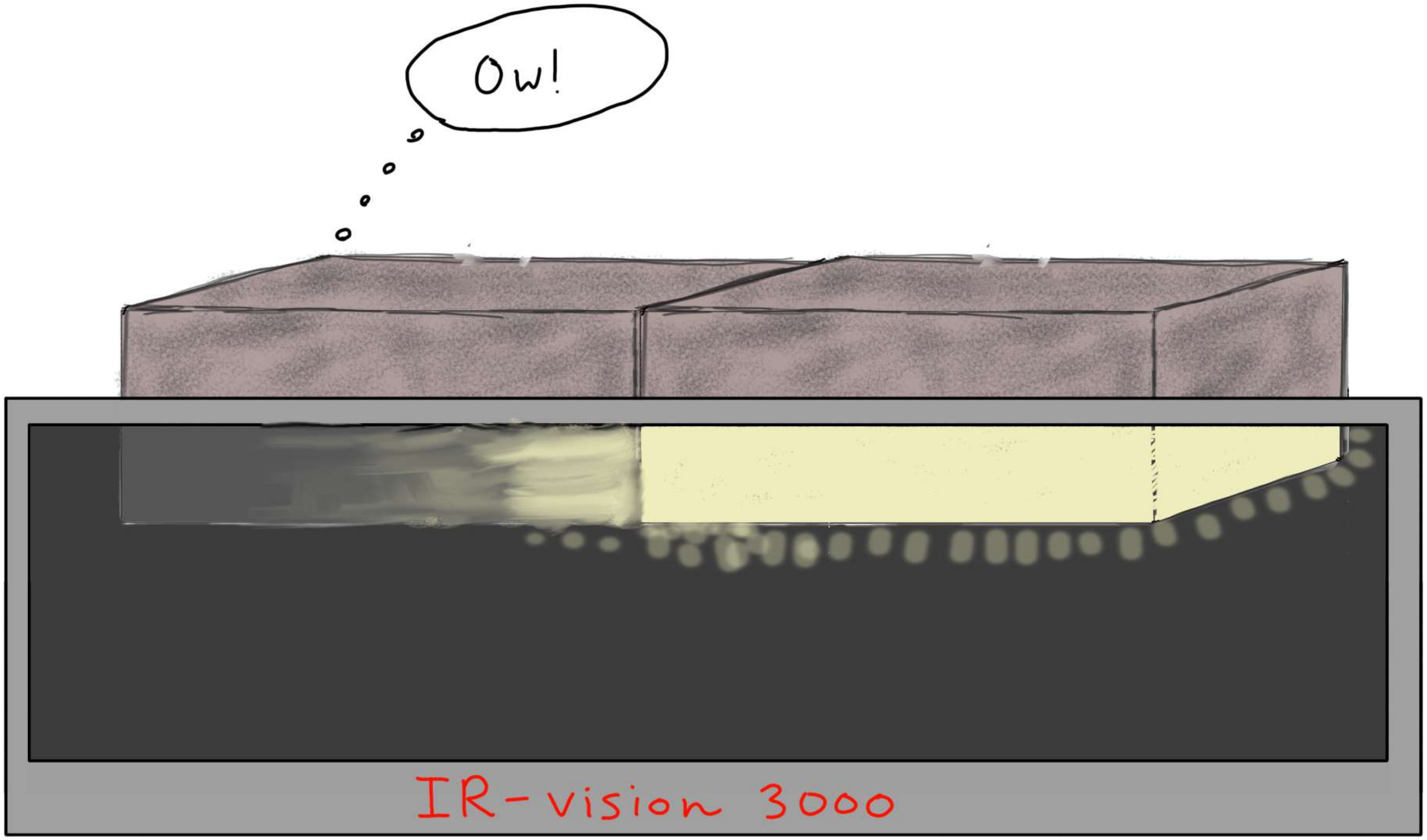
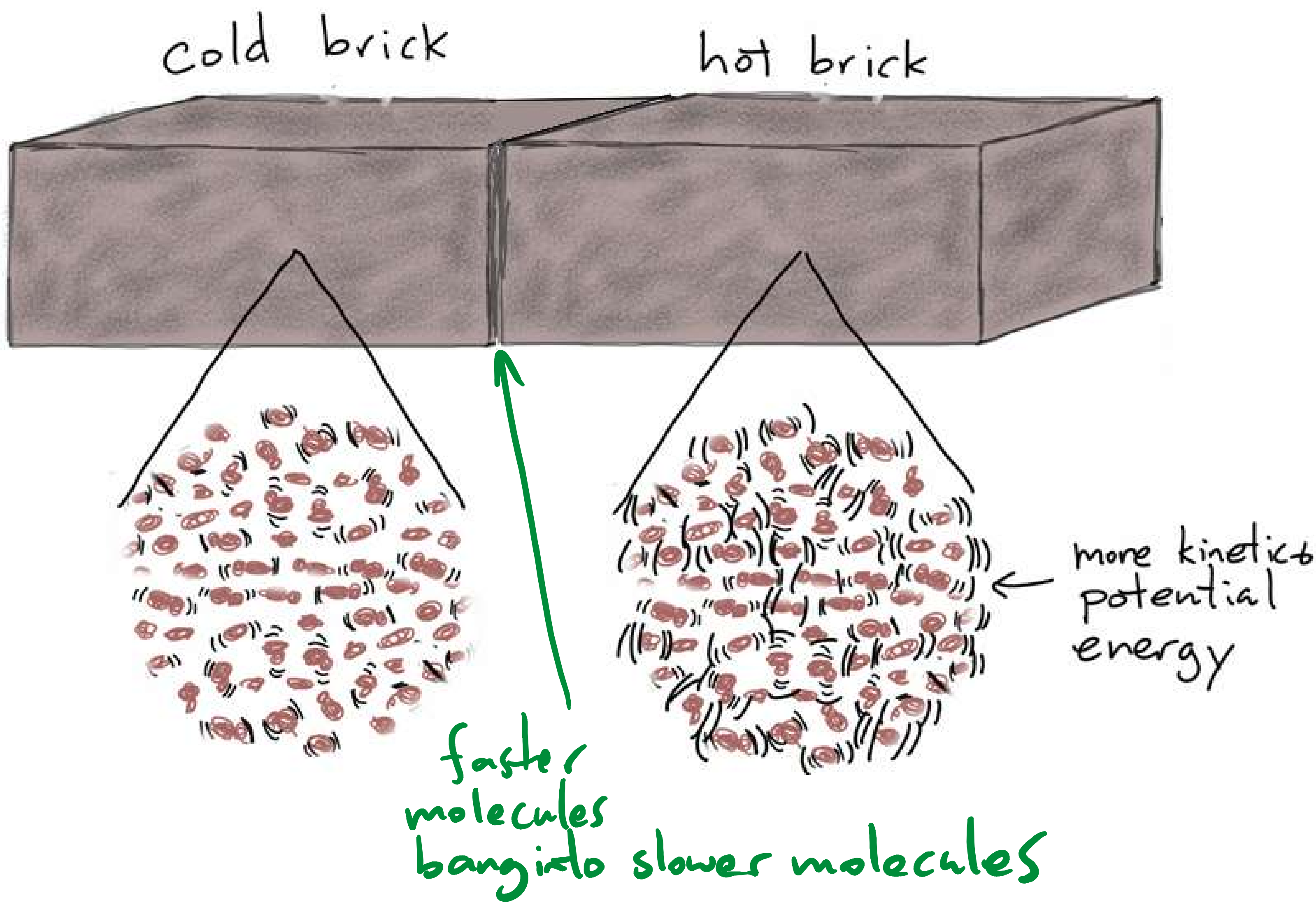
