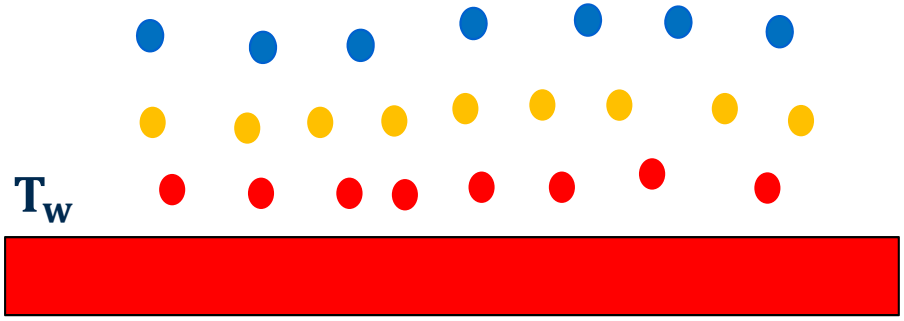
- What is convection?
- How are advection, conduction and convection related to each other?
- What is a heat transfer coefficient (HTC) and what does it relate to?



Introduction to convection

Conduction / heat diffusion in liquids and gases:

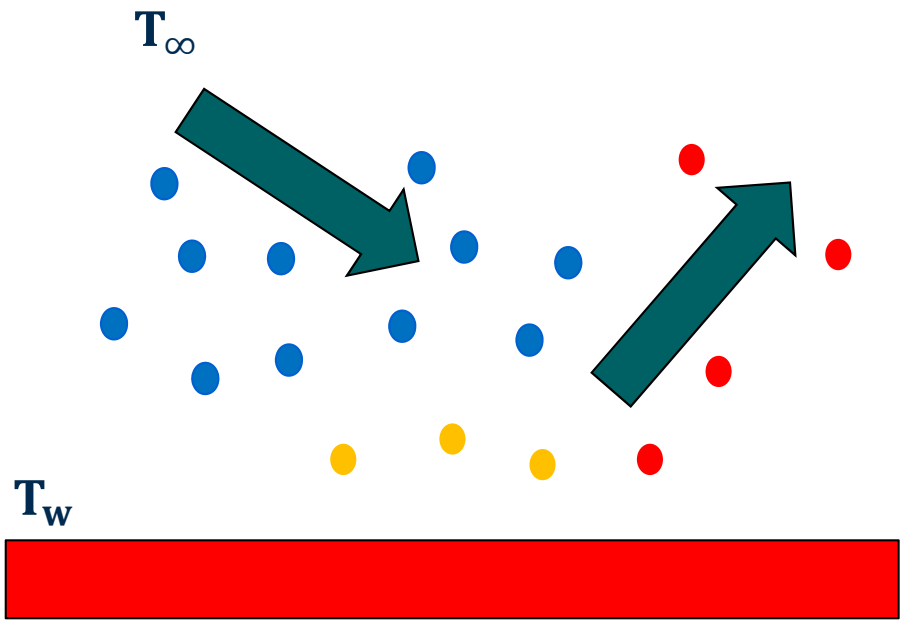
- Energy transfer by random motion of molecules (Brownian motion) in liquids and gases, transfer of thermal energy by collisions



Introduction to convection

Advection:

