Today's Session Summary

- Temperature - Heat

- Heat Capacity

- Heat Conduction

- Thermal contact resistance

- Materials

- Natural Convection

UNIVERSIDAD
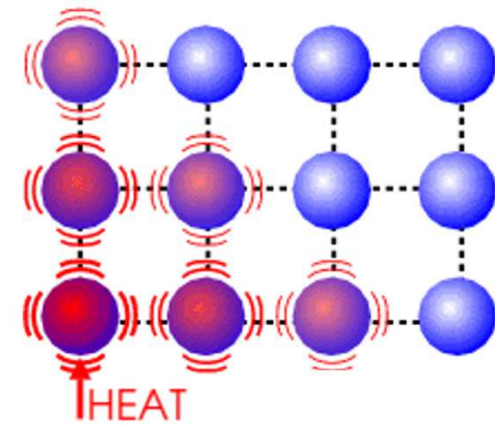**TORCUATO DI TELLA**

Temperature - Heat

Scales
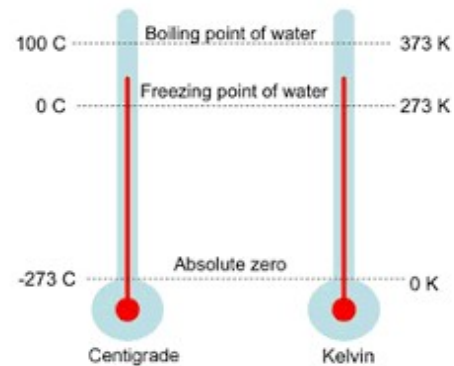
Celsius

0C: Water Freezing
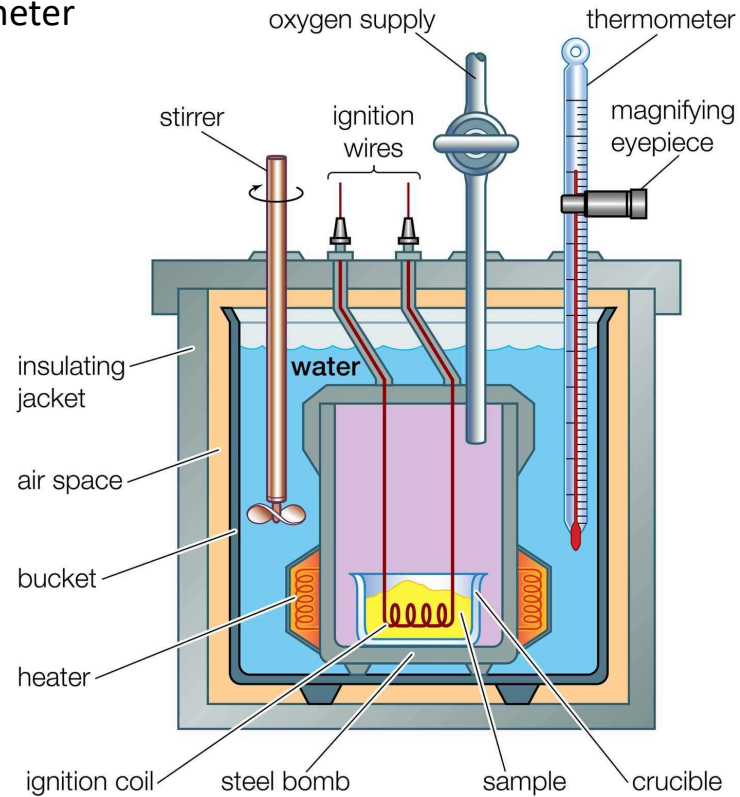
100C: Water Boiling

Kelvin