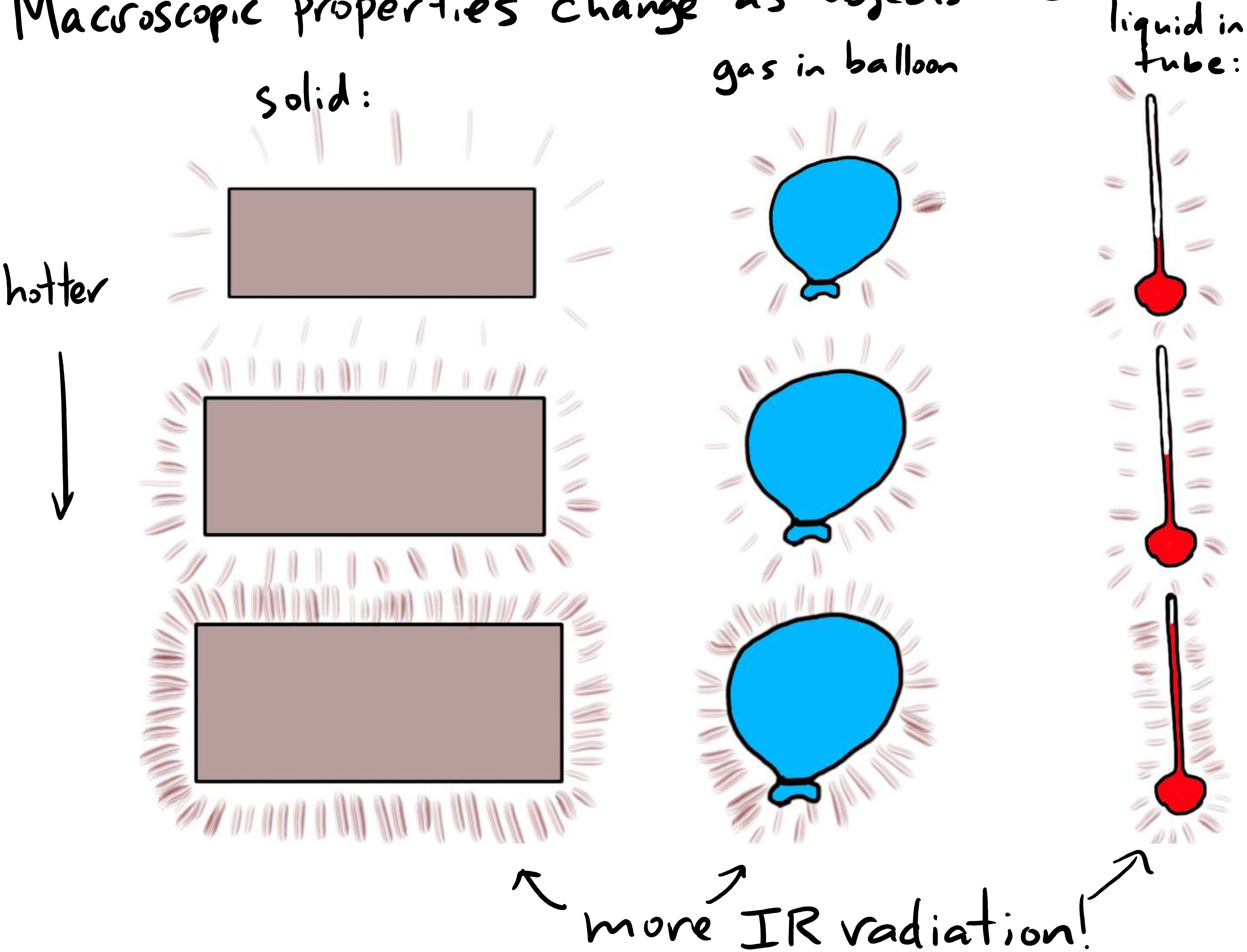
Last time in Physics 157...