- Energy transfer by directed motion of molecules in liquids and gases

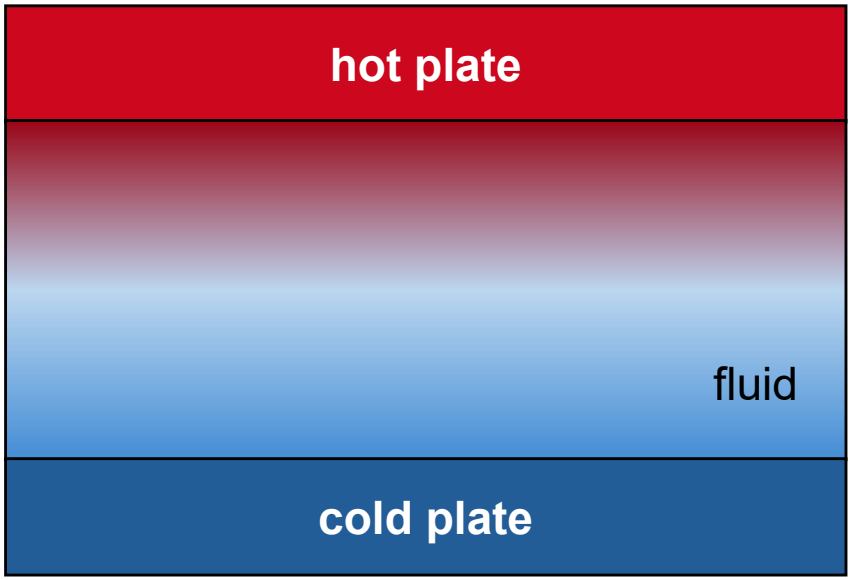


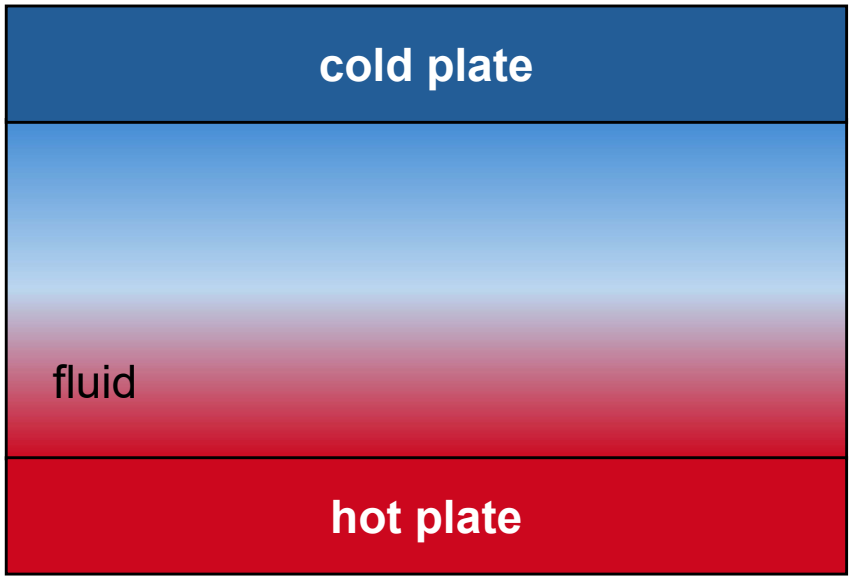
Convection:

- Describes the transfer of energy by the advective motion of molecules and the conductive heat transfer between molecules by collisions

Stable vs. unstable liquid layers

Comparison of pure heat conduction and Rayleigh-Bénard convection:

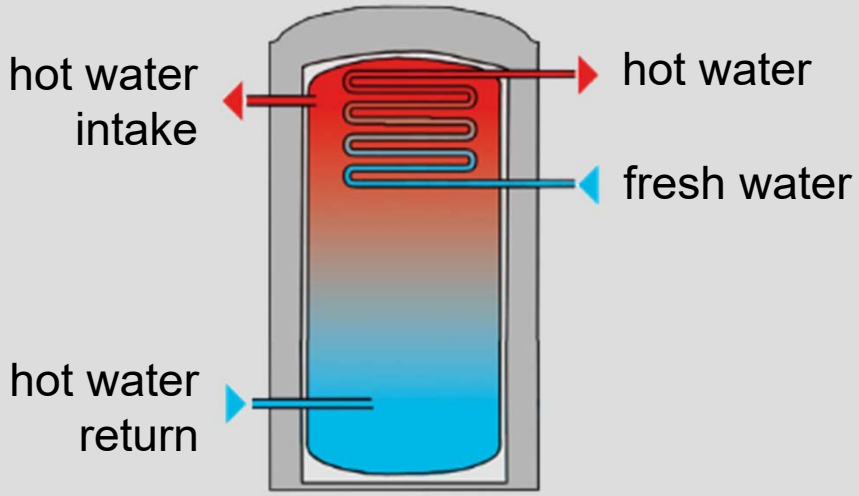




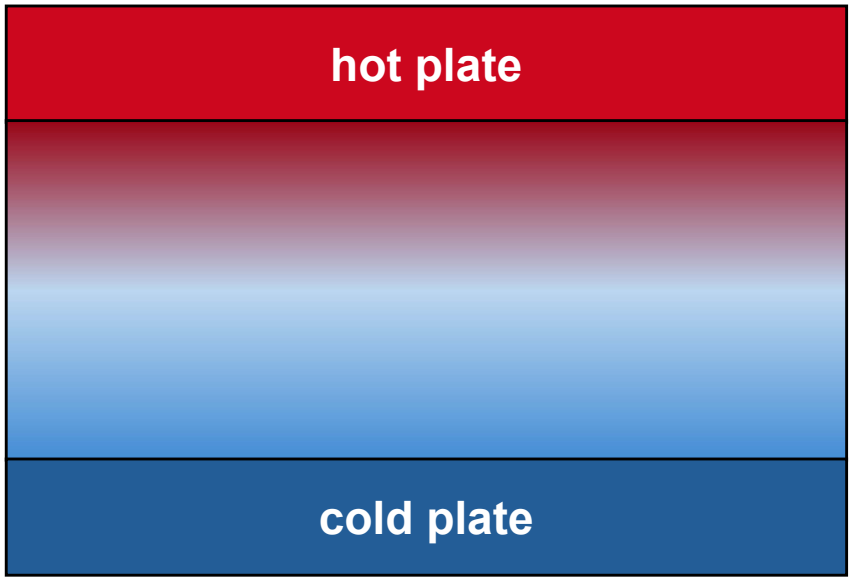
Stable liquid layer

Comparison of pure heat conduction and Rayleigh-Bénard convection:

Example: Hot water tank



- In hot water tank there is intermediate storage of heat in case when hot water is needed



https://www.heizsparer.de/heizung/warmwasseraufbereitung/warmwasserspeicher

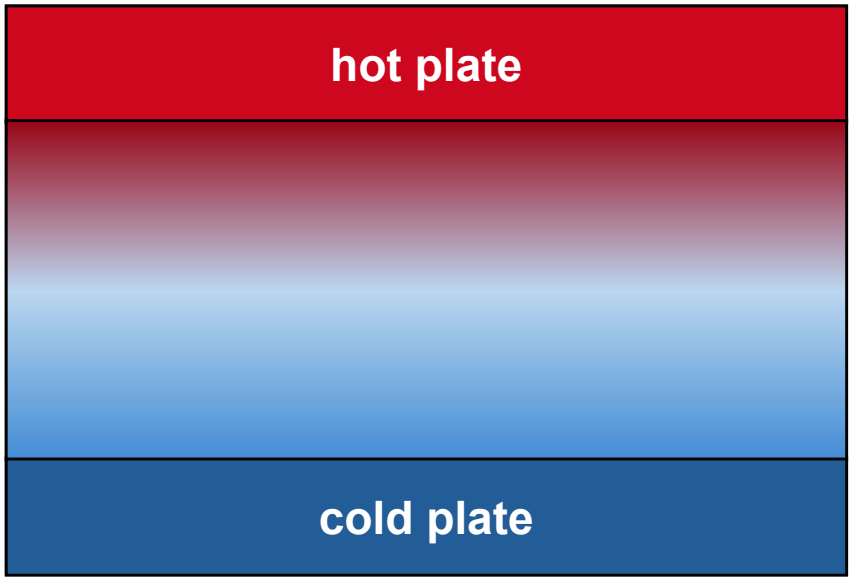
Stable liquid layer

Comparison of pure heat conduction and Rayleigh-Bénard convection:

Simple heat conduction:

- Due to the lower density of the warm liquid, a stable stratification is created.
  Warm fluid remains at the top and the cold fluid at the bottom.
- A motion of the liquid does not occur

