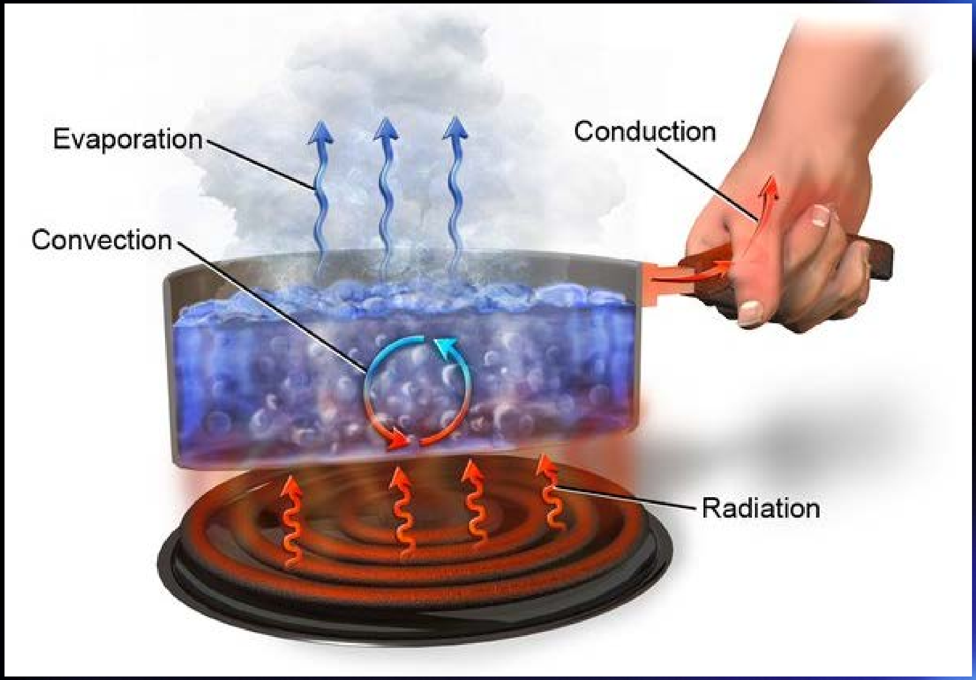
Lecture #1

Energy & Heat Transfer



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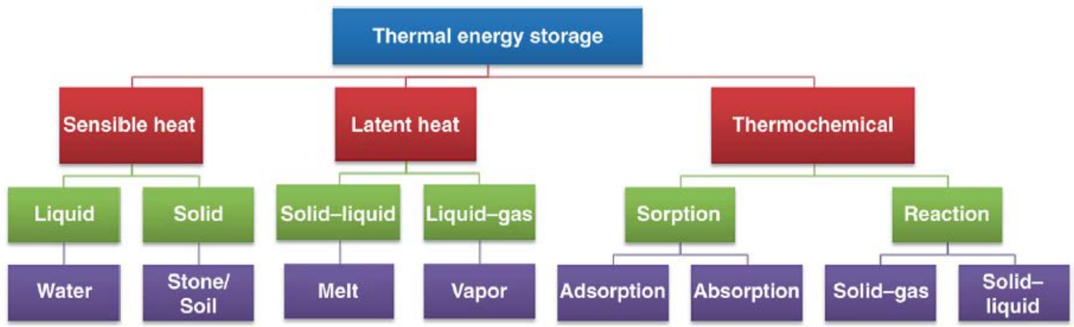
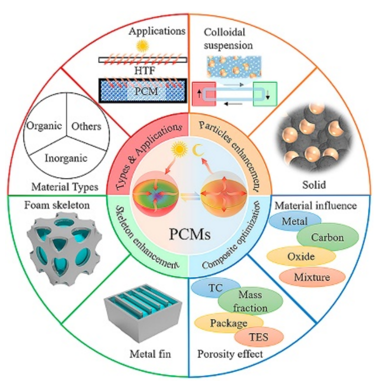
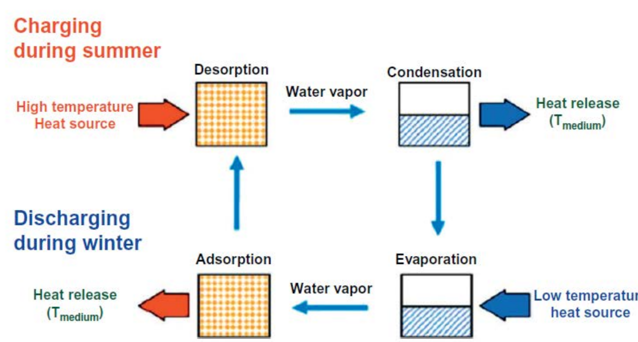
9/5/2022


WELCOME...
DR. M. MEHRALI (MOHAMMAD)
ASSISTANT PROFESSOR


Thermal energy storage
Sensible heat
Latent heat
Thermochemical
Liquid
Solid
Solid–liquid
Liquid–gas
Sorption
Reaction
Water
Stone/ Soil
Melt
Vapor
Adsorption
Absorption
Solid–gas
Solid–liquid


Applications
HTF
PCM
Colloidal suspension
Organic
Others
Inorganic
Material Types
Solid
Foam skeleton
Material influence
Metal
Carbon
Oxide
Mixture
PCMs
Types & Applications
Particles enhancement
Skeleton enhancement
Composite optimization
TC
Mass fraction
Package
TES
Metal fin
Porosity effect


Charging during summer
Desorption
Water vapor
Condensation
High temperature Heat source
Heat release (T_{medium})
Discharging during winter
Adsorption
Water vapor
Evaporation
Heat release (T_{medium})
Low temperature heat source

