Thermal physics I

kinetic theory: world is made up of moving particles, which have different types of bonds depending on the phase (= Aggregatzustand)

abs. zero
−273,(15) °C
= 0 °K

temperature: measure of average kinetic energy of particles

hot:
- more movement
- more vibration
- more space
- expanding

heat: energy transfer from hot to cold

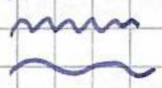
$$heat = W_{thermal} = W_{internal} = W_{kin} + W_{pot}$$

Heat transfer:

- **conduction**  (due to electrons in material)

conductor (metals, graphite, silicon) ↯ isolator (air, wood, rubber, plastics)

- **convection**  (convection current)

- **thermal radiation**  (e.g. infrared)

shorter = stronger

emitter / absorber ↯ reflector

black ■ — white / silver □

thermal equilibrium: same const. temperature or

$$E_{absorbed} = E_{emitted}$$

↑ from sun — ↑ IR to env.

liquids & vapors

 ← evaporation (↯ condensation)
(boiling if at every point)

factors:
- temperature ↑
- surface area ↑
- humidity ↓
- wind ↑

fluid = liquid or gas

Thermal physics II

specific heat capacity

→ material-specific const.

$c_{water} = 4200 \frac{J}{kg \cdot °C}$

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

$$[c] = \frac{J}{kg \cdot °K}$$

"energy per kilogram per °C"

how to measure?

1. electrical heater in object → know energy input, mass & temp change

   ! loss of energy, heater & container also warmed up

2. mix two liquids of different temperatures

   → $m_A c_A (T_A - T_{max}) = m_B c_B (T_{max} - T_B)$

   (all energy transferred from A is now in B)

   ! energy loss, especially at transfer

temperature stays constant during phase transition

specific latent heat

→ material-specific const

$L_{ice} = 330'000 \ J kg^{-1}$

$L_{water} = 2300'000 \ J kg^{-1}$

$$L = \frac{Q}{m}$$

"energy per kilogram for vaporizing/melting"

Gas laws

$V = const \rightarrow p \sim T$ — pressure law

$p = const \rightarrow V \sim T$ — Charles's law

$T = const. \rightarrow p \sim \frac{1}{V}$ — Boyle's law

$$\frac{p \cdot V}{T} = const$$

or

$$\frac{p_1 \cdot V_1}{T_1} = \frac{p_2 \cdot V_2}{T_2}$$

(T_1: before, T_2: after)

T in °K !!!

$$\frac{p \cdot V}{n \cdot T} = R = 8{,}314\ J \cdot mol^{-1} \cdot K^{-1}$$

n: #particles; R: molar gas const.

$$p = \frac{F}{A}$$

"force per area"

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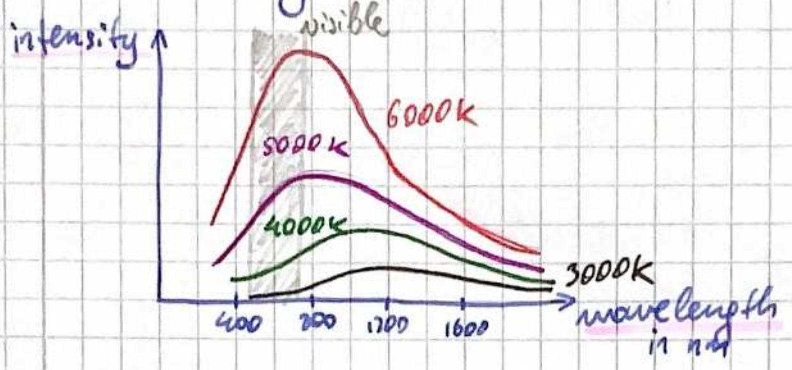
Radiation

Black-body radiation:



Stefan-Boltzman-law: total power radiated

$$P = \sigma \cdot A \cdot T^4$$

- A: surface area
- T: temperature (K)
- σ: Stefan-Boltzman const.

Wien's displacement law:

peak wavelength emitted $\lambda_{max} = \frac{2{,}90 \cdot 10^{-3}}{T}$

intensity $I = \frac{P}{A}$ (power per area)

emissivity $e = \frac{P_{\text{radiated per area}}}{P_{\text{radiated per area by black-body}}}$

$\Rightarrow P = e \cdot \sigma \cdot A \cdot T^4$

albedo $\alpha = \frac{\text{power reflected}}{\text{power incoming}}$

greenhouse gases (absorb and re-emit infrared radiation of the Earth): Methane / CH_4, H_2O, CO_2, Nitrous oxide / N_2O