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



Macroscopic properties change as objects are heated/cooled.



Clicker question: Two objects (each initially in equilibrium) are put into thermal contact and the pair is thermally insulated from its environment. If heat is observed to flow from object A to object B we can say that:

A) Object A initially had more energy than object B.

B) Object A initially had a higher temperature than object B.

C) Both A and B are true.

D) Neither A nor B can be concluded from the question.

Clicker question: Two objects (each initially in equilibrium) are put into thermal contact and the pair is thermally insulated from its environment. If heat is observed to flow from object A to object B we can say that:

A) Object A initially had more energy than object B. → no: A might be very small but hot

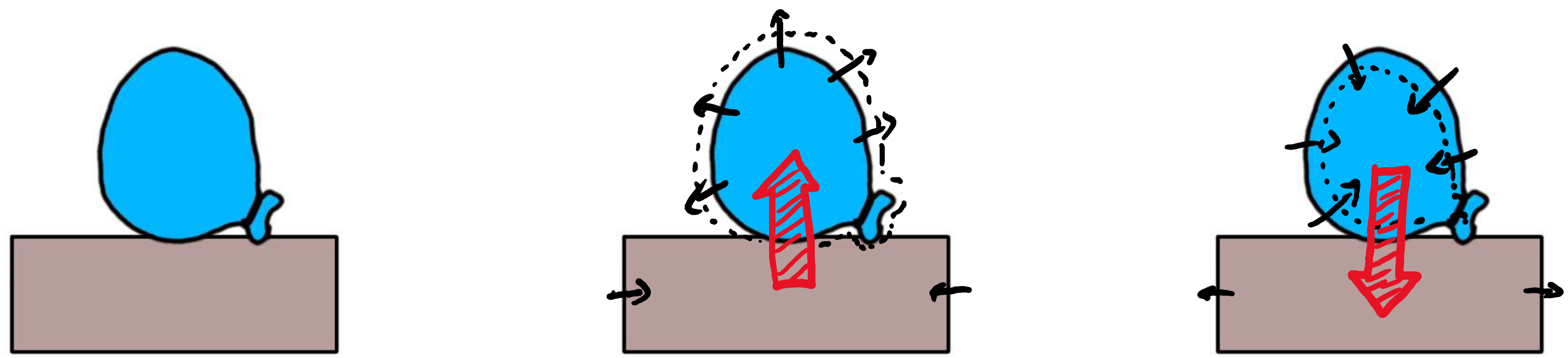
B) Object A initially had a higher temperature than object B.

This is one of the defining properties of temperature (see next slide)

C) Both A and B are true.

D) Neither A nor B can be concluded from the question.