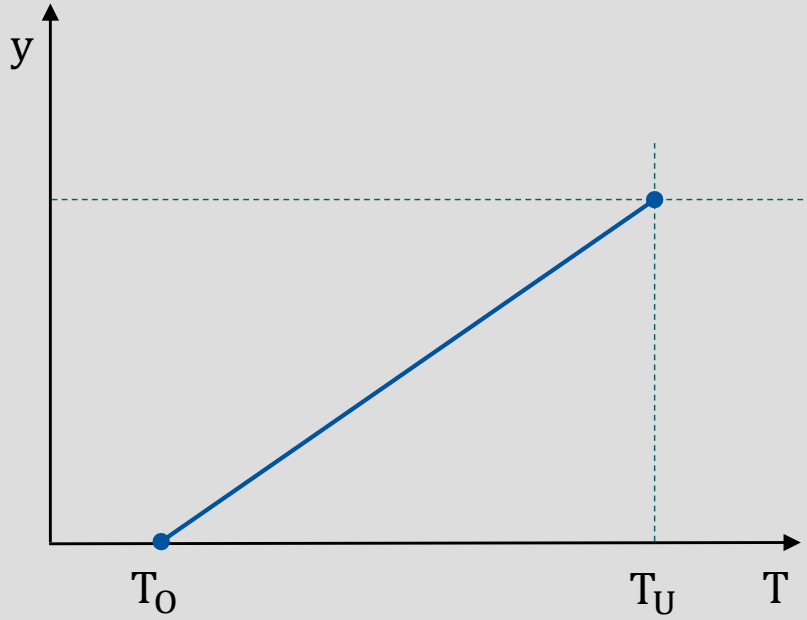
$\Longrightarrow$ The heat is transported downwards only by heat conduction.

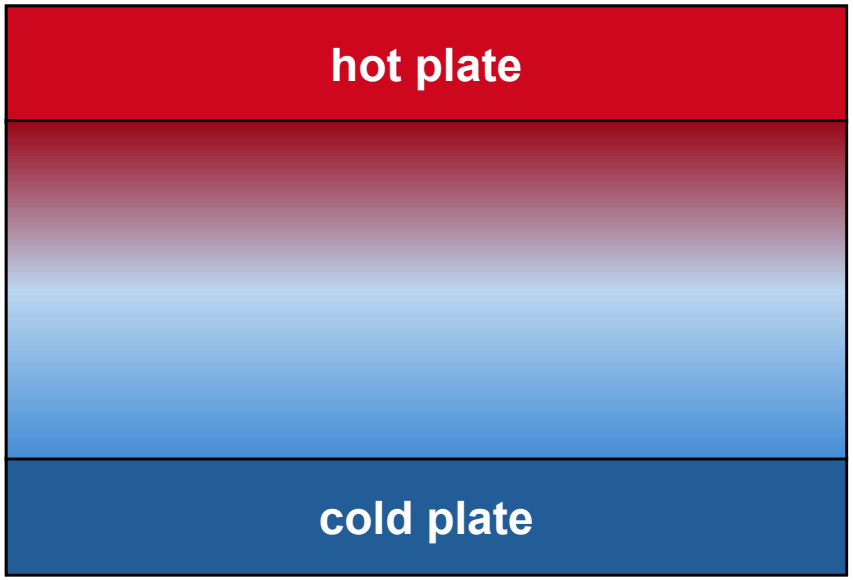


Temperature profile in a stable liquid layer

Comparison of pure heat conduction and Rayleigh-Bénard convection:

Temperature profile:

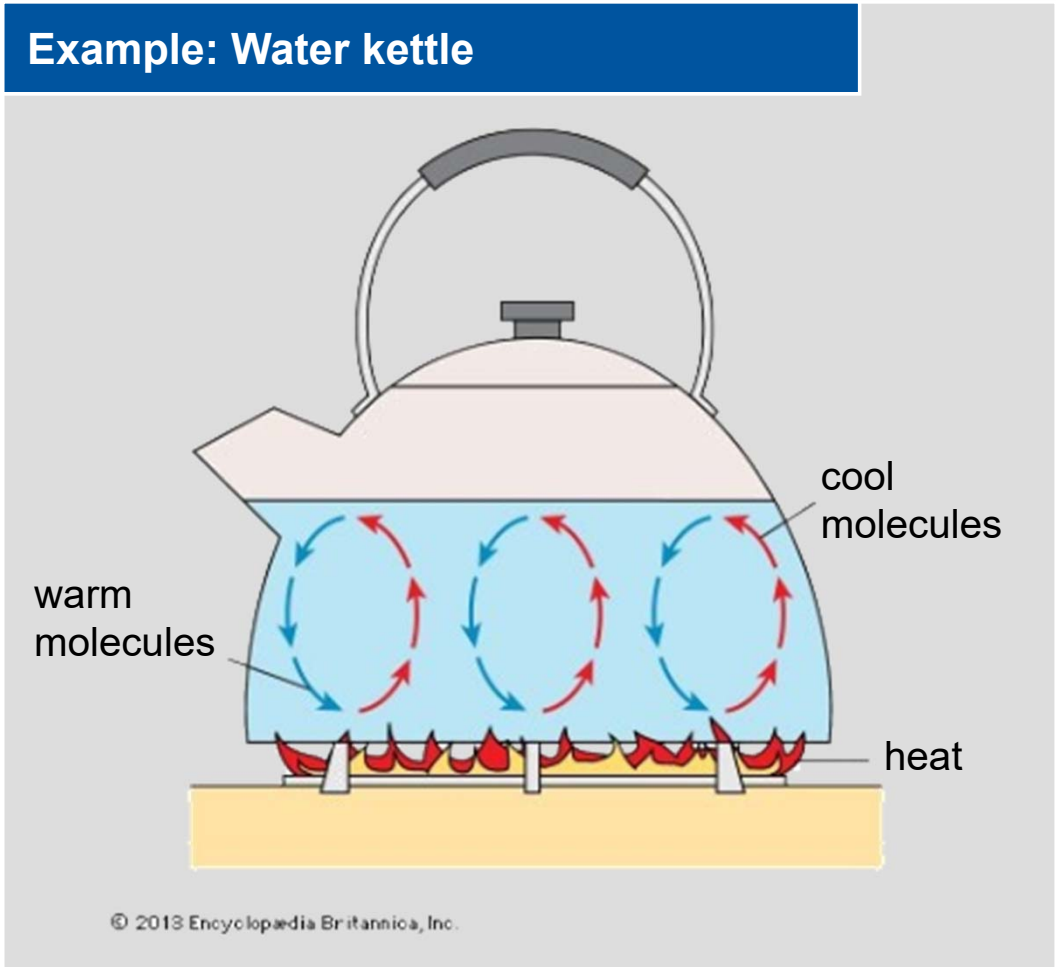


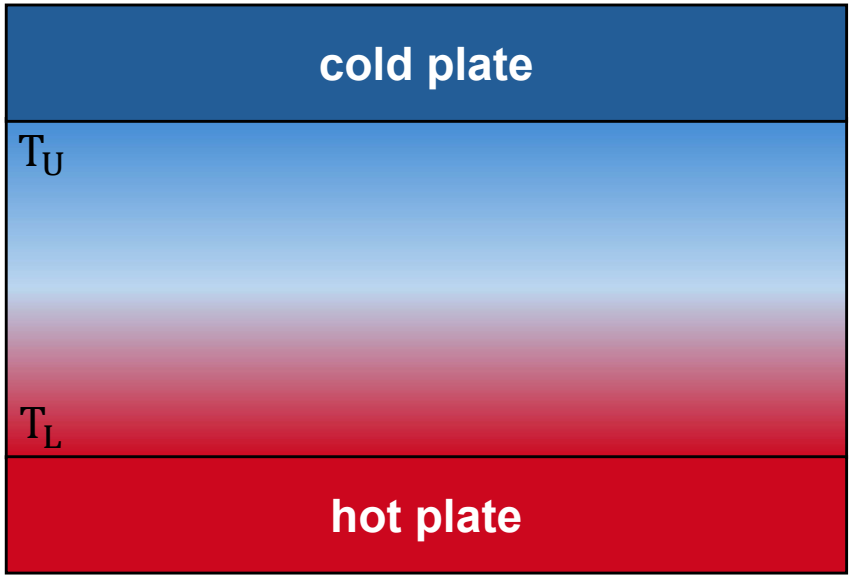


Heat induced fluid motion (natural convection)

Comparison of pure heat conduction and Rayleigh-Bénard convection:

Example: Water kettle





https://taylorsciencegeeks.weebly.com/blog/convection

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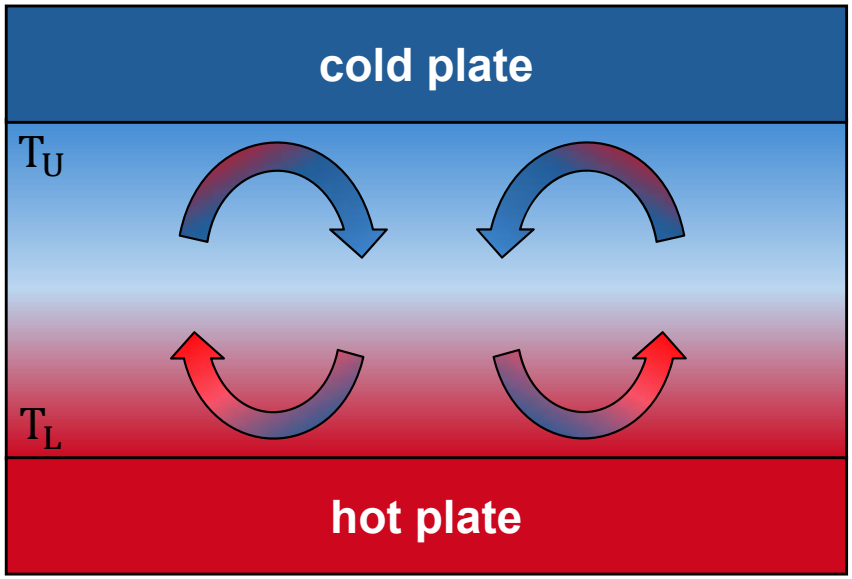
Comparison of pure heat conduction and Rayleigh-Bénard convection:

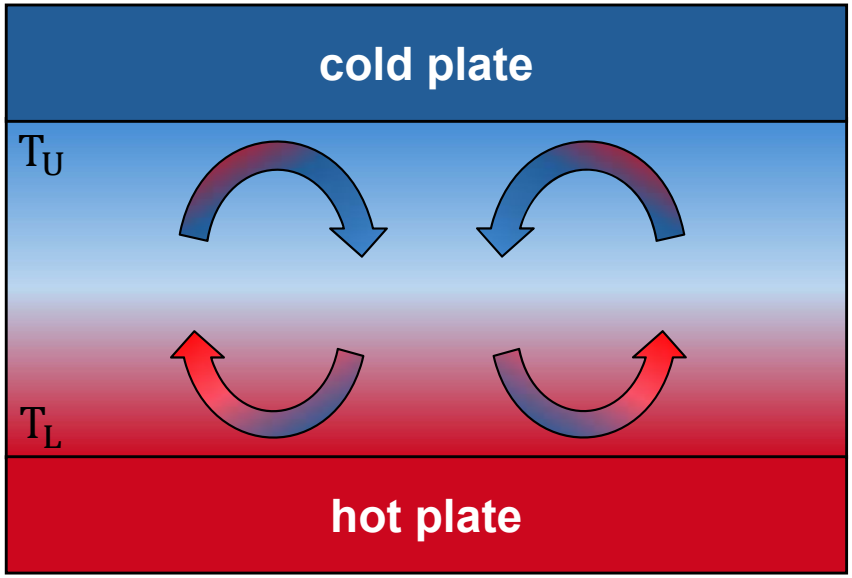
Rayleigh-Bénard convection:

- Fluid heats up at the hot plate and rises, cools down again at the cold plate and descends again due to the increased density.
- Fluid motion is formed naturally in the fluid.

