Recap… Chapter 1+2, Temperature and 0th law of TD

- How to characterise T, which scales exist?

- What is meant with thermal equilibrium?

- What is the 0th law of Thermodynamics?

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  - Temperature is a measure how hot or cold something is (a "state variable", only dependent of the current state of a system).
  - The temperature of a body is given either as absolute temperature T in Kelvin or Celsius temperature $T_c/C = T/K - 273.25$ (also Fahrenheit scale, less used)
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  - 0th law of Thermodynamics: If two systems are in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

Recap… Chapter 1+2, Thermal expansion

- What is thermal expansion?

- Which property of T is important that thermometers function? Which materials are particularly well suited for measuring T?

- Give a physical explanation for the fact that thermal expansion coefficients of liquids are typically larger than that of solids.

Recap… Chapter 1+2, Thermal expansion

- What is thermal expansion?
  - The change in length of a solid, when its temperature changes is directly proportional to the T change **(valid only if T change small!!)**
  - $\Delta l = \alpha l_0 \Delta T$, α: coefficient of linear expansion
  - The change of volume of most solids, liquids and gases is proportional to the T change **(small!!)** and to the original volume $\Delta V = \beta V_0 \Delta T$, $\beta \approx 3\alpha$
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- Give a physical explanation for the fact that thermal expansion coefficients of liquids are typically larger than that of solids.
  - Solids: molecules are tightly bound in a fixed, orderly arrangement (e.g. lattice) —> when heated, the molecules vibrate more vigorously but generally maintain their relative positions, leading to a smaller overall expansion
  - Liquids: molecules are less tightly bound and can move around more freely. —> When heated, these particles move more readily, leading to a more significant increase in volume.

Recap… Thermal expansion

- Linear expansion formula $\Delta l = \alpha l_0 \Delta T$ accurately valid only for infinitely small changes in T
- For n heating steps, i.e. a continuous rise of T, the accurate formula is $l = l_0 \, e^{\alpha \Delta T}$

Recap… Thermal expansion

How much should I care?

"Not much, unless you melt the solid!!"

Material	Aluminium	Bras	Iron	Lead	Quartz
$\alpha\left(C^{\circ}\right)^{-1}$	25×10^{-6}	19×10^{-6}	12×10^{-6}	29×10^{-6}	0.4×10^{-6}

- Melting temperature of:
  Aluminium – 933 K
  Iron – 1811 K
- Estimate a 1 meter long iron bar and aluminium bar: assuming linear thermal expansion from room temperature (300 K) to melting point, the length will be:
  delta l (Al) = 25e-6/K x 633 K x 1m = 0.01583m
  delta l (Fe) = 12e-6/K x 1511K x 1m = 0.0181m
- Compare your results with that obtained from the precise formula of thermal expansion …
  l (Al) = 1m x exp(25e-6/K x 633 K) = 1.01595 —> delta l = 0.01595 m
  l (Fe) = 1m x exp(12e-6/K x 1511K) = 1.0183 —> delta l = 0.0183 m

Conceptual Questions:

- If you heat a thin circular ring in the oven, does the ring's hole get larger or smaller? youtube demonstration: https://www.youtube.com/watch?v=nA-WJyq19H8

- Opening a tight jar lid: When the lid of a glass is tight, holding the lid under hot water for a short time will often make it easier to open. Why?

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    - It might seem counterintuitive at first, as one might expect the material to expand and close up the hole. However, it's important to remember that the expansion is uniform in all directions. Each segment of the ring, no matter where it is located, moves outward from the center of the ring as it expands, thus increasing the diameter of the hole.
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- What is meant with the anomalous behaviour of water?

- What is thermal stress and how can it be computed?

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- What is thermal stress and how can it be computed?
    - Because of thermal expansion, thermal stresses can occur if materials are rigidly fixed and T changes. The required compression to keep an object at its original length can be computed via Young’s modulus E, $\Delta l = 1/E \; P \; l_0$