INTRODUCTION

Teacher

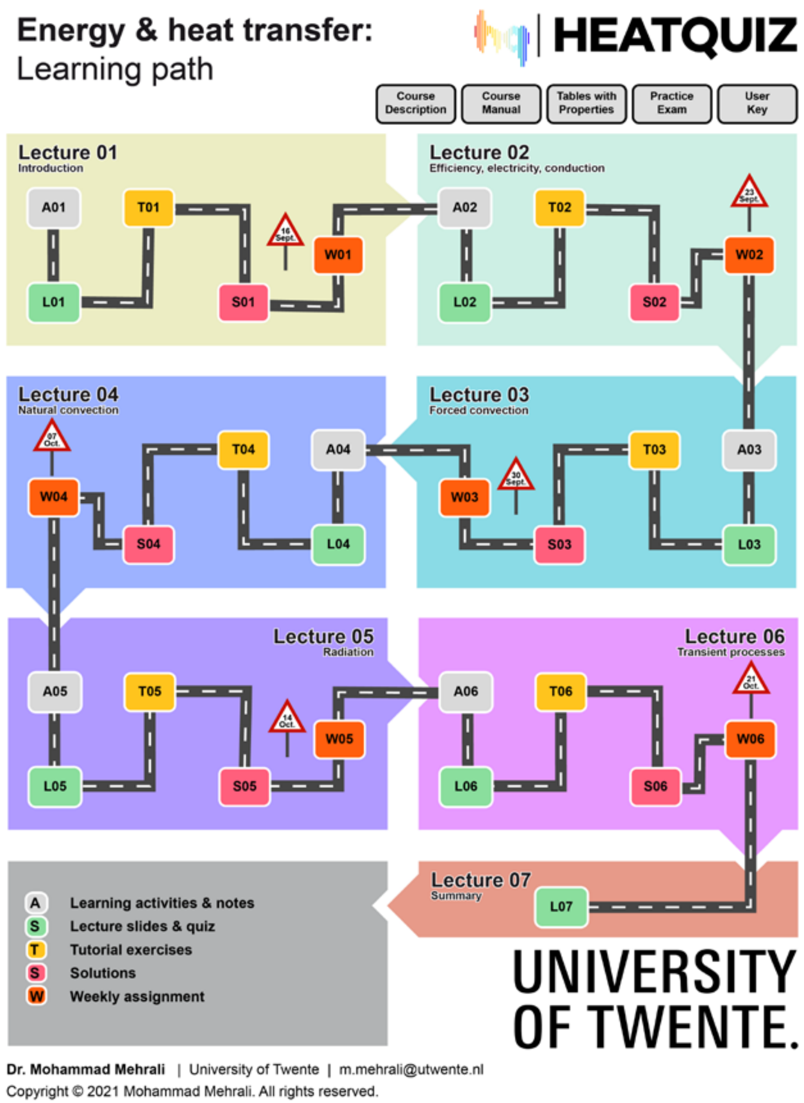
- Dr. Mohammad Mehrali (HR-N244, m.mehrali@utwente.nl)

Teaching assistants

- • Daan Kuiphuis (d.j.g.kuiphuis@student.utwente.nl)
- • Hidde van der Bijl (h.g.vanderbijl@student.utwente.nl)
- • Jochem den Os (j.c.denos@student.utwente.nl)

All information is available on CANVAS (**HEATQUIZ**)

HEATQUIZ



Energy & heat transfer:
Learning path
HEATQUIZ
Course Description
Course Manual
Tables with Properties
Practice Exam
User Key
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T01
L01
S01
W01
Lecture 02
Efficiency, electricity, conduction
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T02
L02
S02
W02
Lecture 03
Forced convection
A03
T03
L03
S03
W03
Lecture 04
Natural convection
A04
T04
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S04
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Lecture 05
Radiation
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Transient processes
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Summary
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A Learning activities & notes
S Lecture slides & quiz
T Tutorial exercises
S Solutions
W Weekly assignment
UNIVERSITY OF TWENTE.
Dr. Mohammad Mehrali | University of Twente | m.mehrali@utwente.nl
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Course organization

Fundamentals

Seven lectures (Online and on Campus) and Six Lectorials (On Campus)

- Study material: sheets &Book :

Y. A. Cengel & A. J. Ghajar. Heat and Mass Transfer: Fundamental & Application.

- Submit weekly assignments in groups.

