

Learning Goals for this lecture:

- Describe what is meant by the conservation of energy.
- Explain at the microscopic level what is happening when an object is heated or cooled.
- List various macroscopically observable properties that change as heat flows into or out of an object
- Explain how we can tell whether two objects have the same temperature or if not, which one has a higher temperature
- Explain what is meant by two objects being in thermal equilibrium.
- State the zeroth law of thermodynamics and explain why this is necessary for the concept of temperature.

Test your i>clicker! Turn it on and enter a response to the question below:

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

You should see a green light if everything worked.

Office hours: today 3:30 - 4:30 Hennings
420

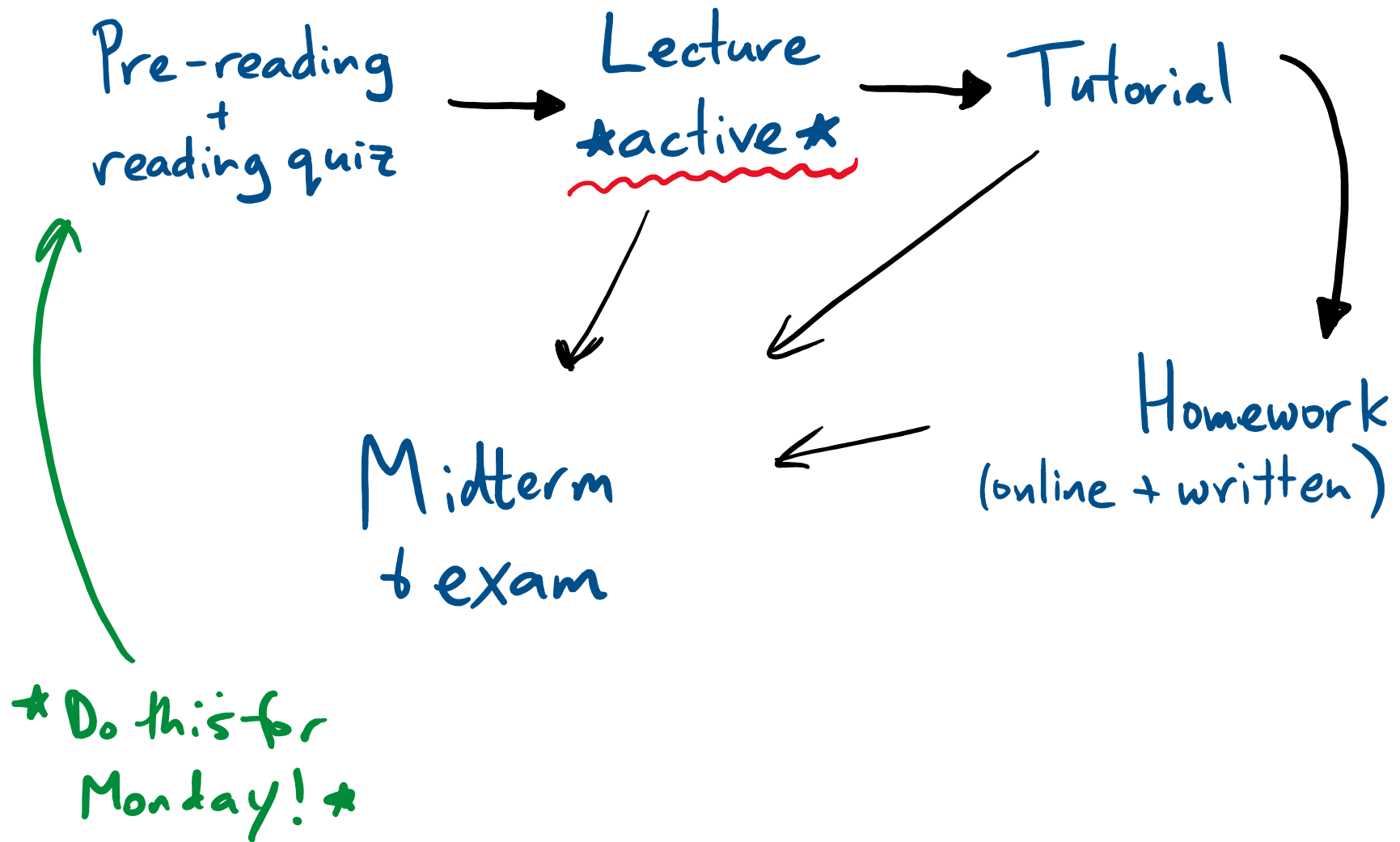
A mercury thermometer sits in a glass of water. If the thermometer reads 20°C , we can conclude that

- 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

The thermometer reading depends on the volume of the mercury, which is determined by its temperature.