Absolute 0: -273C

1C=1K

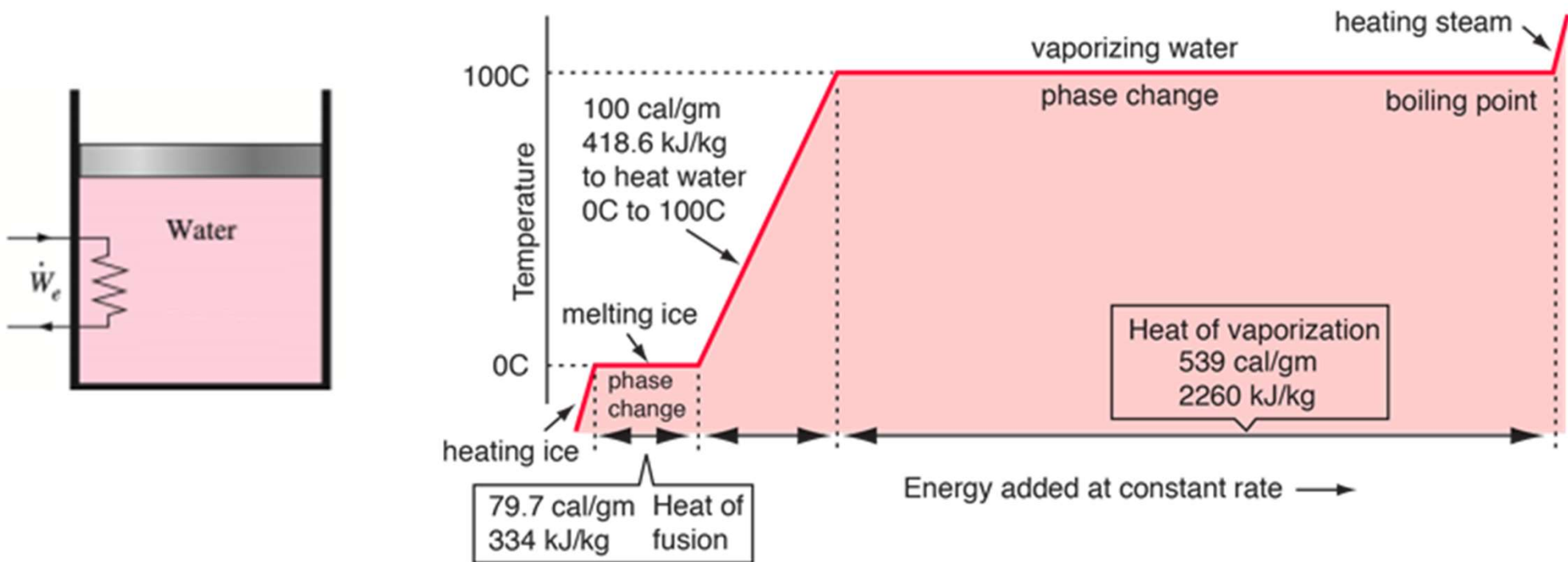# Heat Capacity

Calorimeter

Energy release $mC\Delta T = Q$

Instantaneously $mC\dfrac{dT}{dt} = \dfrac{dQ}{dt}$

$$mC\dot{T} = \dot{Q}$$

Substance	Specific Heat Capacity, C (J/g·°C)
Water (liquid)	4.184
Ice at 0°C	2.010
Steam at 100°C	1.996
Aluminum	0.902
Chromium	0.461
Lead	0.128
Magnesium	1.020
Mercury	0.140
Tin	0.213
Zinc	0.387