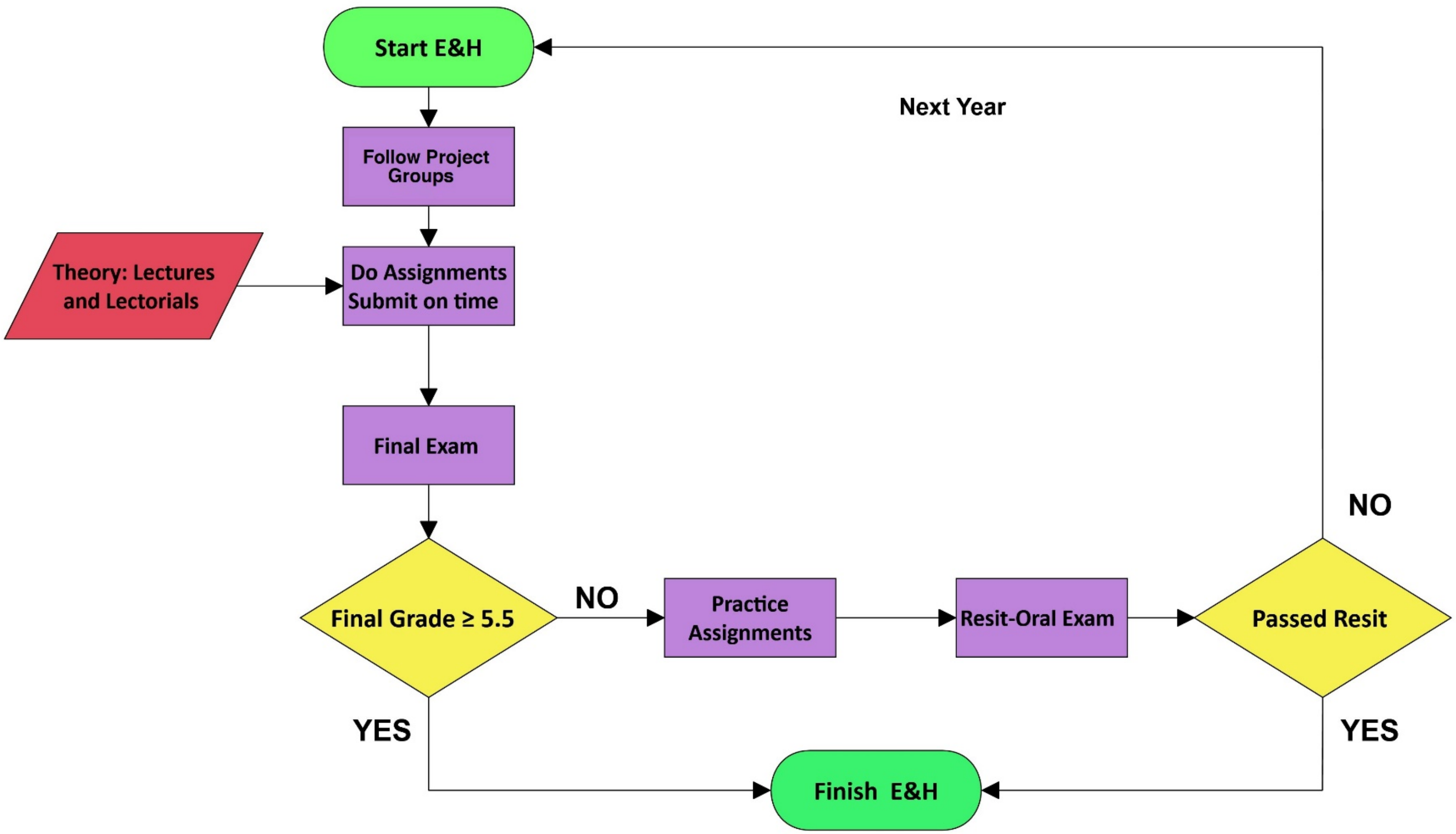
Application

- Assignments in same groups
- Extra gatherings

Finalizing

- Individual written exam (both calculations and understanding)

The “how-to-pass-E&HT” scheme



Grading

- **Final grade**
- 80% final exam (individual)- Monday 7th November
- 20 % of Weekly assignment(group mark)
- Extra 10% Lectorial assignment (Individual mark)

Requirements to Pass EHT ≥ 5.5

- It is required to obtain a minimum grade of ≥ 5.5 from the total grade (Final Exam+ Weekly Assignments+ Lectorial)

Resit Exam

- **Written Exam**
- 80% final exam (individual)- Monday 25th November
- 20 % of Weekly assignment(group mark)

- Bonus is not valid for Resit Exam

Course contents

Fundamentals (3 weeks)

Energy	1: Introduction, organization, work, energy forms, energy contents, power, units
	2a: Energy balance, efficiency, electricity
Heat Transfer	2b: Heat transfer through conduction
	3: Heat transfer through convection (forced)
	4: Heat transfer through convection (natural)
	5: Heat transfer through radiation + simultaneous heat transfer
	6: Time-dependent heat problems

Complete schedule (Manual & Rooster)

Course contents

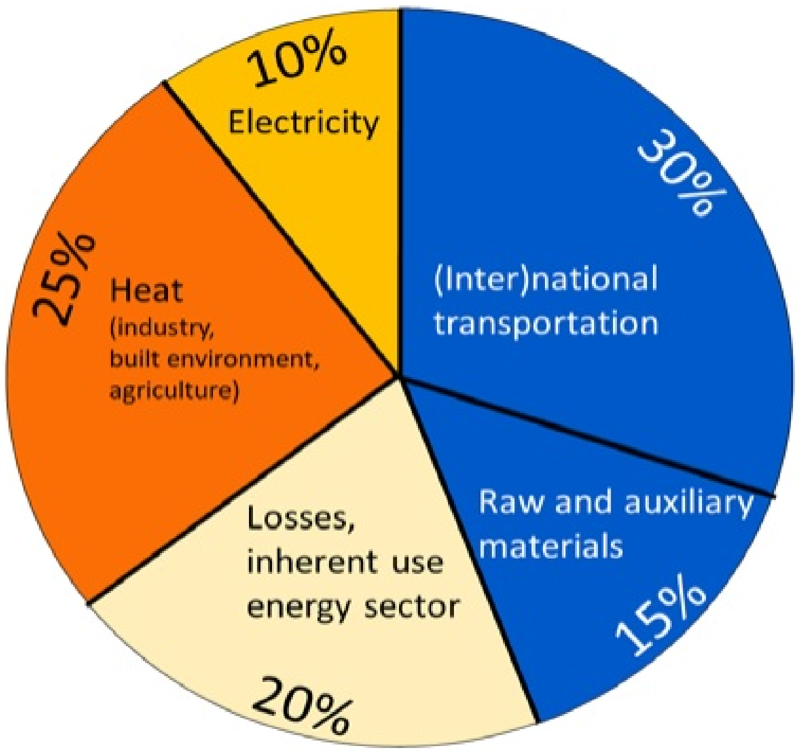
Additionally another 1 lecture:

Lecture	
7	Summary

Question hours : can be done in the class (scheduled) or by making appointment with Mohammad or student assistants

Why Energy and Heat Transfer?