We are not told how long the thermometer has been in the water, so we don't know if it is in equilibrium with (and thus the same temp. as) the water

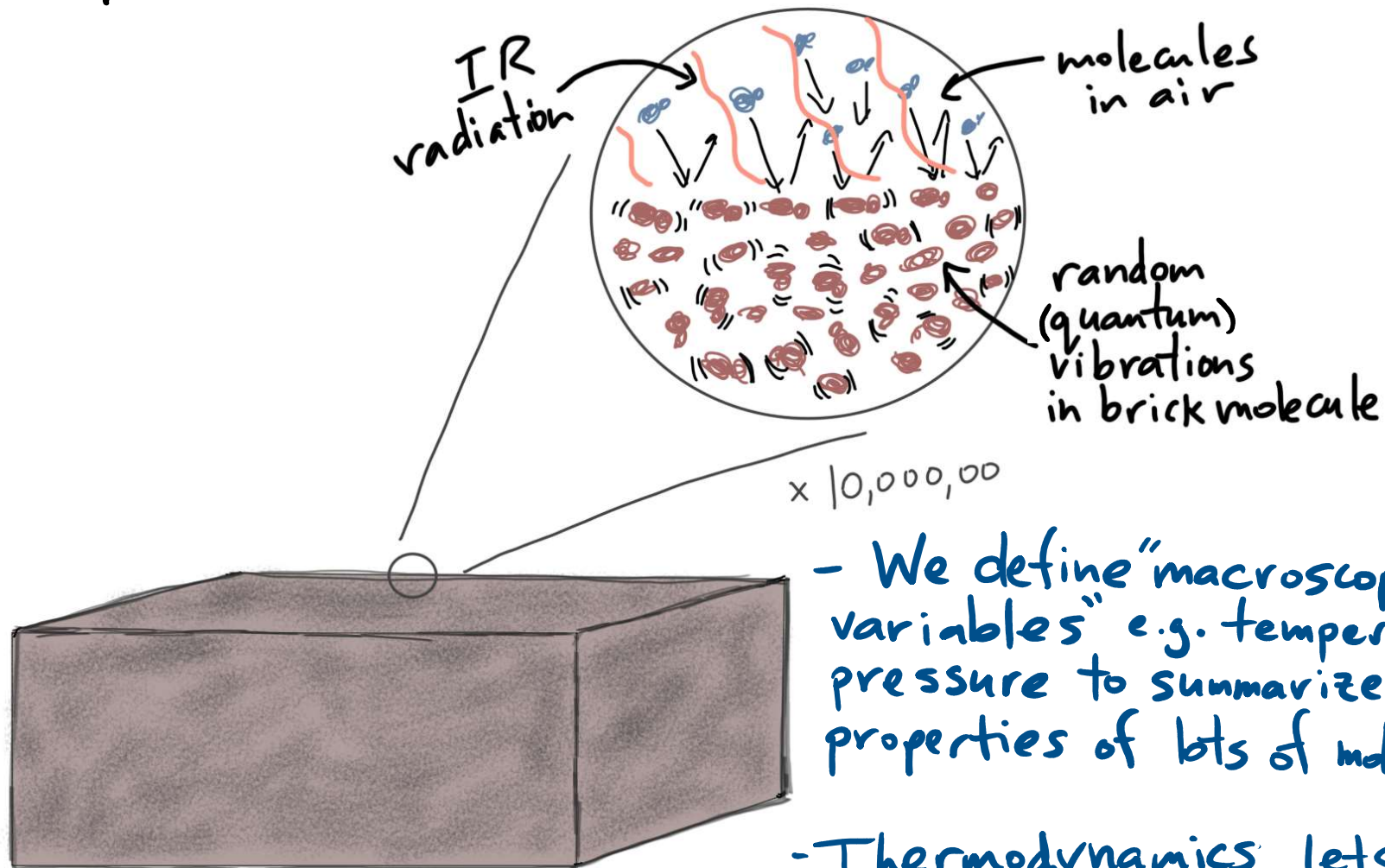
How the course works:



Last time in Physics 157...



