

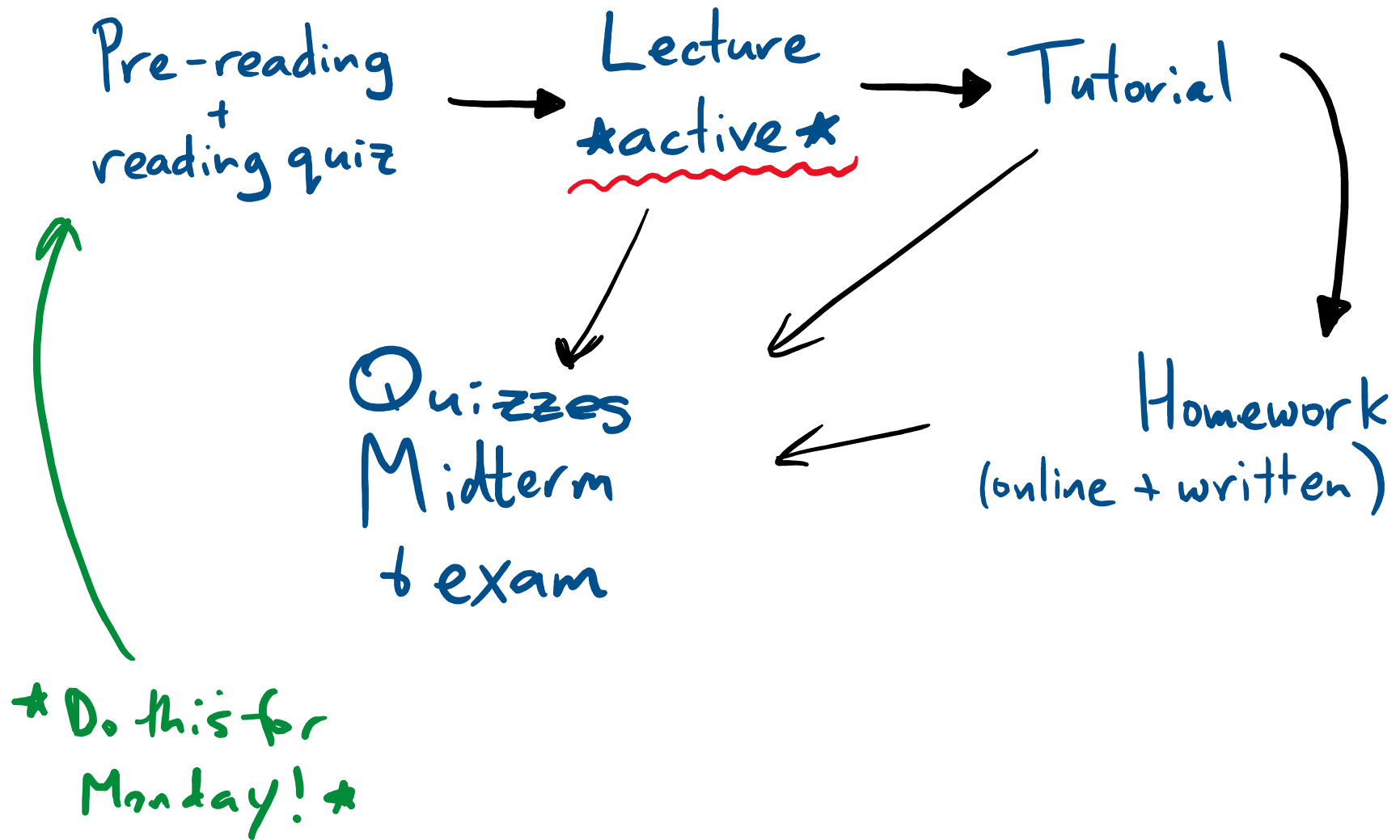
Class will begin soon!