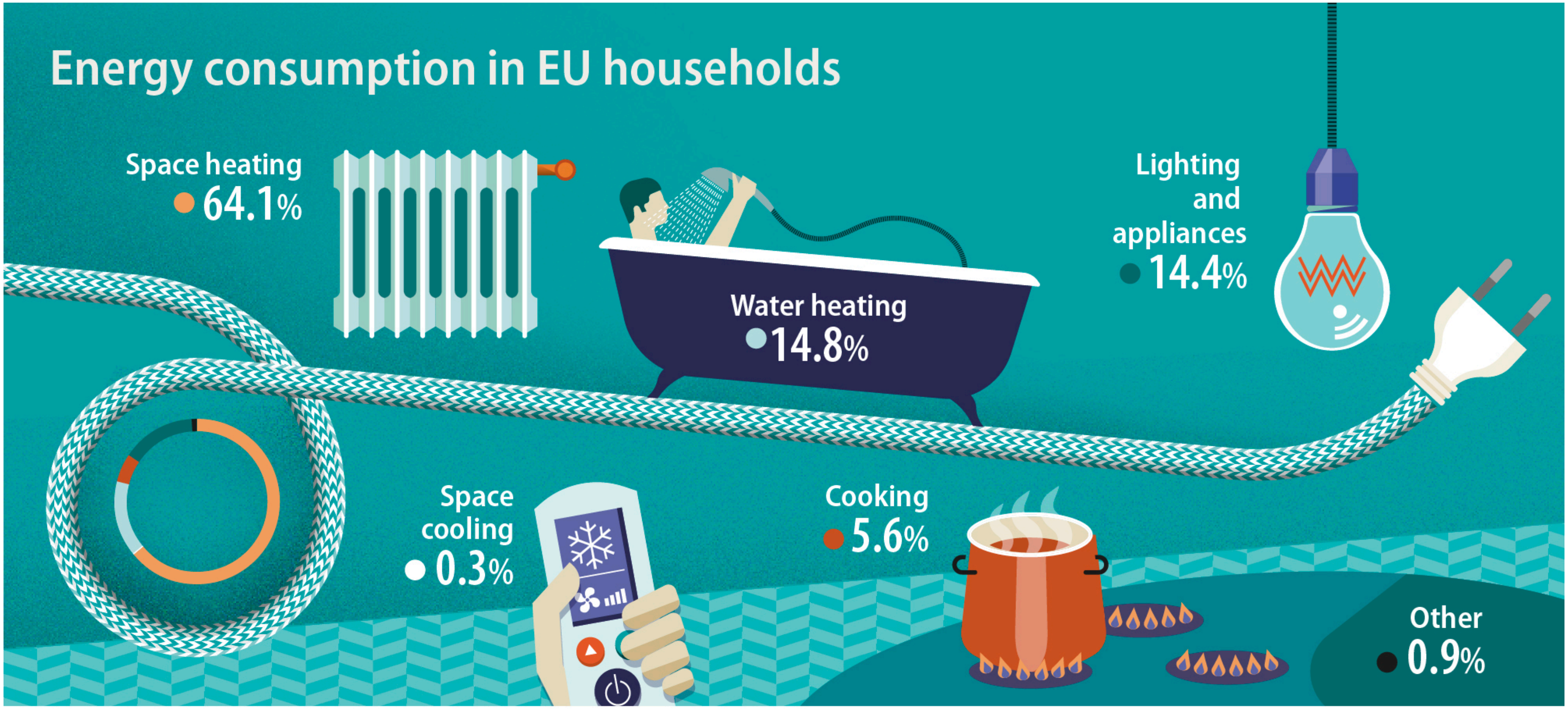
Dutch demand for energy in five domains. Source: CBS



Total use (2016): 3845 PJ

Figure 4. Dutch demand for energy in five domains. Source: CBS [13].

Why Energy and Heat Transfer?

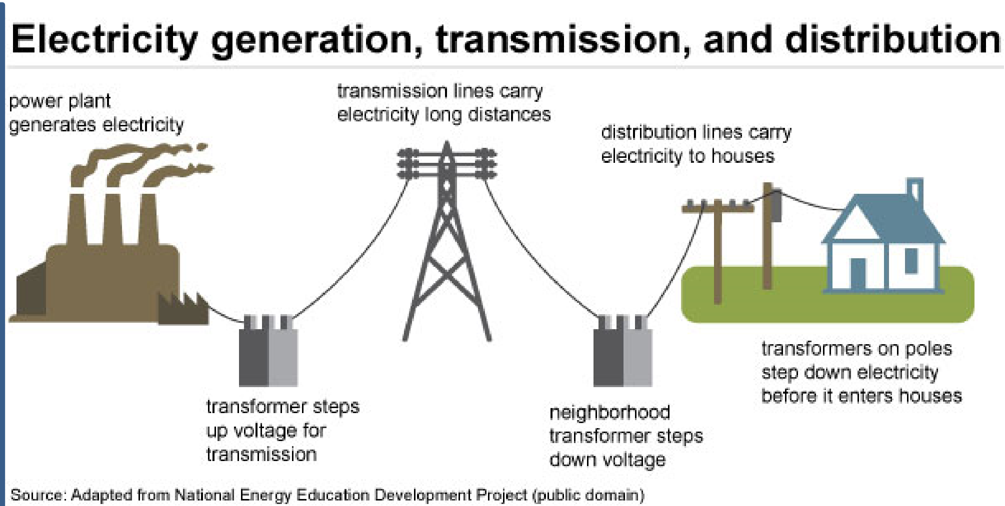


ec.europa.eu/eurostat

WHY ENERGY & HEAT TRANSFER?