If we bring two objects in contact:



either:

no HEAT flows

=

objects are in **EQUILIBRIUM**

=

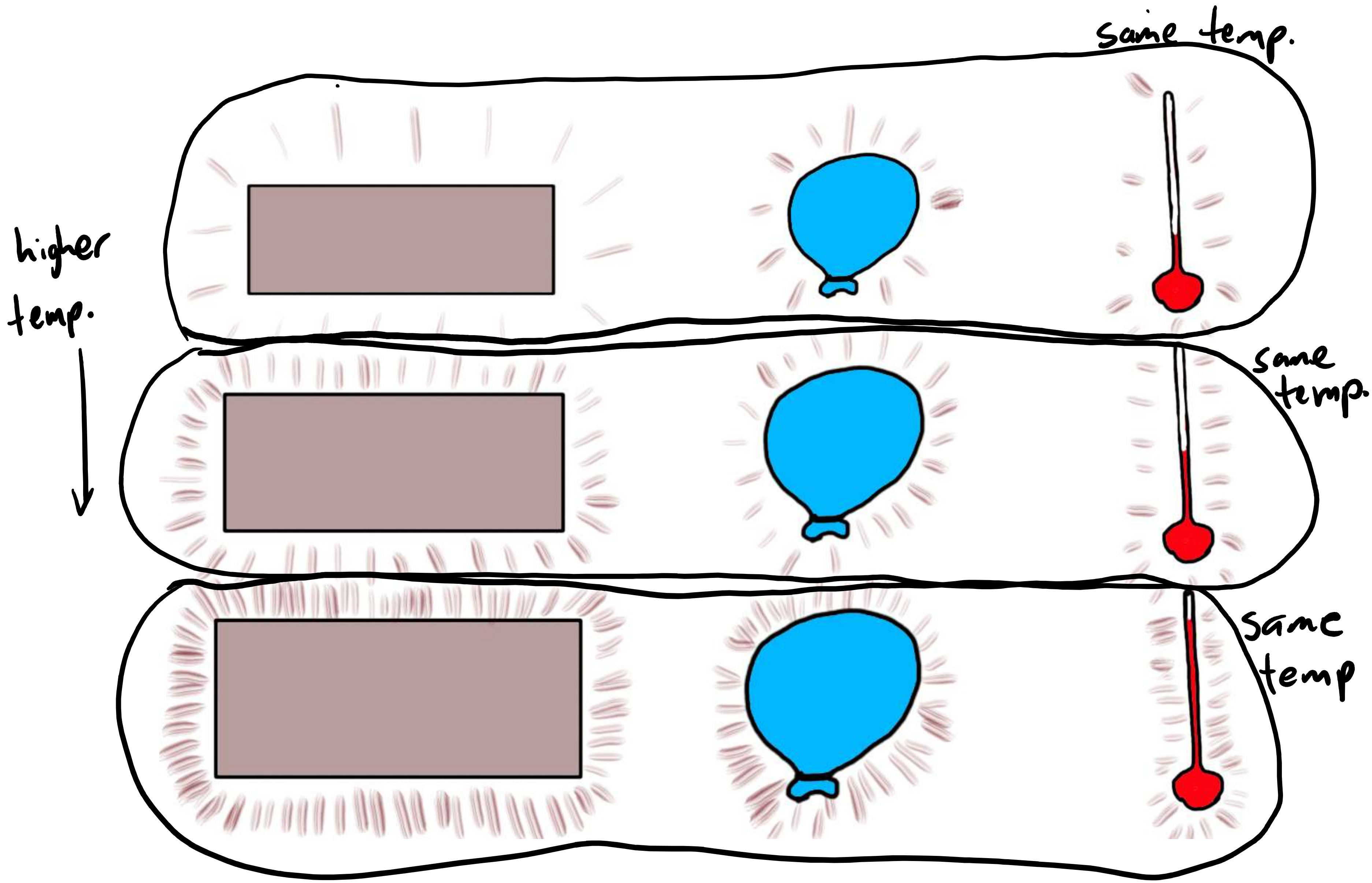
objects have same **TEMPERATURE**

or:

thermal energy is transferred

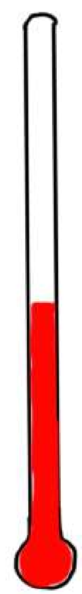
=

HEAT flows from object with higher temperature to object with lower temperature

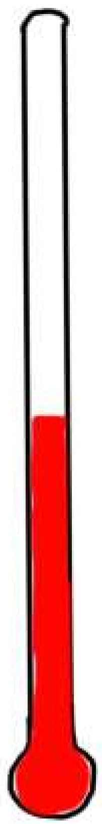


How can we assign a number to temperature?