- If you have technical problems, try reloading the page, or closing your browser and coming back
- Log in to i-clicker – use Canvas link or search “i-clicker login” (you may want to do this on another device, e.g. you phone)
- Office hours today: 3:30-4:30pm (Zoom link on Canvas page)

You might want to: maximize slides OR hide right panel

The image shows a screenshot of a Remo live lecture interface. At the top, a browser window displays the URL `live.remo.co/e/physics-157-sept-11-lecture`. The main interface features a video feed of Mark Van Raamsdonk on the left and a slide on the right. The slide contains the text `t=0 entanglement entropy.` and a diagram of a sphere with a circular cross-section labeled `A`, and a larger, flared, funnel-like structure below it labeled `RT surface \bar{A}` . A red arrow points from the handwritten text "maximize slides" to the maximize button in the top right corner of the slide window. Another red arrow points from the handwritten text "hide right panel" to the close button in the top right corner of the right-hand sidebar, which contains "Chat", "Participants", and "Q&A" sections. The bottom of the interface has a control bar with buttons for "Present Off", "Cam Off", "Mic Off", "Share Screen", and "More". A "Need help?" button is visible in the bottom left corner. The Windows taskbar at the very bottom shows the search bar and various application icons, with the system tray displaying "ENG US" and "12:13 PM 2020-09-10".

How the course works:



Ways to ask questions in class:

General Chat: these will be answered by the TA in real time (or moved to the Q&A)

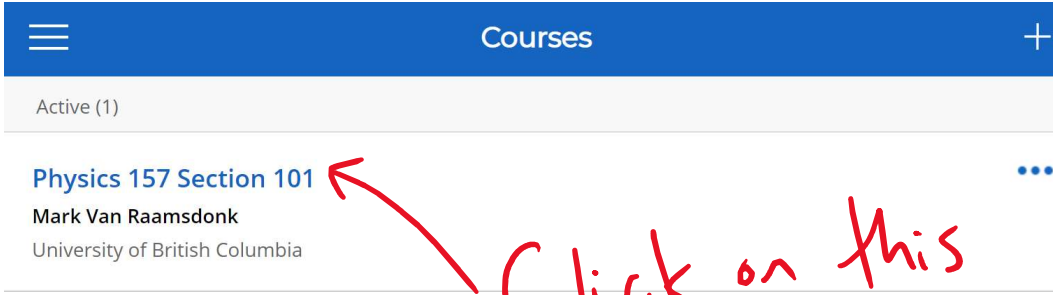
Reserve this for questions only

Q&A: I will answer these when I notice or pause for questions

Raise hand: will answer these when I notice or pause for questions

1) Follow the i-Clicker link in Canvas or Google “i-clicker login” and choose “Reef – Login”.

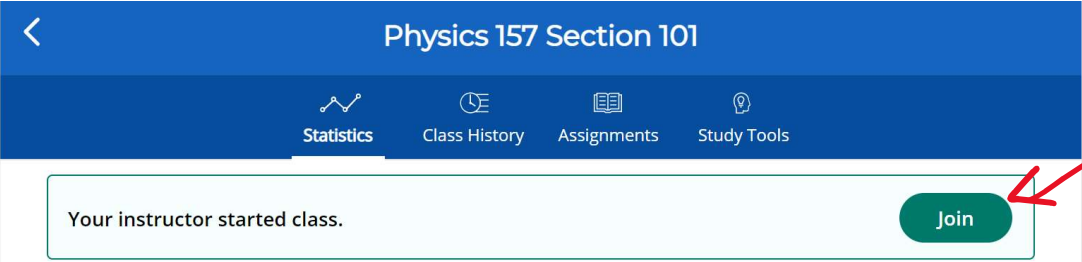
2)



The screenshot shows the Canvas 'Courses' page. At the top, there is a blue header with a hamburger menu icon on the left, the word 'Courses' in the center, and a plus sign on the right. Below the header, it says 'Active (1)'. A course entry is listed: 'Physics 157 Section 101' in blue text, with 'Mark Van Raamsdonk' and 'University of British Columbia' below it. A red arrow points from the handwritten text 'Click on this' to the course title.

Click on this

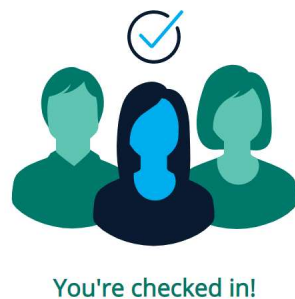
3)



The screenshot shows the Canvas course page for 'Physics 157 Section 101'. The top blue header has a back arrow on the left and the course title in the center. Below the header is a navigation bar with icons and labels for 'Statistics', 'Class History', 'Assignments', and 'Study Tools'. A light green box contains the message 'Your instructor started class.' and a green 'Join' button. A red arrow points from the handwritten text 'Click here' to the 'Join' button.