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



- We define "macroscopic variables" e.g. temperature, pressure to summarize average properties of lots of molecules.
- Thermodynamics lets us understand behavior of these

Our starting point:



Conservation of Energy

ASIDE:

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

Emmy Noether 1882-1935



Proved "Noether's Theorem"
that explains how conserved
quantities are related to
"symmetries" in nature

(ask me later!)

In practice:

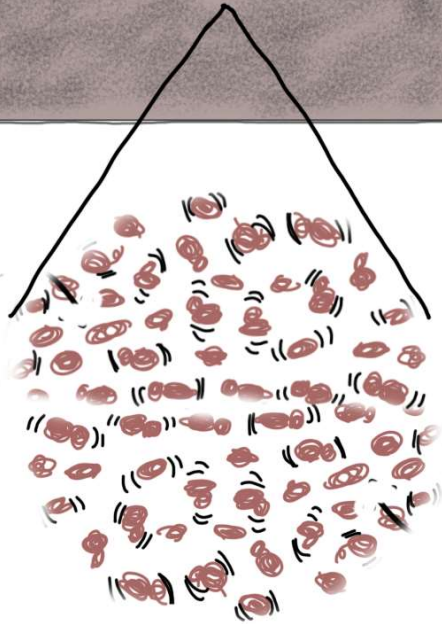
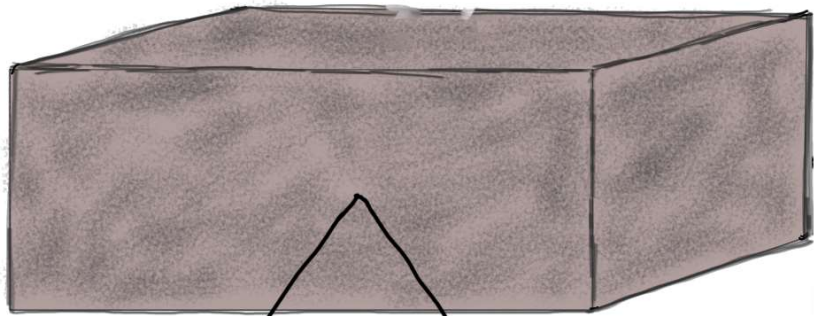
- each part of a physical system has a certain amount of energy
- the total energy of an isolated system doesn't change with time

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

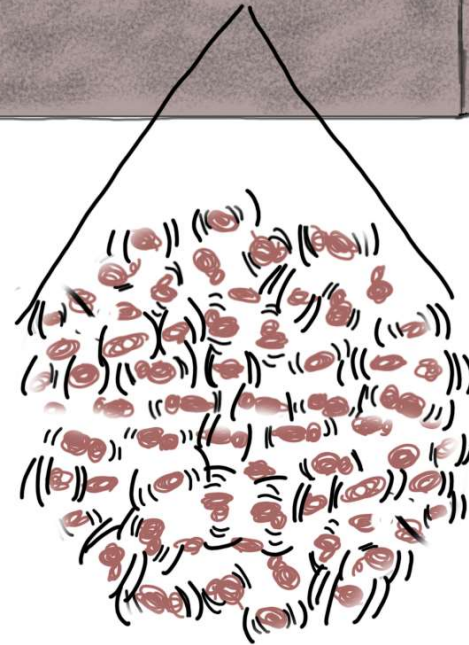
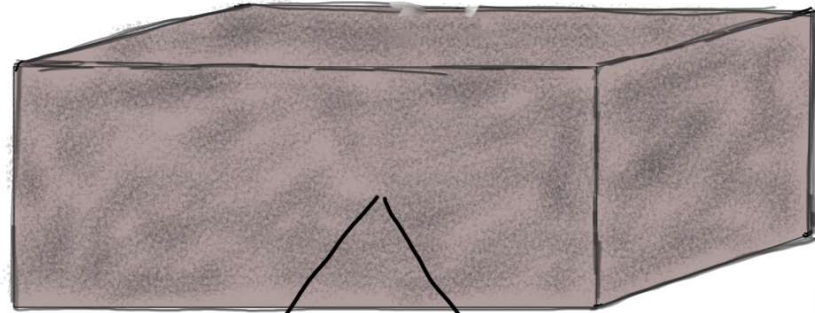
In thermodynamics we care about the microscopic kinetic & potential energy of atoms & molecules

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?