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)



Discussion question



While trying to find a cheap copy of the 157 text online, you notice that Amazon has a sale on (liquid) thermometers for only 79 cents each. It seems like a really good deal, so you order six (Christmas is coming up). When they arrive, you realize that none of them have any markings on them.☹

Just as you are about to send them back, you develop a powerful feeling that you ***really really*** want to know what temperature it is in the room. How could you figure out the temperature (in degrees Celcius) using your cheapo Amazon thermometers?

EXTRA: will your method give the exact temperature? Why or why not? Are you assuming anything?

One way: Let it come to equilibrium w. boiling water, Mark 100°C

Let it come to equilibrium w. melting ice, Mark 0°C

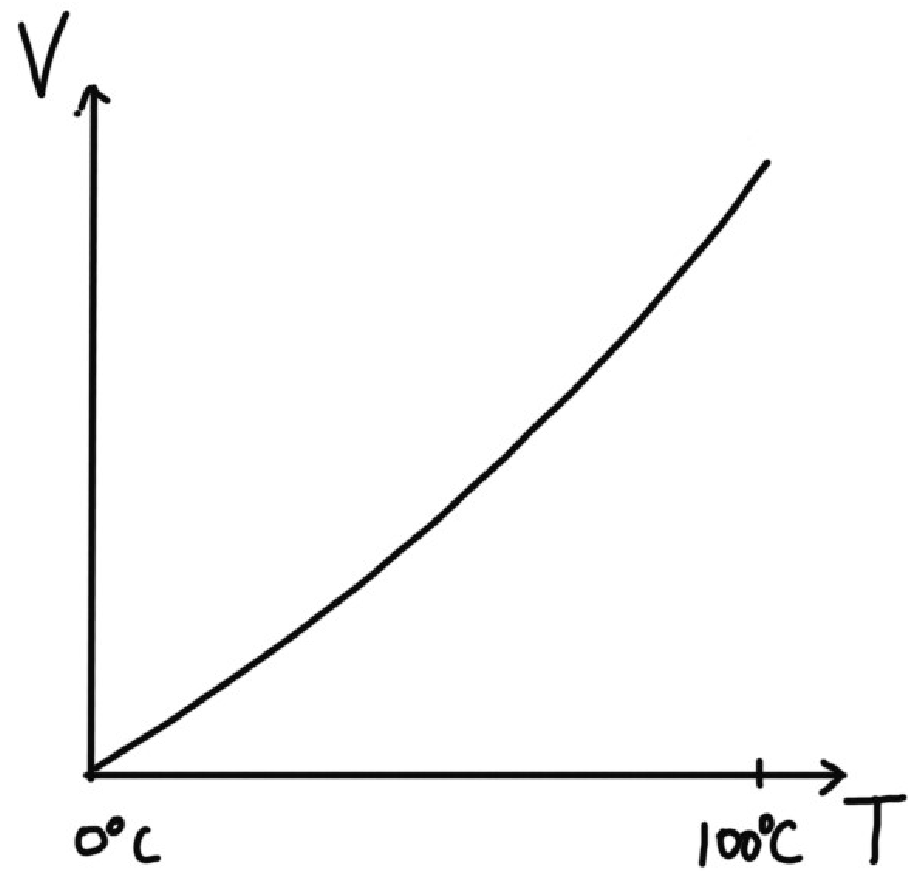
Place equally spaced markings between 0 and 100°C and label these with the intermediate temperatures

Bonus clicker question: The graph shows the volume vs temperature relationship for a sample of mercury. For a mercury thermometer with equally spaced temperature markings, if the thermometer reads 50ºC, the actual temperature is

A) Exactly 50ºC.

B) A bit higher than 50ºC.

C) A bit lower than 50ºC.