Click here

4) You should see this:



A mercury thermometer sits in a glass of water. If the thermometer reads 20°C , we can conclude that

- A) The temperature of the water is 20°C .
- B) The temperature of the mercury in the thermometer is 20°C .
- C) Both A and B
- D) Neither A nor B

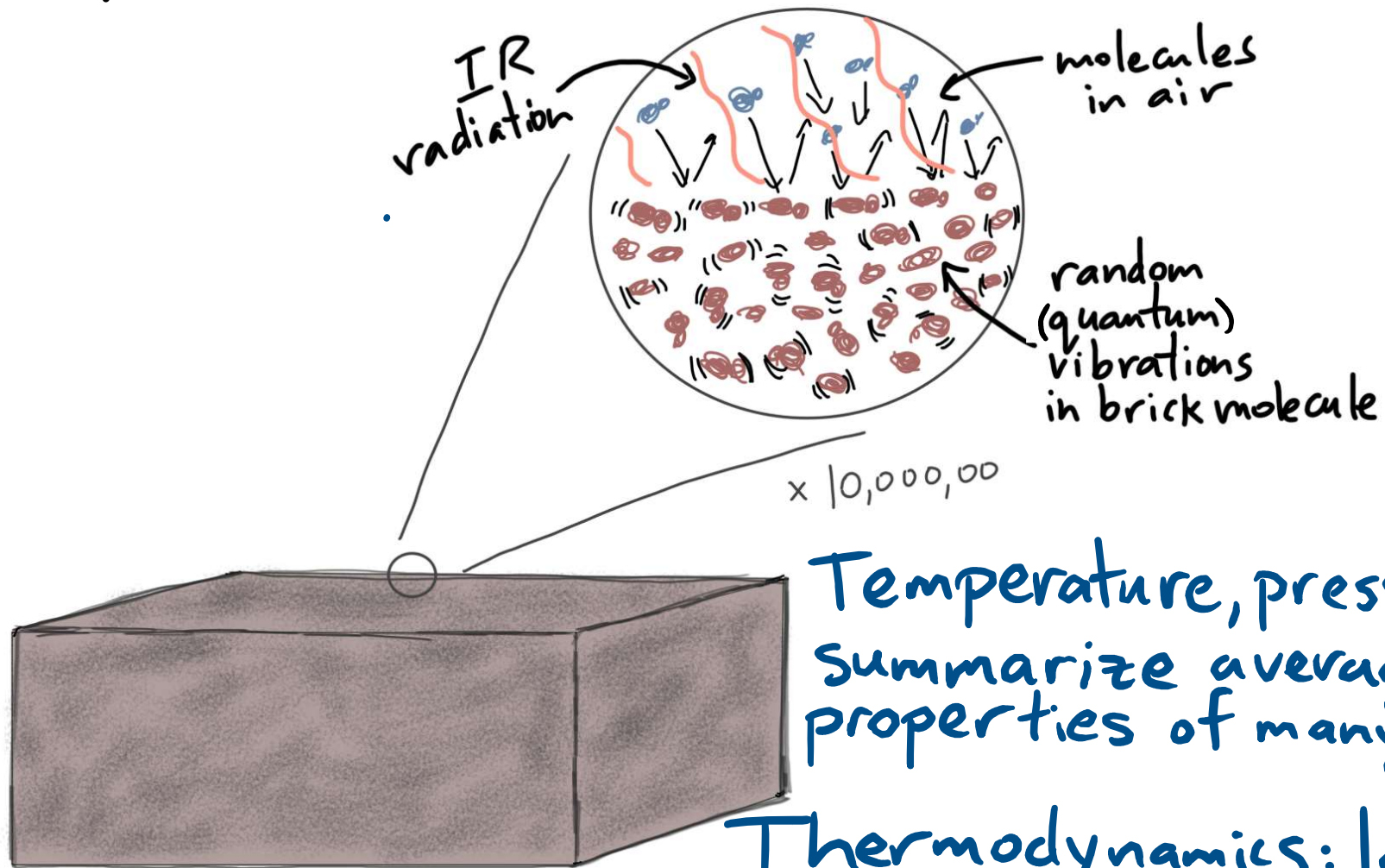
A mercury thermometer sits in a glass of water. If the thermometer reads 20°C , we can conclude that

- A) The temperature of the water is 20°C .
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- C) Both A and B
- D) Neither A nor B

Last time in physics 157...