From Equations to Innovation:
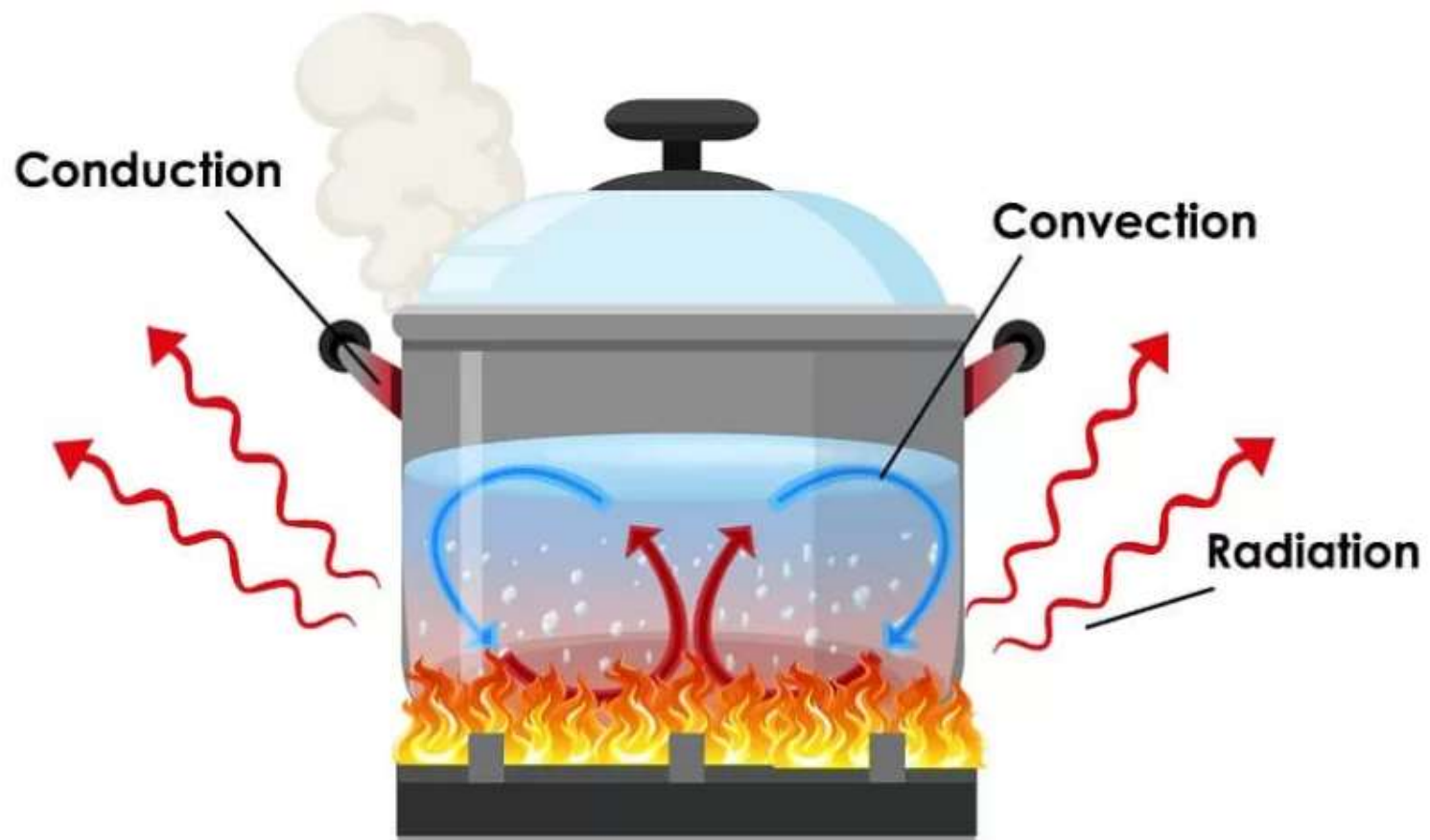Modeling and Optimization in Engineering

Phase Changes

Practice

How much energy do I need to boil pasta?