84%

Fossil Fuels

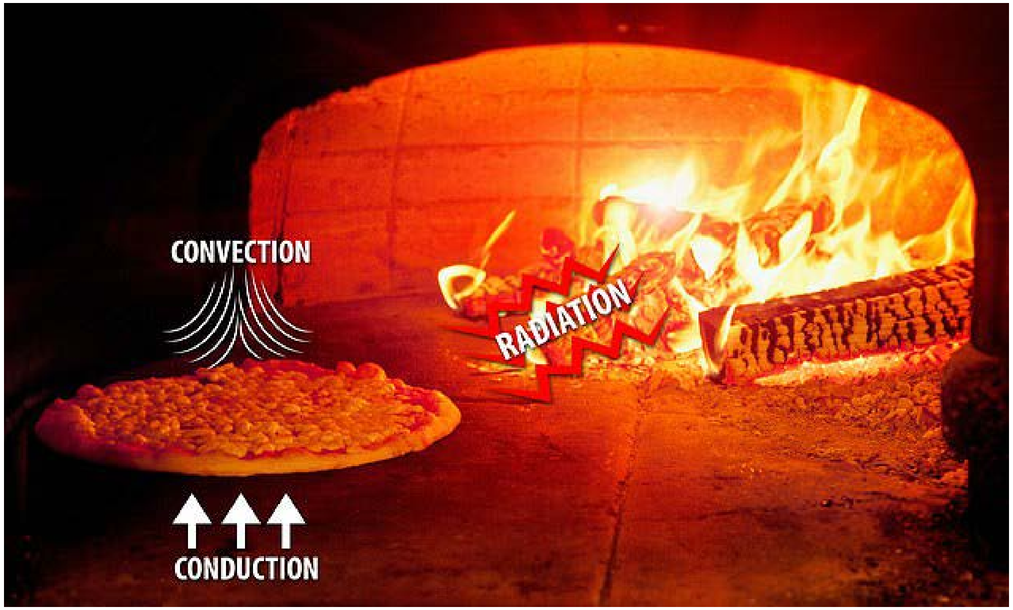


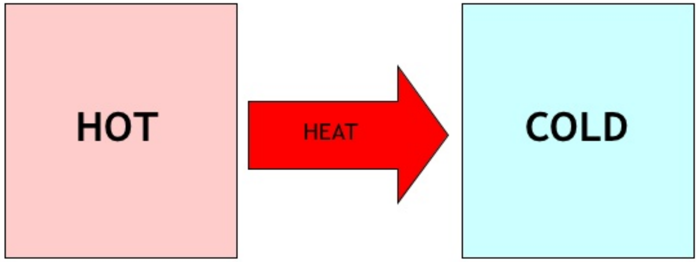
Chemical Energy → **Heat Energy** → **Mechanical Energy** → **Electrical Energy** → **Heat Energy**

Why Energy & Heat Transfer?

What aspects are interesting for a Design Engineer to design a sustainable electric kettle? (Think about the aspects related to the heat and energy)

Why Energy & Heat Transfer?

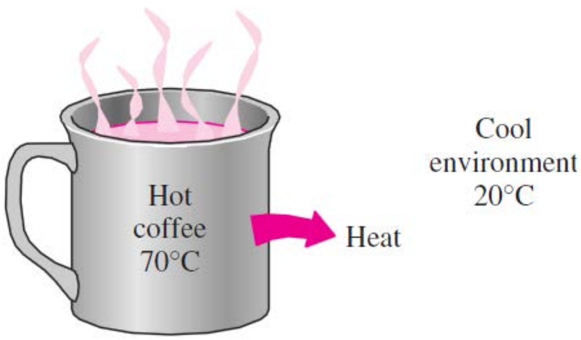




- Heat always moves from HOT to COLD.
  hot→cold

Why Energy & Heat Transfer?

Illustration 1:Hot Coffee



Coffee mug

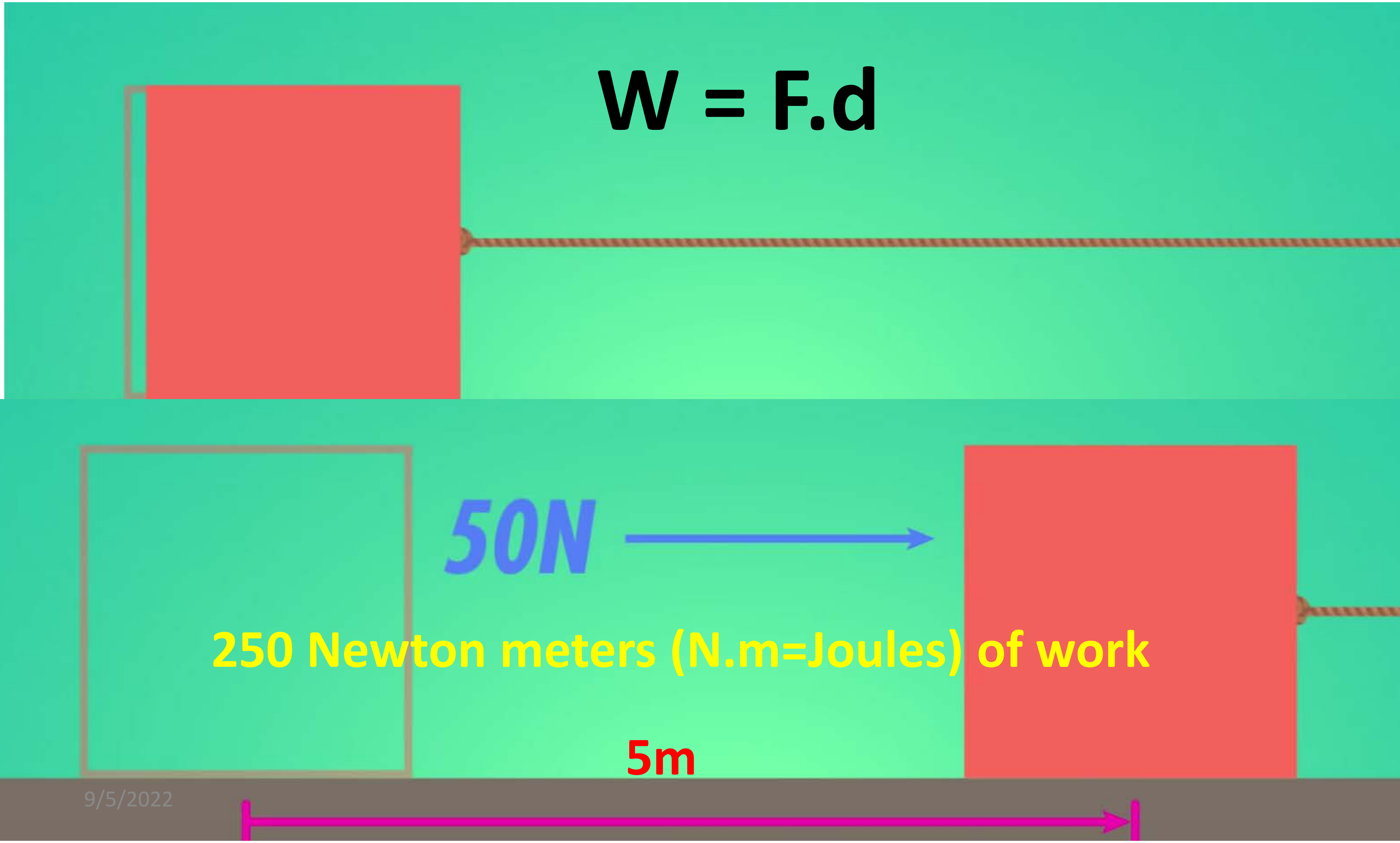
We are normally interested in how long it takes for the hot coffee in a thermos to cool to a certain temperature, which cannot be determined from a thermodynamic analysis alone