Thermodynamics: how to summarize microscopic physics of $10^{23} +$ things.



Temperature, pressure, ...:
Summarize average
properties of many atoms

Thermodynamics: lets us
understand behavior of these

Our starting point:



Conservation of Energy

Conservation of Energy

- each part of a physical system has a certain amount of energy
- the total energy of an isolated system doesn't change with time

BUT: energy can move between different parts and take different forms

In thermodynamics we care about the microscopic kinetic & potential energy of atoms & molecules

ASIDE:

First understood fully by
one of the greatest physicists
of all time...

guess who with i-Clicker



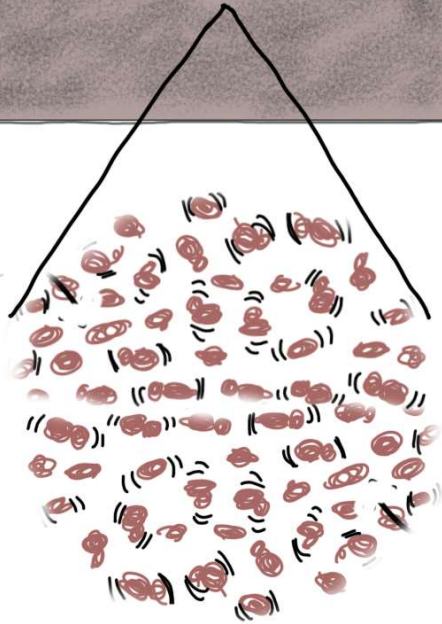
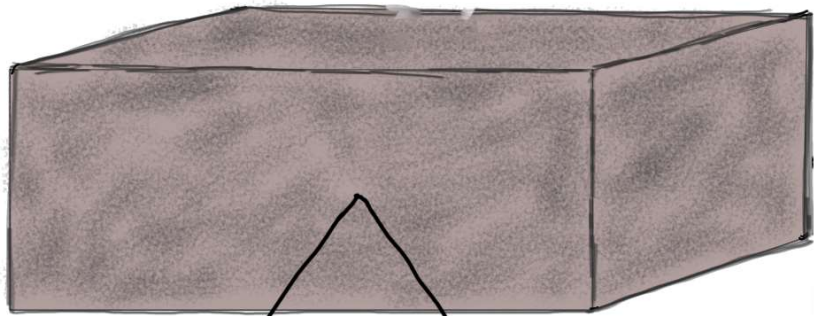
Emmy Noether 1882-1935



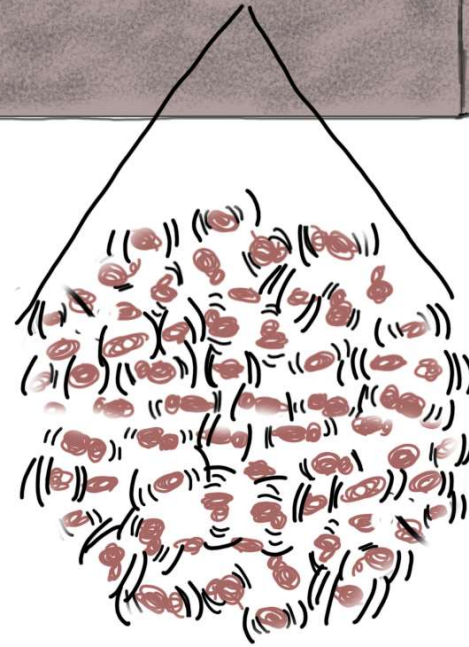
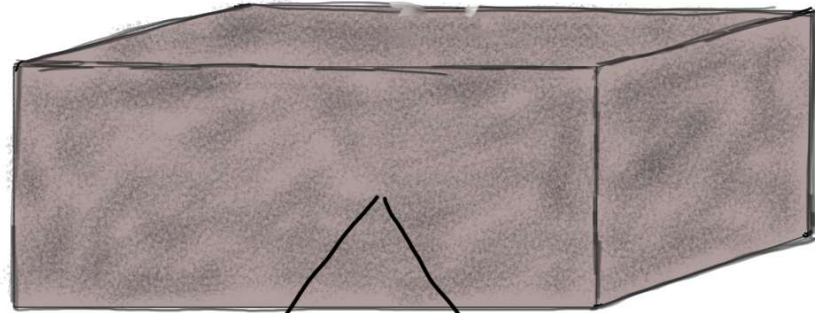
Proved "Noether's Theorem"
that explains how conserved
quantities are related to
"symmetries" in nature
(ask me later!)