Ambient Temperature: 20C

Cooking time: 10 min

$$mC\Delta T = Q$$

Heat Transfer Methods

Heat Conduction

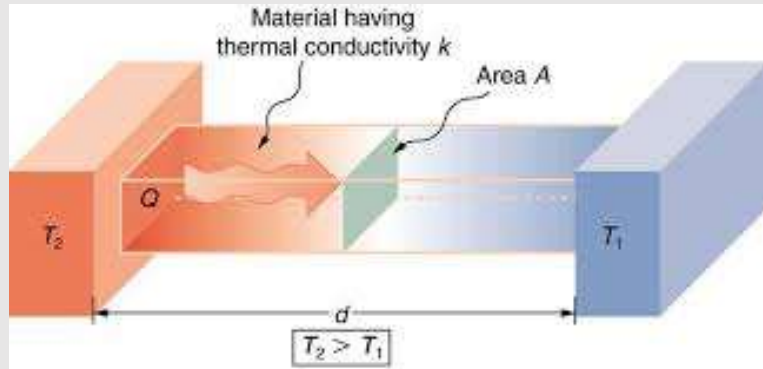Metal   Atom

Atoms are energised and start vibrating   Heat

Heat and vibrations spread

Material having thermal conductivity k Area A

$T_2 > T_1$

Heat Sources

$$k \frac{T_2 - T_1}{d} A = \dot{Q}$$

$$Q[w]; \; k \left[\frac{w}{K\,m}\right]; T[K]; A[m^2]$$
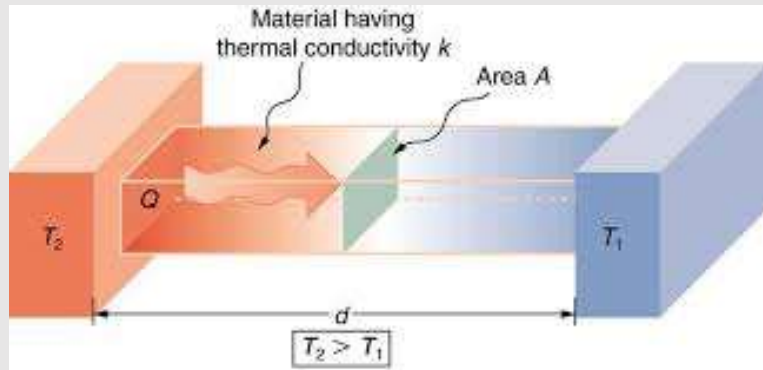
$$k \frac{dT}{dx} A = \dot{Q}$$

Fourier Law

UNIVERSIDAD
TORCUATO DI TELLA

From Equations to Innovation:
Modeling and Optimization in Engineering

Practice

Material having thermal conductivity k

Area A

Q

T_2

T_1

d

$T_2 > T_1$

$$k \frac{T_2 - T_1}{d} A = \dot{Q}$$

Material	Thermal Conductivity (W/mK)
Silver	406
Copper	385
Gold	314
Brass	109
Aluminum	205
Iron	79.5
Steel	50.2
Lead	34.7
Ice	1.6
Glass	0.8
Water at 20° C	0.6
Wool felt	0.04
Styrofoam	0.033
Wood	0.12-0.04
Air at 0° C	0.024