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

* Most of them (but often only slightly)

↓
size/
volume/
density

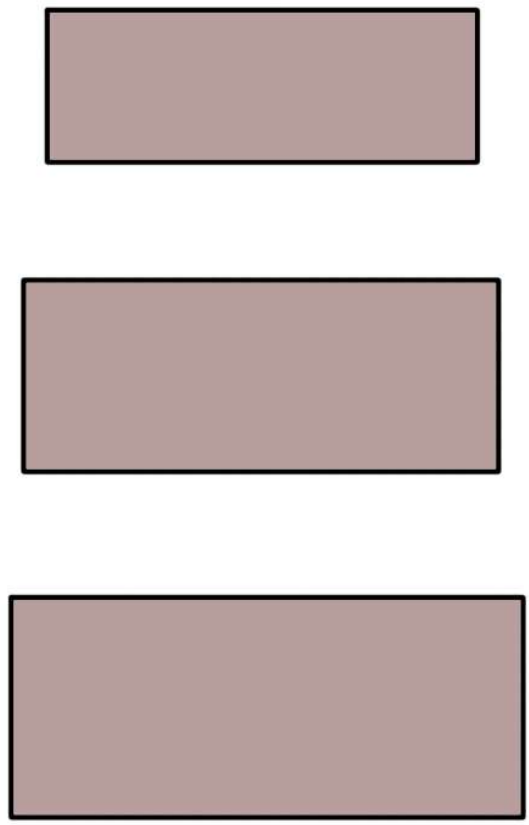
↓
amount of light/IR radiation
emitted at different frequencies

(and many others
e.g. electrical conductivity)

Examples:

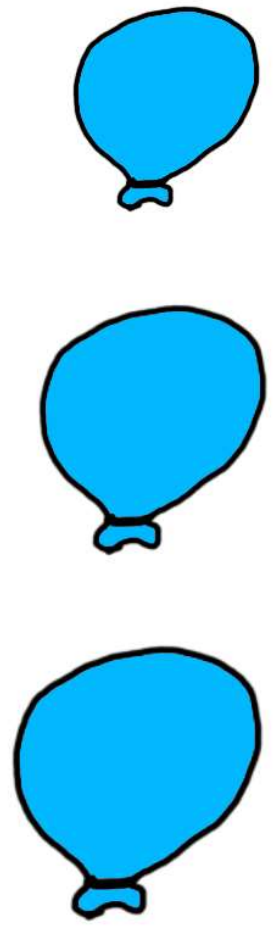
solid:

hotter



(size changes greatly exaggerated)

gas in balloon



liquid in tube:

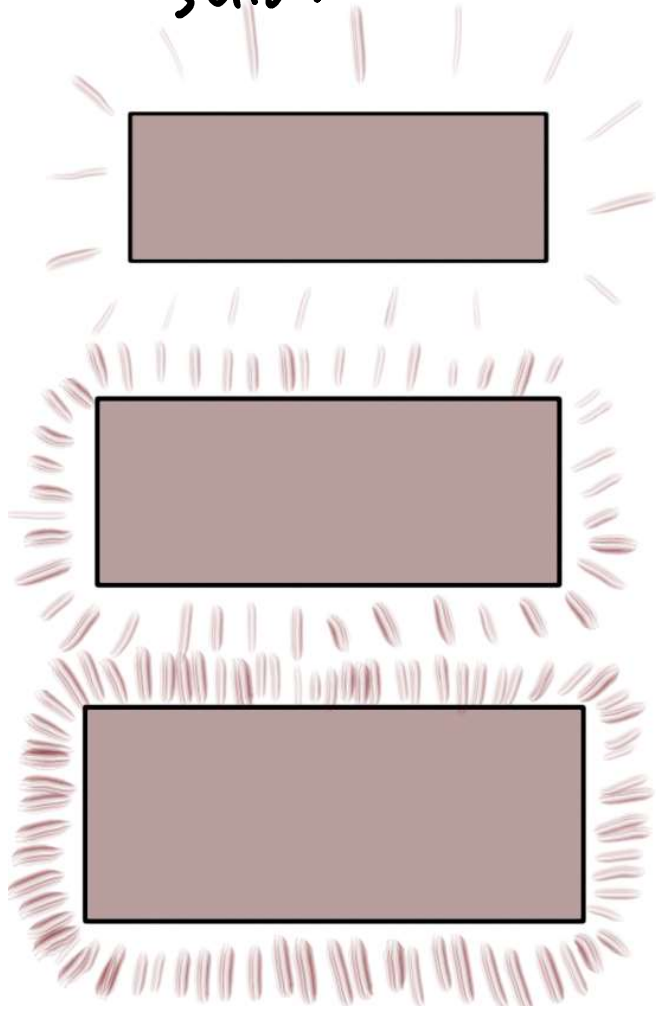


there are exceptions!