$\Longrightarrow$ The heat is transported from the bottom to the top by advection and conduction



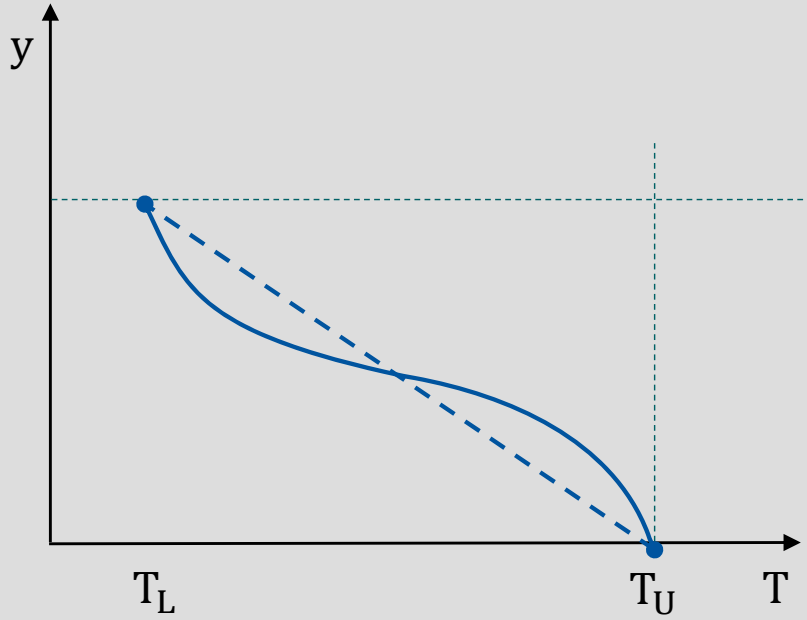
Comparison of pure heat conduction and Rayleigh-Bénard convection:

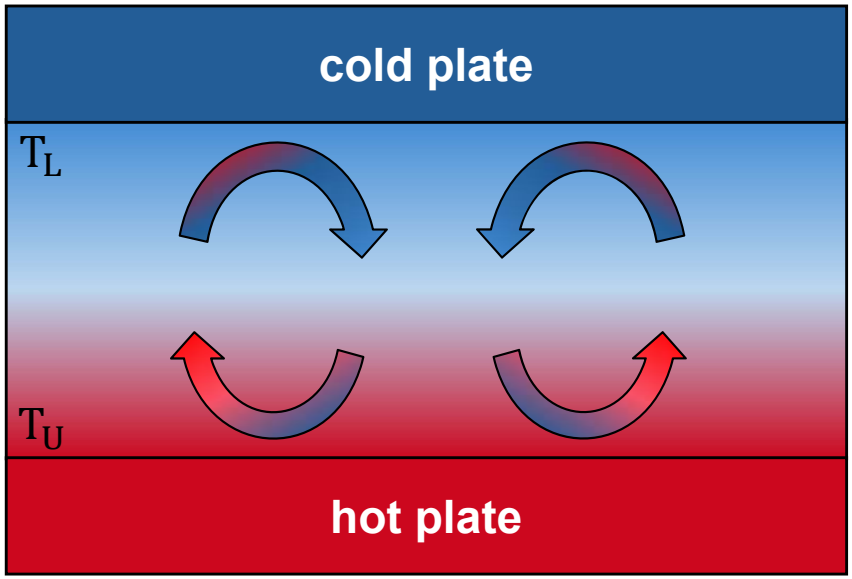


Temperature profile with Rayleigh-Bénard convection

Comparison of pure heat conduction and Rayleigh-Bénard convection:

Temperature profile:





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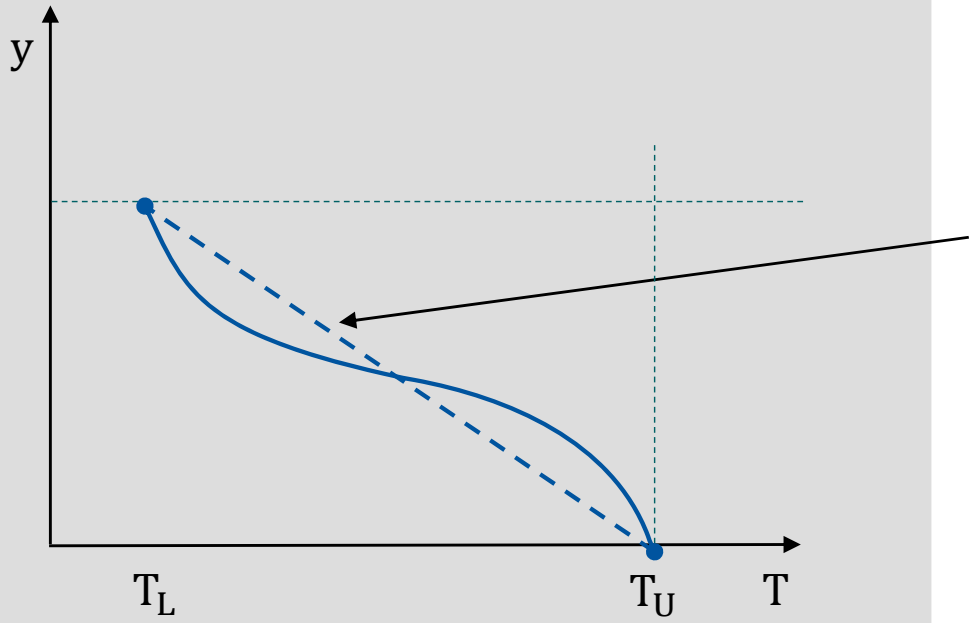