Determine the heat transferred by an isolated 5cm x 5cm x 5cm square section rod.
Evaluate Copper and Styrofoam as materials.
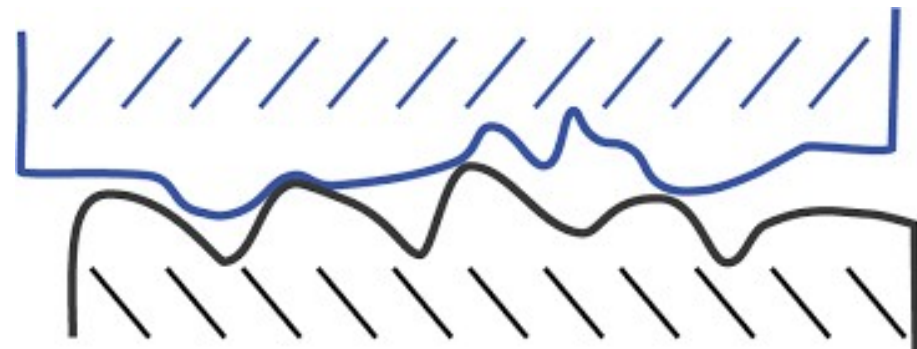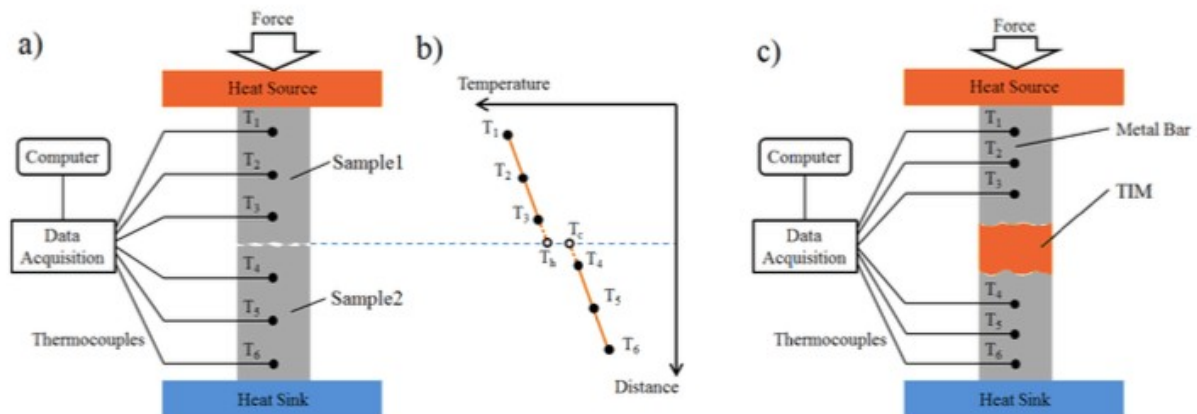
UNIVERSIDAD
TORCUATO DI TELLA

Practice

$$k \frac{T_2 - T_1}{d} A = \dot{Q}$$

What Happens if combined 1cm Copper, 3cm Styrofoam and 1cm Copper?

$$k_{Cu} \frac{T_{High} - T_{intermediate\ 1}}{d_{Cu}} A = k_S \frac{T_{Intermediate\ 1} - T_{intermediate\ 2}}{d_S} A = k_{Cu} \frac{T_{Intermediate\ 2} - T_{Low}}{d_{Cu}} A = \dot{Q}$$

Thermal Contact Resistance

UNIVERSIDAD
TORCUATO DI TELLA

Practice - Thermal Contact Resistance

CPU Operating Temperature: 80C

Power: 253 W

Air Temperature: 30C

Air gap: 0,1mm

Coper thickness: 0,1mm

Area:0,0025m^2

Determine Q

$$k_{Cu} \frac{T_{High} - T_{intermediate\ 1}}{d_{Cu}} A = k_{air} \frac{T_{Intermediate\ 1} - T_{intermediate\ 2}}{d_{air}} A = k_{Cu} \frac{T_{Intermediate\ 2} - T_{Low}}{d_{Cu}} A = \dot{Q}$$