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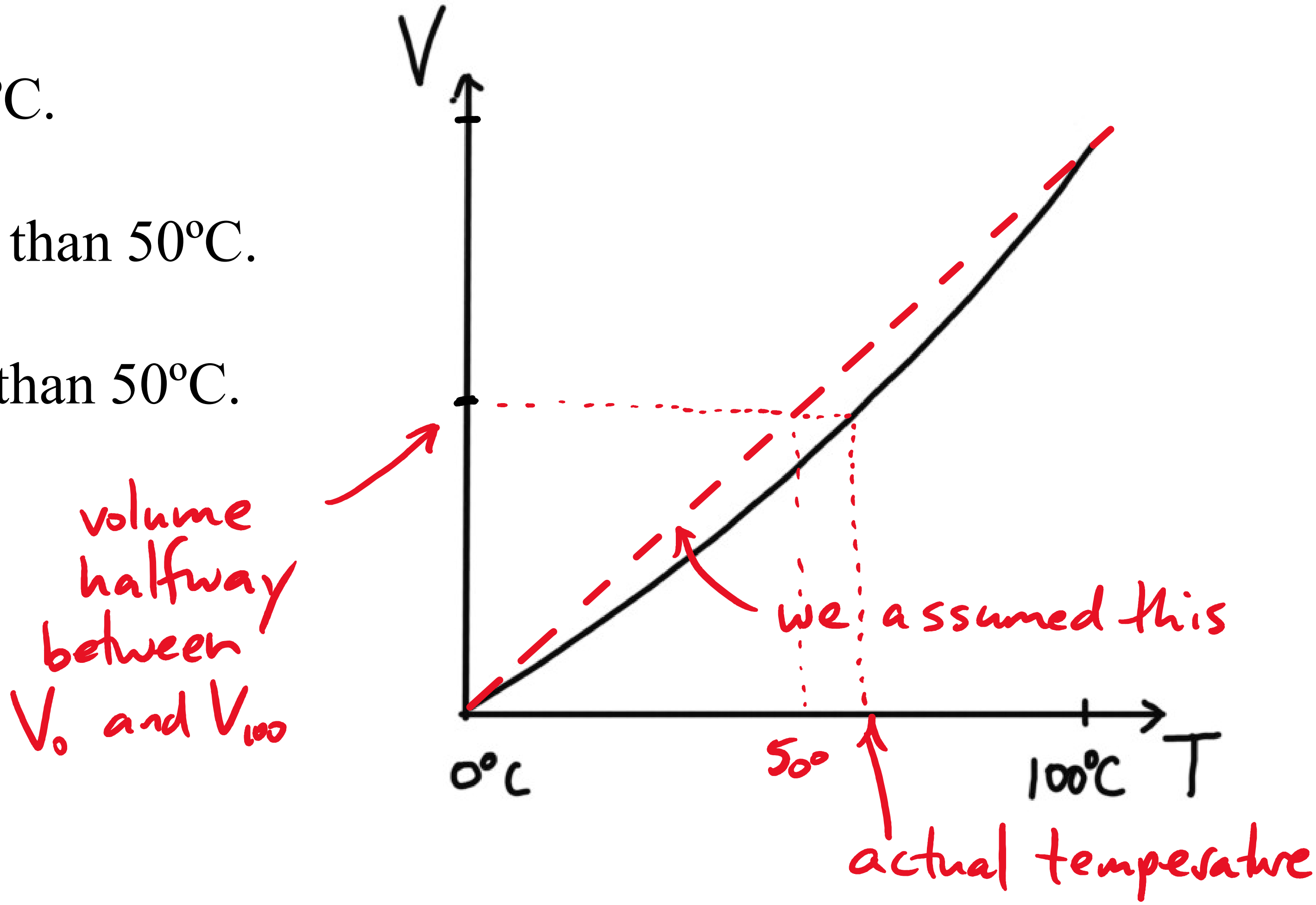
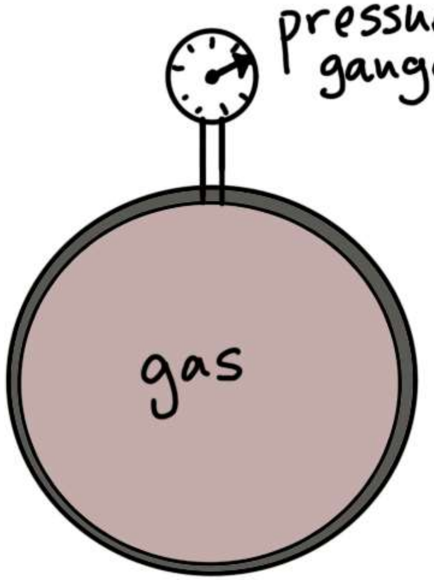
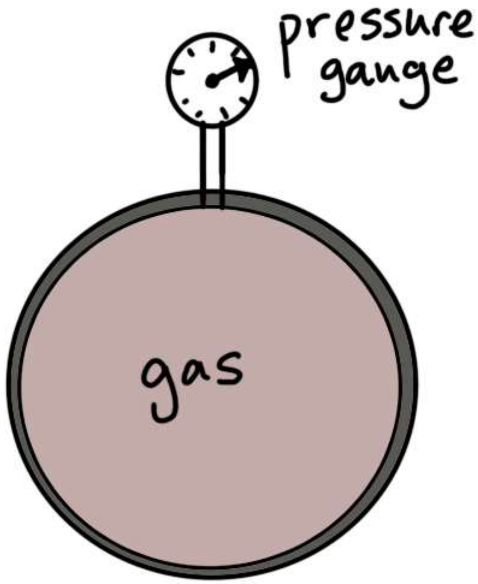


Many materials ⟶ Many possible definitions of T.