Gradient in the case of pure heat conduction is significantly lower, i.e. overall less heat is transported from the hot to the cold plate.

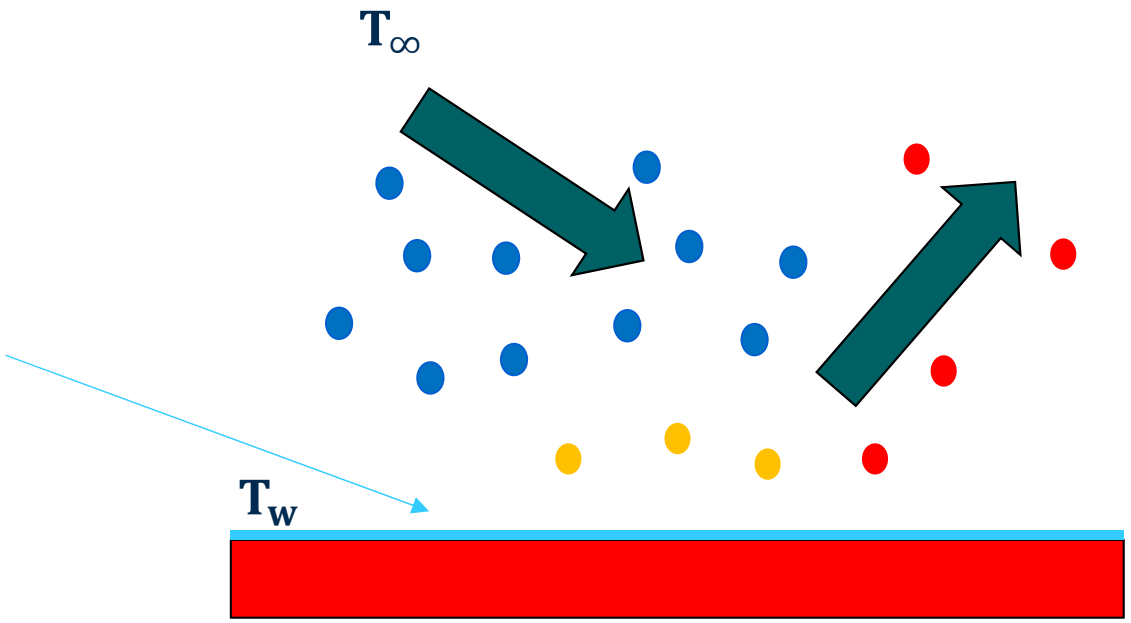
How can we describe the heat transferred by convection?

Heat flow by convection:

$$\dot{Q} = \alpha A \, (T_W - T_\infty)$$

Explanation:

A:	Area for convective transport $[\mathrm{m}^2]$
$(\mathrm{T_w} - \mathrm{T_\infty})$:	Temperature difference between wall with $\mathrm{T_w}$ and fluid with $\mathrm{T_\infty}$
α:	**Heat Transfer Coefficient** $\left[\frac{\mathrm{W}}{\mathrm{m^2 K}}\right]$



Comprehension questions

What is convection and how can it be described empirically?

What is the shape of the temperature profile close to the wall on the fluid side due to convection?

What is the meaning of the heat transfer coefficient (HTC)?