Practice - Thermal Contact Resistance

Thermal Interface material

CPU Operating Temperature: 80C

Power: 253 W

Air Temperature: 30C

Air gap: 0,1mm

Coper thickness: 0,1mm
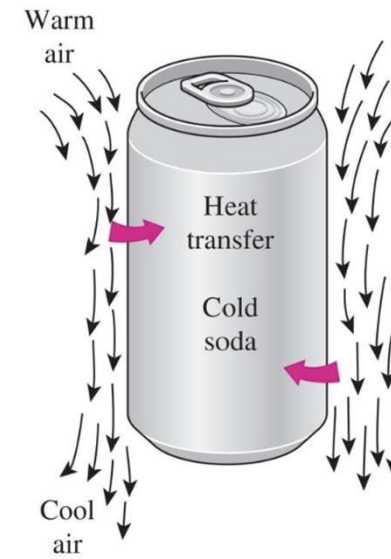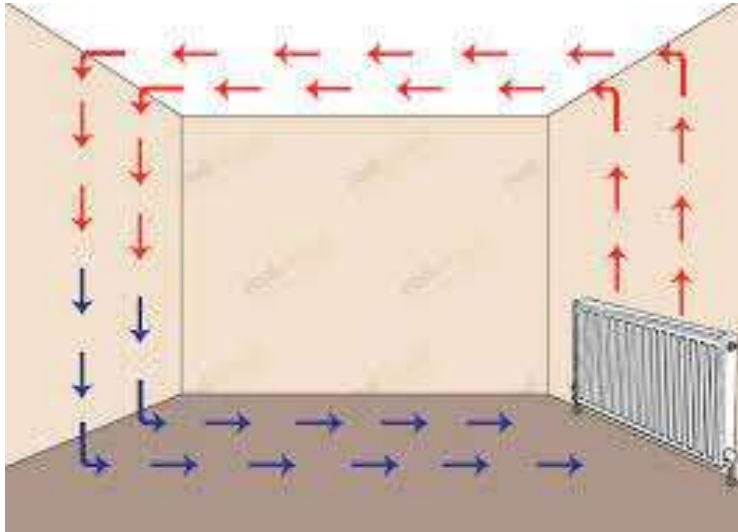
Grease conductivity: 7,5w/K/m
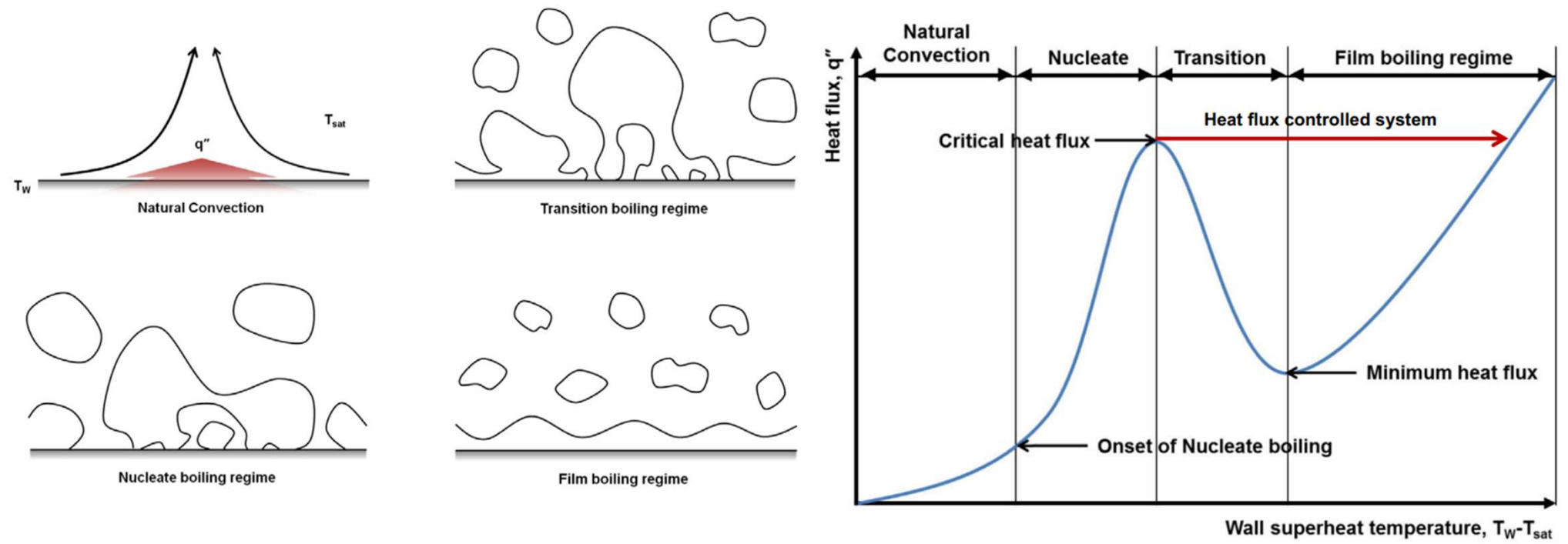
Area:0,0025m^2