Simplest is based on the simplest material: ideal gas
=
molecules with negligible interaction
(good approx. at low density)

Look at changes in pressure for fixed volume let's remember what pressure means...



constant volume gas thermometer:

Pressure = Force on wall per unit area

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

S.I. unit: Pascal $= N/m^2$

Clicker question: The air pressure in the room is about 100kPa. The force of the air on the top of your head (say 10cm by 10cm) is similar to the downward force from

A) a 100g mass

B) a 1kg mass

C) a 10kg mass

D) a 100kg mass

E) a 1000kg mass

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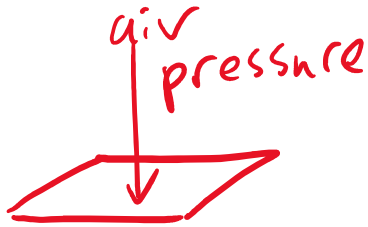
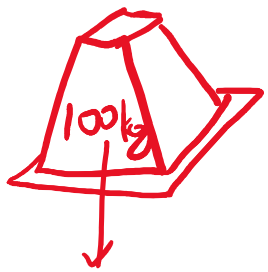


$$F = P \cdot A$$

$$= 100{,}000\,\text{Pa} \times 0.01\,\text{m}^2$$

$$= 1000\,\text{N}$$

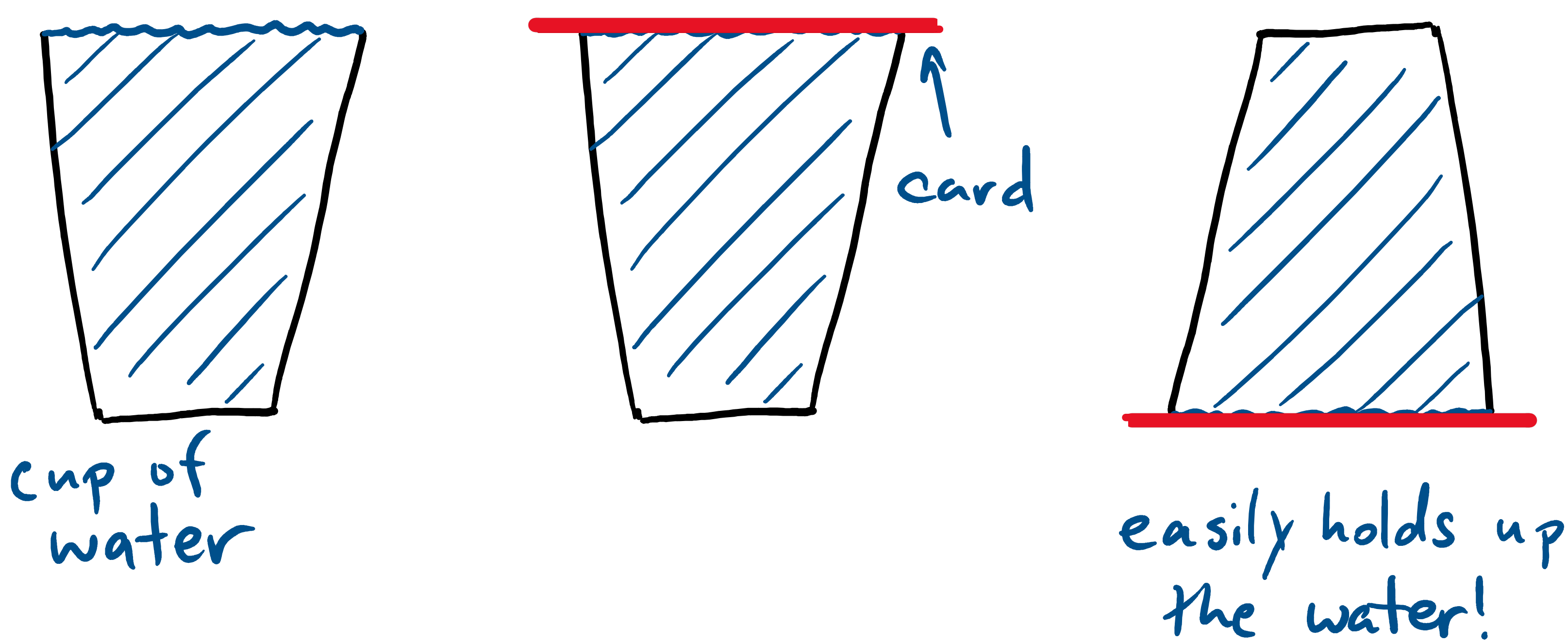


same as from a 100kg mass:

$$F = mg$$

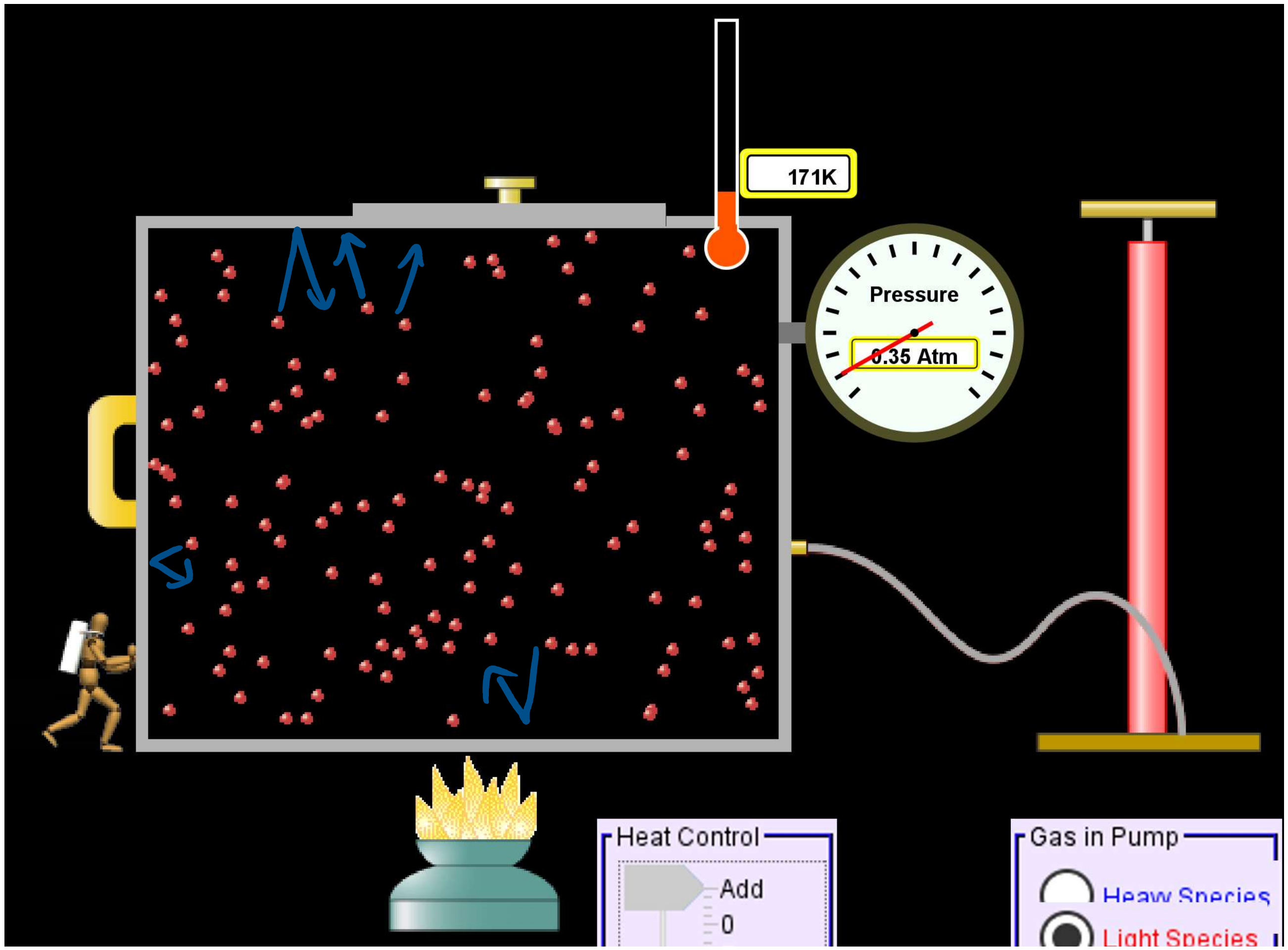
$$\approx 1000\,\text{N}$$

DEMO: (try this at home!)



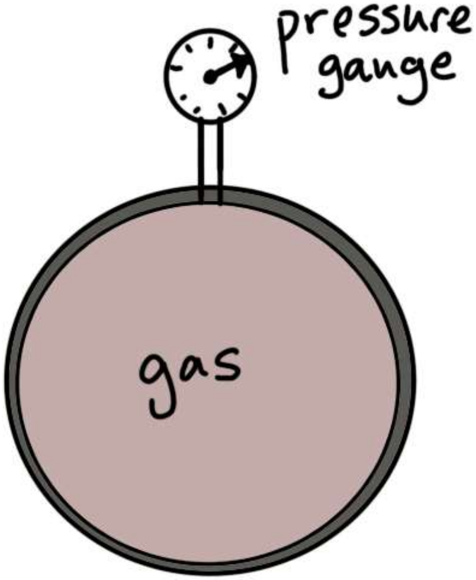
What is really holding the water up?

Simulation of an ideal gas: pressure is from the molecules hitting the wall!



As we heat the gas, the molecules move faster so pressure increases.

Gas properties PHET from U. Colorado



constant
volume
gas thermometer:

Define Kelvin scale by:

$$T = \text{const.} \times P$$

const. ← depends on particular thermometer; will discuss calibration later

P ← pressure