Thermo Flask

Learning objectives lecture 1

- Define and distinguish work/energy/power
- Distinguish corresponding units
- Develop a sense for reasonable quantities
- Calculate energy content

$$W = F.d$$



250 Newton meters (N.m=Joules) of work

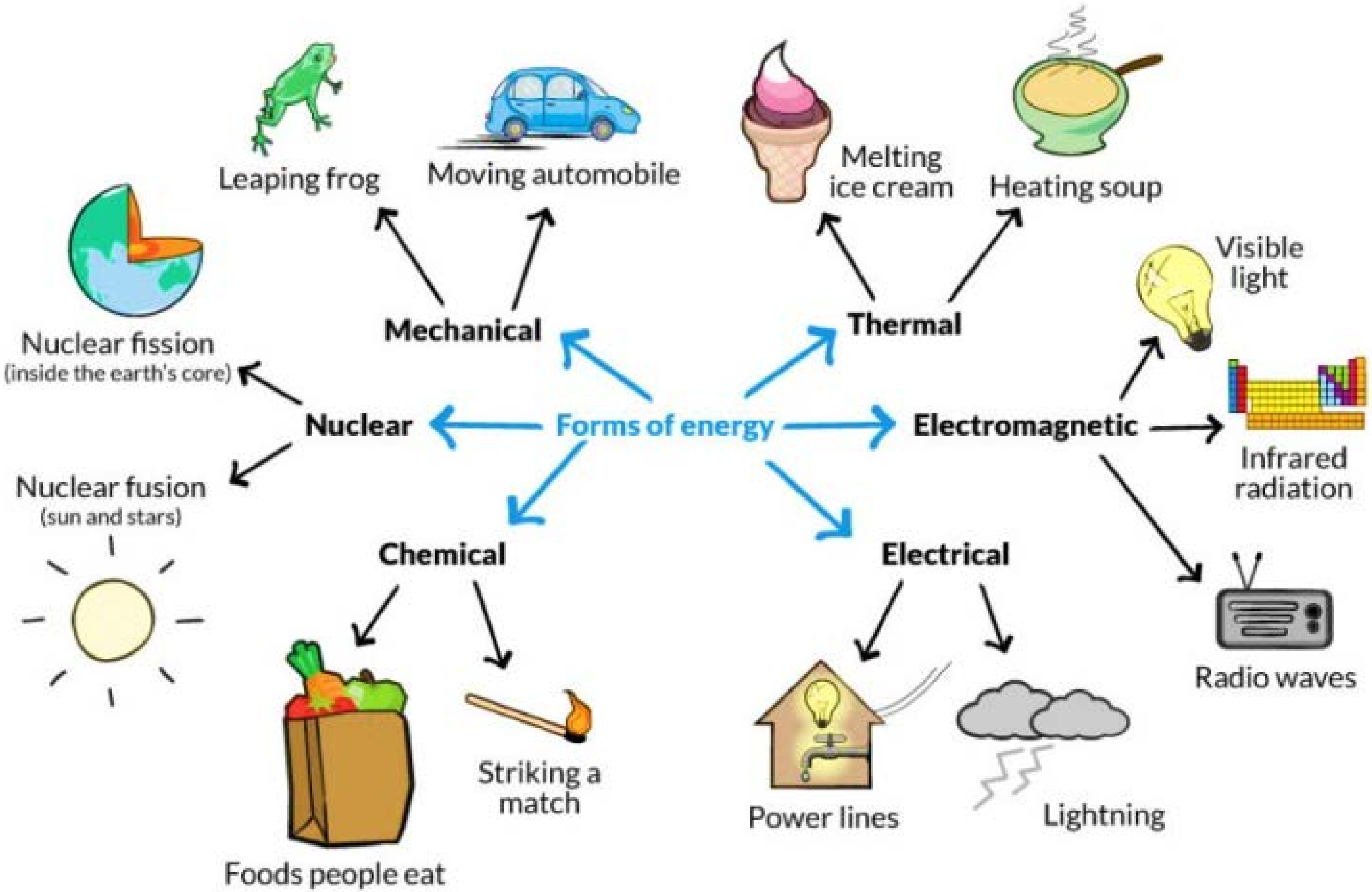
If you pull the rope and therefore the box with a force of 50 N, while you moved it 5 m, then we would say that you did 250 N.m of work on the box. More commonly however, the work is expressed in unites knows as Joules.

Work uses the same unit as energy because work is just a change in energy.

What happens when an external force is applied to a system and changes the energy of that system?

In fact that's one of the way to define energy! It is the ability to do work.

Different forms of Energy



- **Energy** is the **quantitative property** that must be transferred to an object in order to perform **work** on, or to **heat**, the object.
- **Energy** is a **conserved quantity**; the law of conservation of energy states that energy can be converted in form, but not created or destroyed.
- The **SI unit** of energy is the **joule**, which is the energy transferred to an object by the work of moving it for one meter against a force of 1 newton.
- Common forms of energy include the **kinetic energy** of a moving object, the **potential energy** stored by an object's position in a force field (**gravitational, electric** or **magnetic**), the **chemical energy** released when a fuel burns, the **radiant energy** carried by light, and the **thermal energy** due to an object's temperature.
- **Work (electrical),** the energy transferred by a force from an electric field acting on a charge through a distance
- **Work (physics),** the energy transferred by a force acting through a distance
- **Work (thermodynamics),** the energy transferred from one system to another by macroscopic forces measurable in the surroundings

Joule Definition

- 1 Joule is the energy required to move an object 1 meter using a force of 1 Newton:

$$\boxed{1\,J = 1\,N \cdot m}$$

Power: The Rate of Doing Work

$$\text{Power} = \frac{\text{Change in energy}}{\text{Change in time}}$$

$$P = \frac{\Delta E}{\Delta t} \Rightarrow \text{W} = \frac{\text{J}}{\text{s}}$$

So: 1 Watt = 1 Joule per second

Power determines how quickly we can do a certain amount of work or heat transfer → J/s

Watch out:
Quantity ≠ unit!

$$P = \frac{\Delta E}{\Delta t} = \frac{\text{J}}{\text{s}}$$

Wrong!

$$\text{Right}: P = \frac{\Delta E}{\Delta t} = \frac{100\text{J}}{20\text{s}} = 5\text{W}$$

Work, energy, power

Quantity	**Symbol**	**Unit**
Work	W	J (Joule)
Energy	E	J (Joule)
Power	P	W (Watt)

Watch out!