Determine Q

$$k_{Cu} \frac{T_{High} - T_{intermediate\ 1}}{d_{Cu}} A = k_{grease} \frac{T_{Intermediate\ 1} - T_{intermediate\ 2}}{d_{grease}} A = k_{Cu} \frac{T_{Intermediate\ 2} - T_{Low}}{d_{Cu}} A = \dot{Q}$$
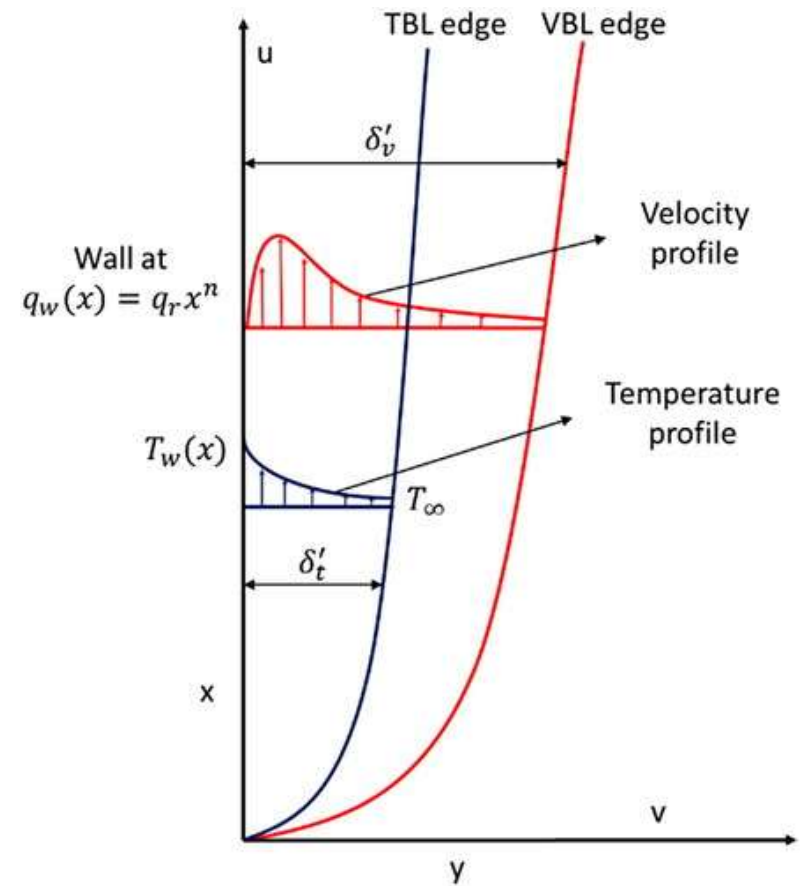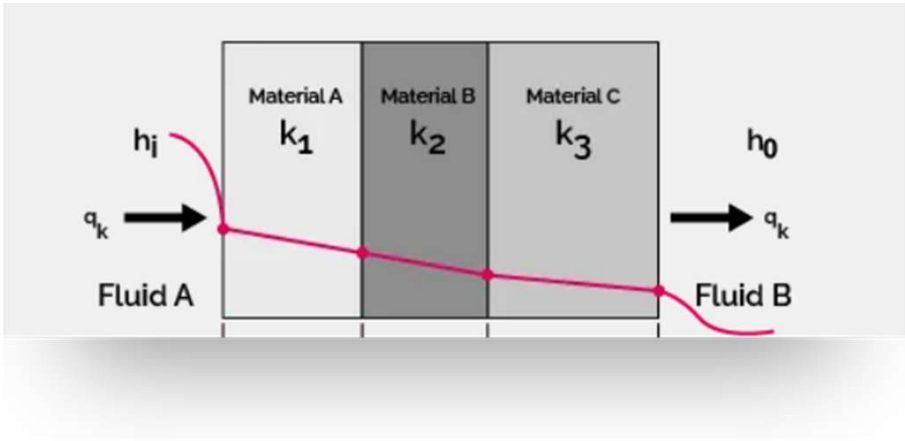
UNIVERSIDAD
TORCUATO DI TELLA