When we heat/cool an object, we are adding/removing energy at the molecular level:

cold brick



hot brick



← more kinetic +
potential
energy

But, heating/cooling also
affects macroscopic/observable
properties

Which macroscopic properties of objects change when they are heated/cooled?

(discuss!)

Which macroscopic properties of objects change when they are heated/cooled?

* Most of them (but often only slightly)

↓
size/
volume/
density

↓
amount of light/IR radiation
emitted at different frequencies

(and many others
e.g. electrical conductivity)

Examples:

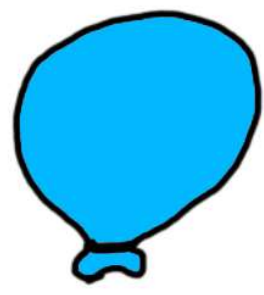
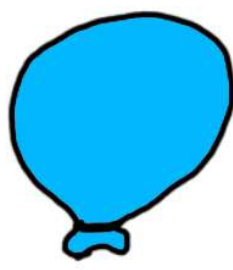
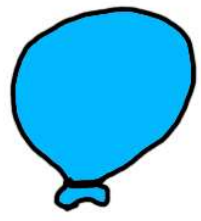
solid:

hotter



(size changes greatly exaggerated)

gas in balloon



liquid in tube:

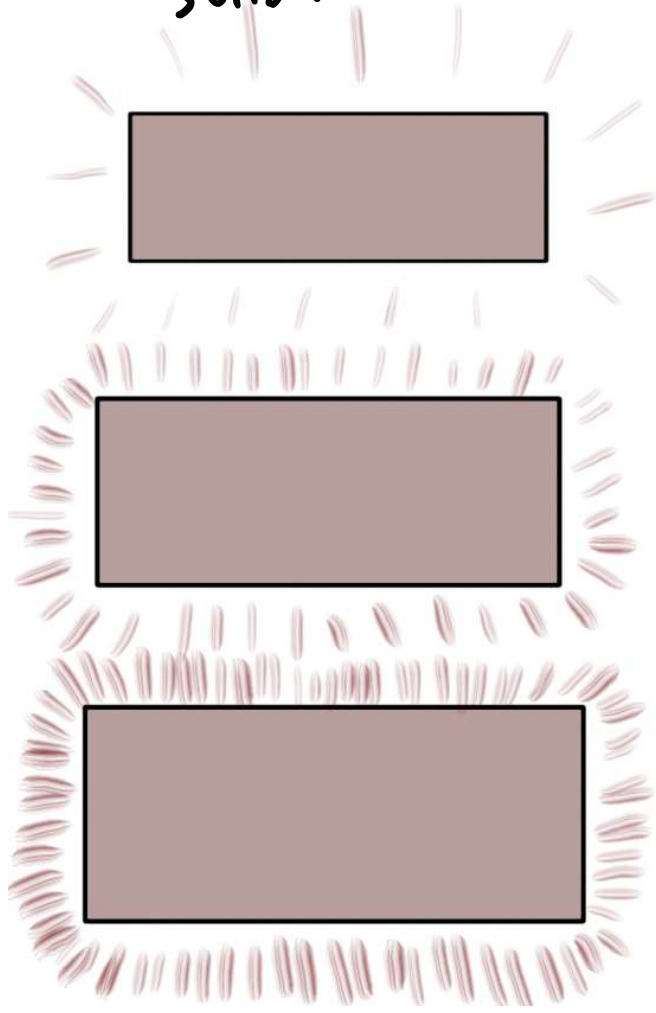


there are exceptions!