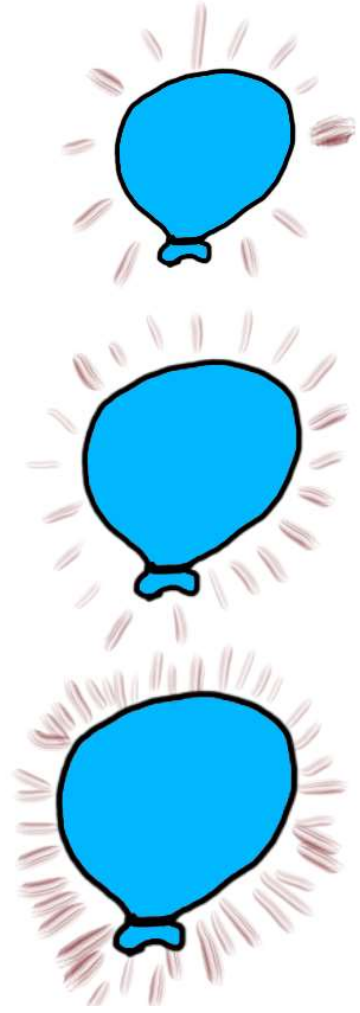
Examples:

solid:

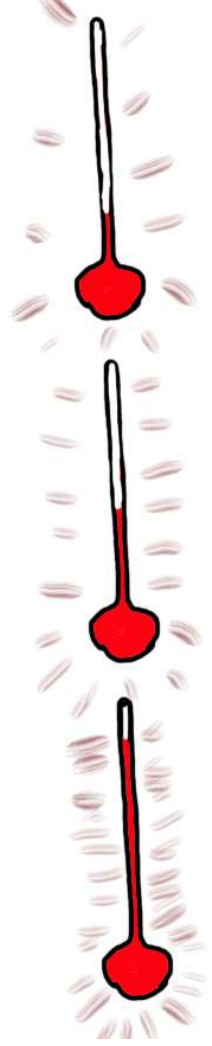
hotter



gas in balloon



liquid in tube:

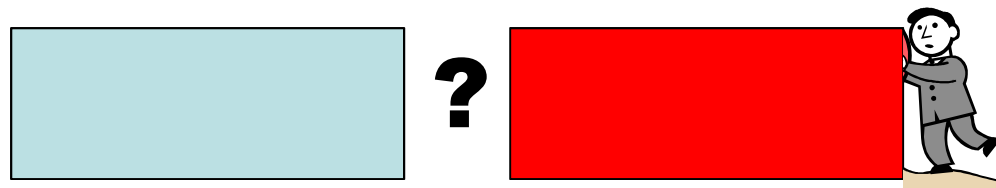


more IR radiation!

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

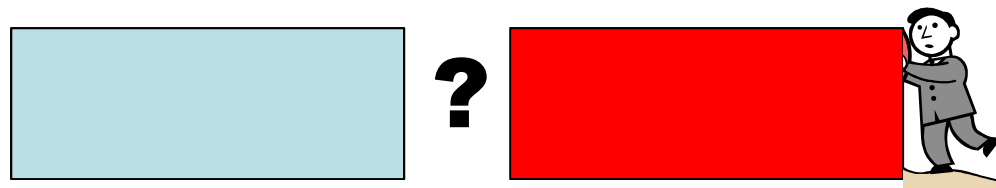


Hot block + room temperature block

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

→ 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)