Natural Convection

UNIVERSIDAD
TORCUATO DI TELLA

Natural Convection

UNIVERSIDAD
TORCUATO DI TELLA

Natural Convection

Newton's Cooling Equation

$$\dot{Q}_c = h_c(T - T_\infty)$$

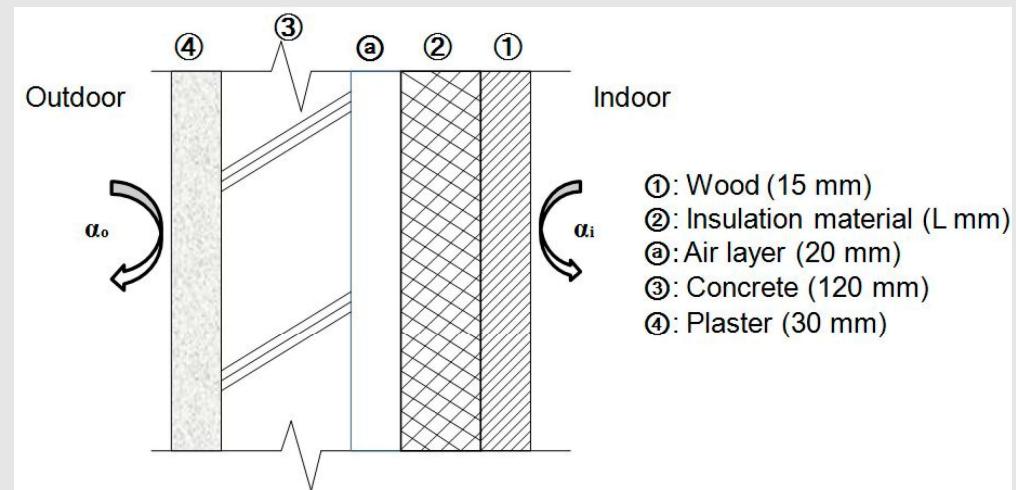| Conditions of heat transfer	W/(m²K)
Gases in free convection	5–37
Water in free convection	100–1200
Oil under free convection	50–350
Gas flow in tubes and between tubes	10–350
Water flowing in tubes	500–1200
Oil flowing in tubes	300–1700
Molten metals flowing in tubes	2000–45000
Water nucleate boiling	2000–45000
Water film boiling	100–300
Film-type condensation of water vapor	4000–17000
Dropsize condensation of water vapor	30000–140000
Condensation of organic liquids	500–2300

Wall Isolation

Inside Air Temperature: 24C

Inside Air Temperature: 10C

Outdoor convective heat transfer coefficient: 31.45 w/m2/K

Indoor convective heat transfer coefficient: 24.92 w/m2/K

Determine heat lost per hour and surface area

①: Wood (15 mm)
②: Insulation material (L mm)
ⓐ: Air layer (20 mm)
③: Concrete (120 mm)
④: Plaster (30 mm)

Building Material	Thermal Conductivity (k) [W/mK]	Density (ρ) [kg/m³]	Specific Heat (Cp) [J/kgK]
Wood	0.179	530	2300
Expanded polystyrene	0.037	16	1340
Glass wool	0.051	10	837
Wood cement board	0.16	680	1675
Air layer	0.026	1.2	1006
Concrete	0.9	2000	879
Plaster	0.43	1250	1050

End Session 18

UNIVERSIDAD
TORCUATO DI TELLA