A garage hoist steadily lifts a car up 2 meters in 20 seconds. Calculate the power delivered to the car. Use 1000 kg for the mass of the car.($g=9.81 m/s^2$)

A. 985

B. 990

C. 981

D. 1050

Learning objectives lecture 1

- Define and distinguish work/energy/power
- **Distinguish corresponding units**
- Develop a sense for reasonable quantities
- Calculate energy content

Other units

Energy

J

Power

W

kJ = 10^3 J

kW = 10^3 W

MJ = 10^6 J

MW = 10^6 W

GJ = 10^9 J

OTHER UNITS

Energy

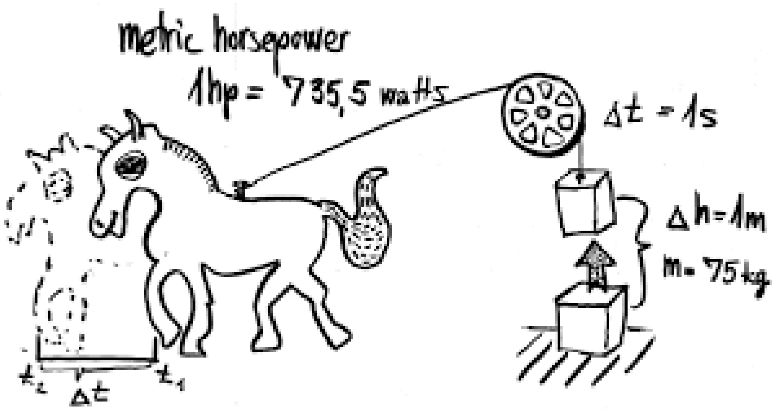
J

Power

W

kJ = 10^3 J
kW = 10^3 W
MJ = 10^6 J
MW = 10^6 W
GJ = 10^9 J

Metric Horsepower :
1hp = 735,5 W



Large units often convenient when using large amounts of energy/power

Tons of Joule

- kWh – kilowatt-hour: no power but energy!
- 1 kWh = the energy when using 1 kW for 1 hour

- $= 1 \cdot 10^3\ W \cdot 3600\ s = 3{,}6 \cdot 10^6\ W \cdot s$

$$= 3{,}6 \cdot 10^6\ J$$

$$= 3{,}6\ MJ$$

$1\ kcal = 4{,}184 \cdot 10^3\ J$

- kcal – kilocalorie: the **energy** it takes to raise the temperature of 1kg of water by 1˚C.

Learning objectives lecture 1

- Define and distinguish work/energy/power
- Distinguish corresponding units
- **Develop a sense for reasonable quantities**
- Calculate energy content

View on energy

- **Equivalents**:
  - 1 medium Big Mac menu with fries = 835 kcal = 3494 kJ

- **Activities at home**:
  - Toasting 2 slices of bread: 216 kJ
  - Watching one hour of television: 720 kJ
  - 15 minutes of vacuum cleaning: 1440 kJ
  - One full load of laundry: 4320 kJ

- **Physical activities**:
  - 1 hour of walking (normal speed): 1440 kJ
  - 1 hour of jogging(10,5 km): 2760 kJ
  - 1 hour of cycling (15 km): 1600 kJ

Where we are

- Definitions work, energy, power
  - Work W: delivering a certain performance
  - Energy E: capacity to deliver work
  - Power P: change of energy per unit of time

Unit J = N · m

Unit W = J / s

$$P = \frac{\Delta E}{\Delta t}$$

- Other units
  - Energy: kJ, MJ, GJ, kWh, kcal, Calvé, …
  - Power: kW, MW, hp, …

- Quantities / proportions of energy

  → How to calculate these?

Learning objectives lecture 1

- Define and distinguish work/energy/power
- Distinguish corresponding units
- Develop a sense for reasonable quantities
- **Calculate energy content**

Electrical energy

- Ohm's law

  $U = I \cdot R$

- So Electrical power

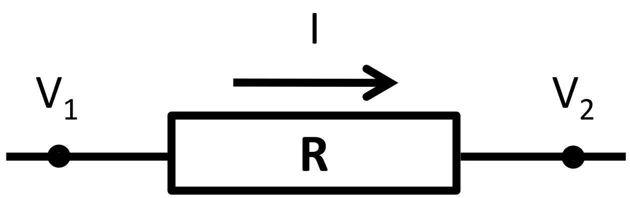
  $P = U \cdot I$

  $P = (I \cdot R) \cdot I = I^2 \cdot R$

- Electrical energy:

  $\Delta E = P \cdot \Delta t$

  $= U \cdot I \cdot \Delta t = I^2 \cdot R \cdot \Delta t$



$$U = V_1 - V_2$$

$$R = \frac{U}{I}$$

$$\Omega = \frac{\mathrm{V}}{\mathrm{A}}$$

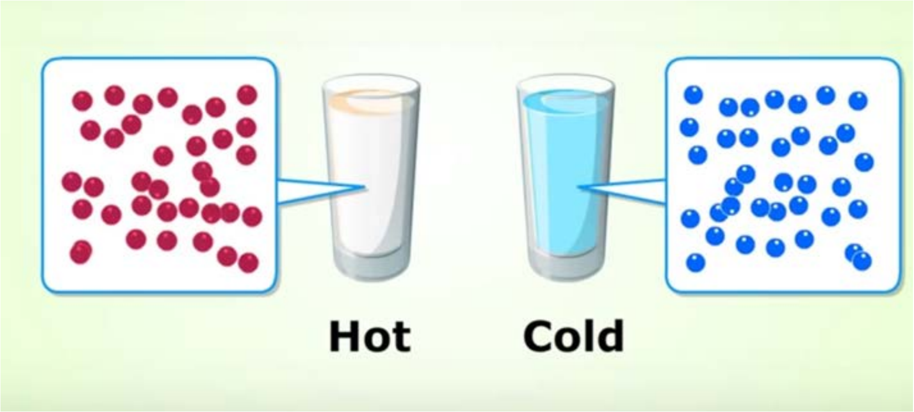
1 Ω → 1 V required to cause a 1 A current to flow