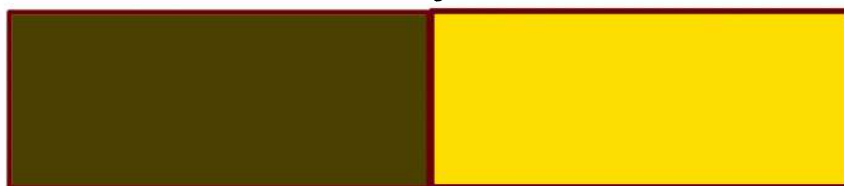
in equilibrium with room



in equilibrium w. hot plate



place in thermal contact



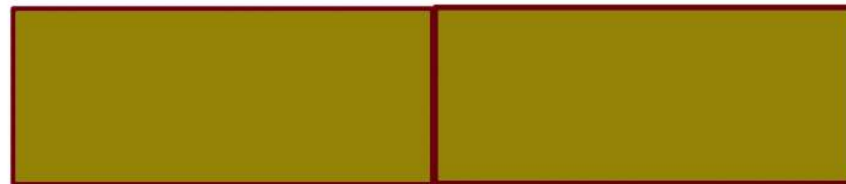
blocks are not in equilibrium with each other.



heat flows

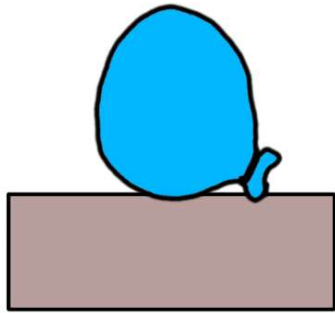
also each block not in an equilibrium state (some parts hotter)

blocks in equilibrium



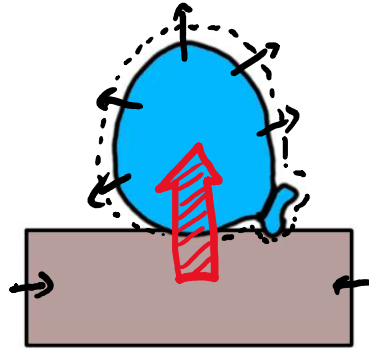
If we bring two objects in contact:

3 options:



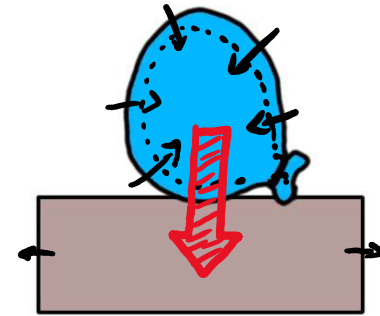
nothing
changes

we say the
systems are
EQUILIBRIUM
same
TEMPERATURE



energy from
brick → balloon
= flow of **HEAT**

brick has
higher
temperature

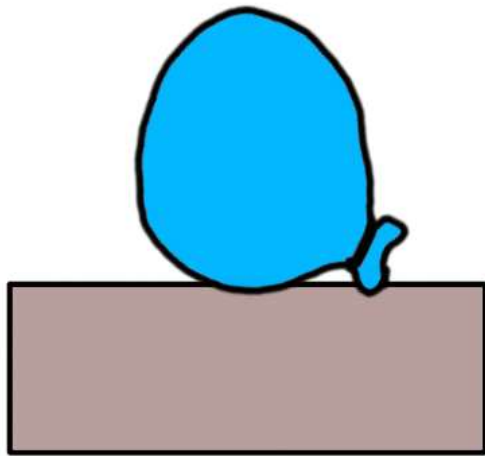


energy from
balloon to brick

balloon has
higher
temperature

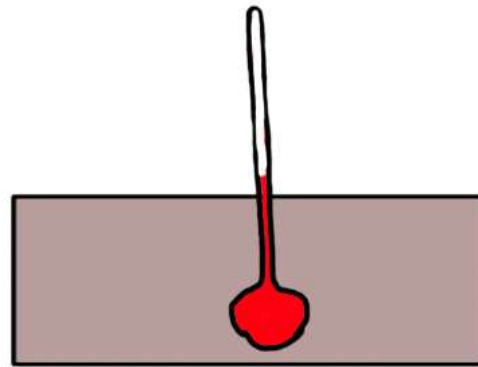
Zeroth Law of Thermodynamics:

If



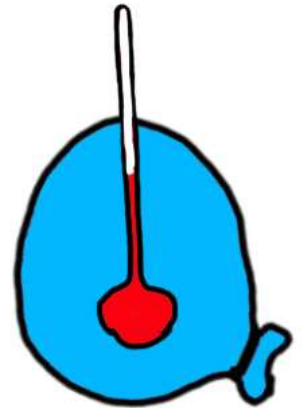
in
equilibrium

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)