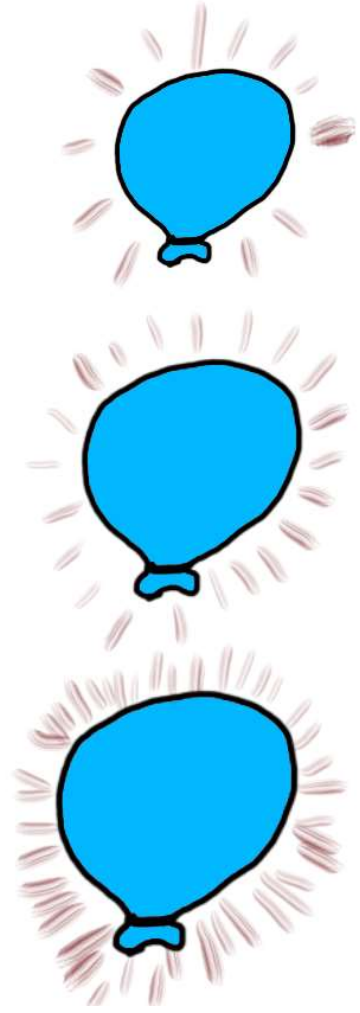
Examples:

solid:

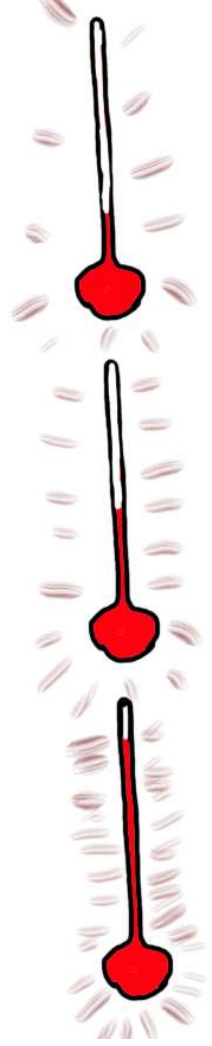
hotter



gas in balloon



liquid in tube:



more IR radiation!

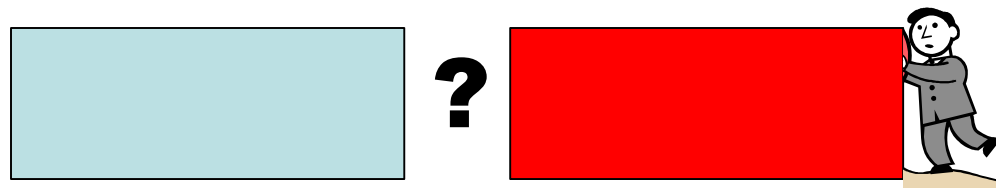
Demo: <https://www.youtube.com/watch?v=kfCVtnayKk4>

Bonus demo: https://youtu.be/iqPS_JiKSHo

Hot block + room temperature block

What happens if we put a hot block in contact with a room temperature block?

- A. Nothing
- B. Heat flows until they are the same temperature
- C. The hot block will cool down to room temperature
- D. The room temperature block will heat up to the temperature of the hot block
- E. None of the above

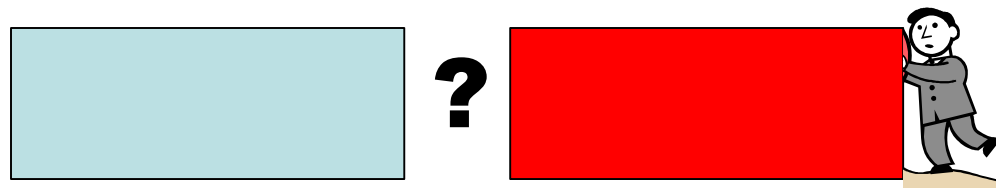


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→ final temperature depends on how hot the hot block was



Demo: IR camera

Make a prediction:

We put together two blocks of aluminum, one heated on the hot plate and the other left in the room for a long time. We observe this on an infrared (IR) camera. It shows hotter objects as brighter.

Make a sketch of what you think we will see

- a) just as we bring the blocks together
- b) after a short amount of time
- c) after a long amount of time

BEFORE:



room temp



hot

(shade in regions that are brighter on the IR camera)

https://youtu.be/xe_oCx5lyF4

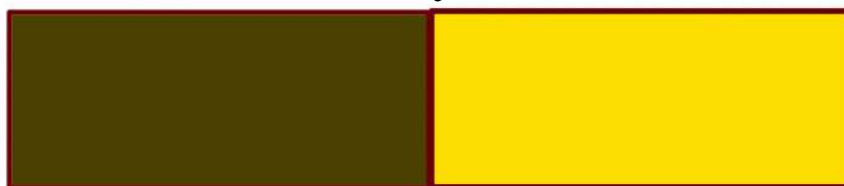
in equilibrium with room



in equilibrium w. hot plate



place in thermal contact



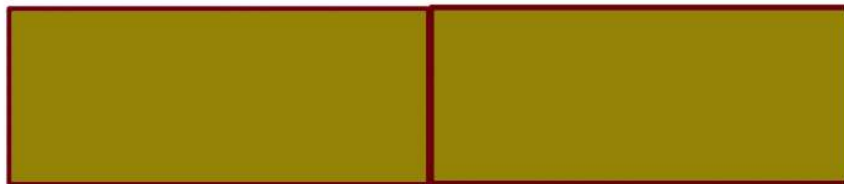
blocks are not in equilibrium with each other.