ELECTRICAL ENERGY

- An **electric current** is the rate of flow of electric charge past a point.
- **Ohm's law** states that the current through a conductor between two points is directly proportional to the potential difference across the two points.
- **Electric power** is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second.

Thermal energy

- Thermal energy: kinetic energy of molecules and atoms.



Heat Transfer: $\Delta E = Q$

$$\boxed{Q = m \cdot c \cdot \Delta T}$$

m = mass of "system" (kg)

ΔT = temperature change of system during process (K)

c = specific heat capacity (J / (kg · K))

Thermal energy

c = specific heat capacity (J / (kg · K))

"The amount of energy required to heat 1 kg of a substance by 1 Kelvin"

→ Joule per kilogram per Kelvin

Alternatively:

C = *m* · *c* = heat capacity (J / K)

"The amount of energy required to heat a complete system by 1 Kelvin"

→ Joule per Kelvin

$$\boldsymbol{Q = m \cdot c \cdot \Delta T = C \cdot \Delta T \quad (\mathrm{J})}$$

lowercase uppercase

$$\boldsymbol{Q = m \cdot c \cdot \Delta T}$$

Check:

$$Q = m \cdot c \cdot \Delta T$$

$$\mathrm{kg} \frac{\mathrm{J}}{\mathrm{kg} \cdot \mathrm{K}} \mathrm{K} = \mathrm{J}$$

$$[Q] = \mathrm{J}$$ ✔

Specific heat Capacity

	Substance	c (J / kg · K)	
Solids	Stainless Steel Aluminum Polyester Polypropene	$0{,}480 \cdot 10^3$ $0{,}903 \cdot 10^3$ $1{,}170 \cdot 10^3$ $1{,}925 \cdot 10^3$	
Liquids	Water Engine oil	$4{,}184 \cdot 10^3$ $1{,}900 \cdot 10^3$	
Gases	 Air Methane (Steam)	c_p $1{,}007 \cdot 10^3$ $2{,}226 \cdot 10^3$ $1{,}865 \cdot 10^3$	c_v $0{,}721 \cdot 10^3$ $1{,}708 \cdot 10^3$ $1{,}403 \cdot 10^3$

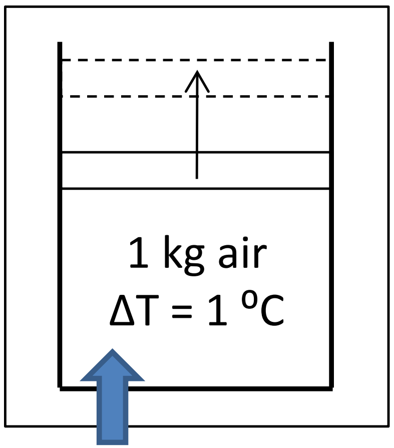
1 kcal =
$4{,}184 \cdot 10^3$ J

Energy required to heat 1 kg of water by 1 K.

Values at room temperature!

Specific heat for gases

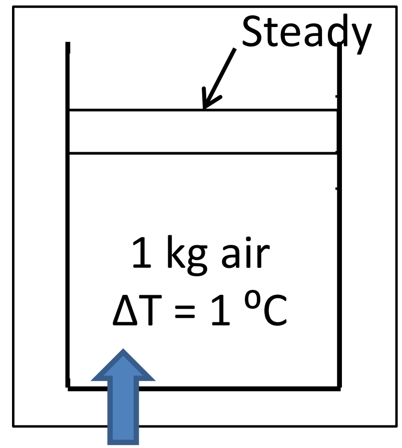
Heating in open environment
- Pressure constant
- Volume changes



Q = 1007 J

$\boldsymbol{c_p}$

Heating in a fixed volume, closed
- Volume constant
- Pressure changes



Q = 721 J

$\boldsymbol{c_v}$

$c_p > c_v$; why?

Heating at constant pressure → larger volume → mechanical work

Energy Transfer: Work and Heat

Symbol	Definition	Units
W	Work	kJ
w	Specific work = work per unit mass, $w = W/m$	kJ/kg
P	Power = rate of work*	kW (= kJ/s)
Q	Heat transfer	kJ
q	Specific heat transfer = heat transfer per unit mass, $q = Q/m$	kJ/kg
$\dot{Q}$	Rate of heat transfer*	kW (= kJ/s)

- NOTE: Rates are denoted by a dot on top of the variable.
- However, sometimes these dots are hard to see in PowerPoint.

Quantities of energy - summarized

- Mechanical work : $W = F \cdot D$
- Thermal energy (change): $\Delta E = m \cdot c \cdot \Delta T$
- Chemical energy

Everything in Joule!

Summary (1-2)

- Work W, energy E, power P $$P = \frac{\Delta E}{\Delta t}$$
- Units J, W = J/s, kWh, hp, …
- Work *W*, Energy *E* in $\mathrm{J} = \mathrm{N}\cdot\mathrm{m} = \frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}\cdot\mathrm{m}$
- Power $P = \frac{\Delta E}{\Delta t}$ in W = J / s
- Units kWh, kcal, hp, ….
- Comparison / estimating / proportion

Summary (2-2)

- Mechanical work $W = F \cdot D$
- Thermal energy $Q = m \cdot c \cdot \Delta T$
  – c is specific heat capacity in J / (kg · K)

Energy & heat transfer:
Learning path

HEATQUIZ

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