heat flows

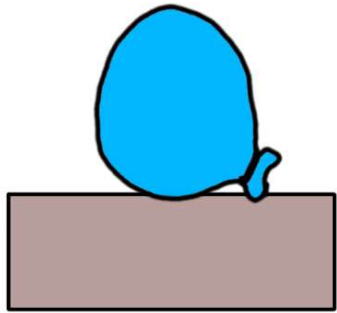
also each block not in an equilibrium state (some parts hotter)

blocks in equilibrium



If we bring two objects in contact:

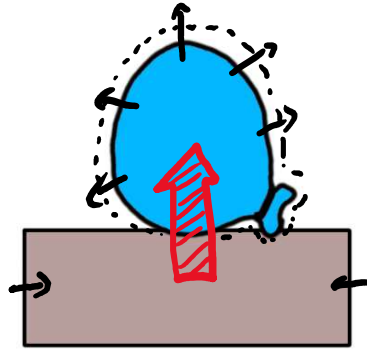
3 options:



nothing
changes

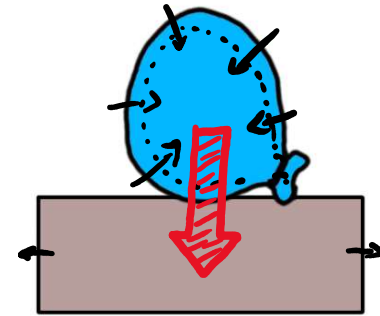
we say the
systems are
EQUILIBRIUM

same
TEMPERATURE



energy from
brick → balloon
= flow of HEAT

brick has
higher
temperature

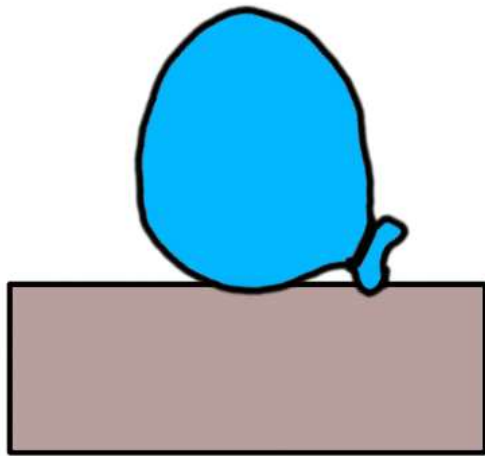


energy from
balloon to brick

balloon has
higher
temperature

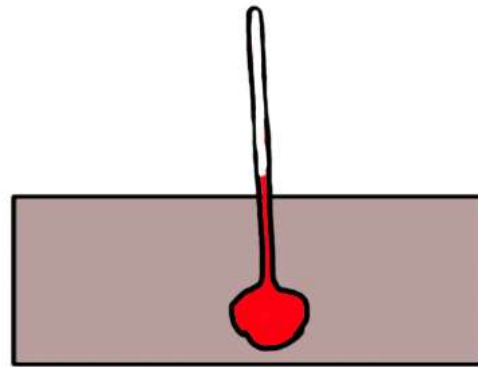
Zeroth Law of Thermodynamics:

If



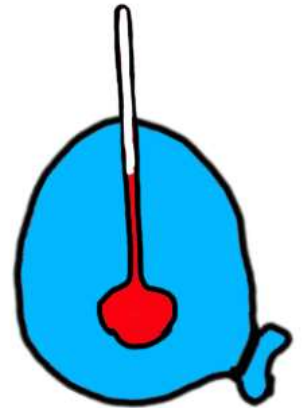
in
equilibrium

and



in
equilibrium

then:



in
equilibrium

otherwise, temperature wouldn't make sense!

We can assign a numerical value for different temperatures by using some temperature-dependent macroscopic property of a standard object (e.g. volume of liquid in a tube)

