Learning Goals:

- Explain how a temperature-dependent macroscopic property of a material can be used to define a temperature scale or build a thermometer
- Describe the relationship between pressure and force
- To describe the typical magnitude of forces on everyday objects produced by gases at atmospheric pressure
- Explain how the Kelvin scale is defined
- Calculate the force from a gas on a certain surface given the pressure and area or the pressure given the force and the area

**Adjusted office hours today:**
I will be available from 2:30-4:00pm in Hennings 420. Feel free to drop by if you have any questions about the course material or physics in general, or just want to introduce yourself.

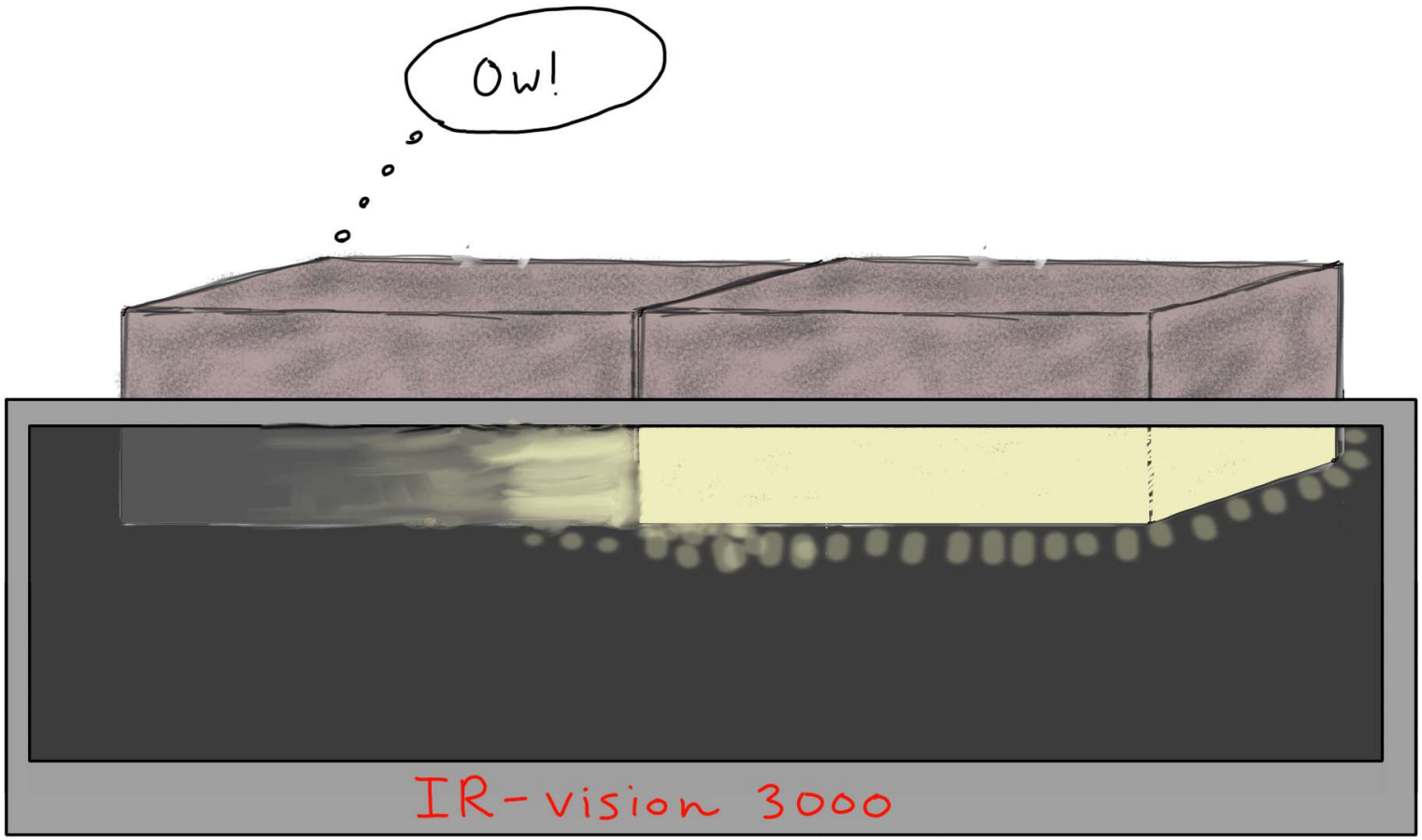
Usually, my Monday office hours will be 4-5:20.

**Mastering Physics access codes:** if you bought the textbook package at the bookstore but it didn't have a code included, you can pick up a code in the lobby of Hebb 100 at these times:

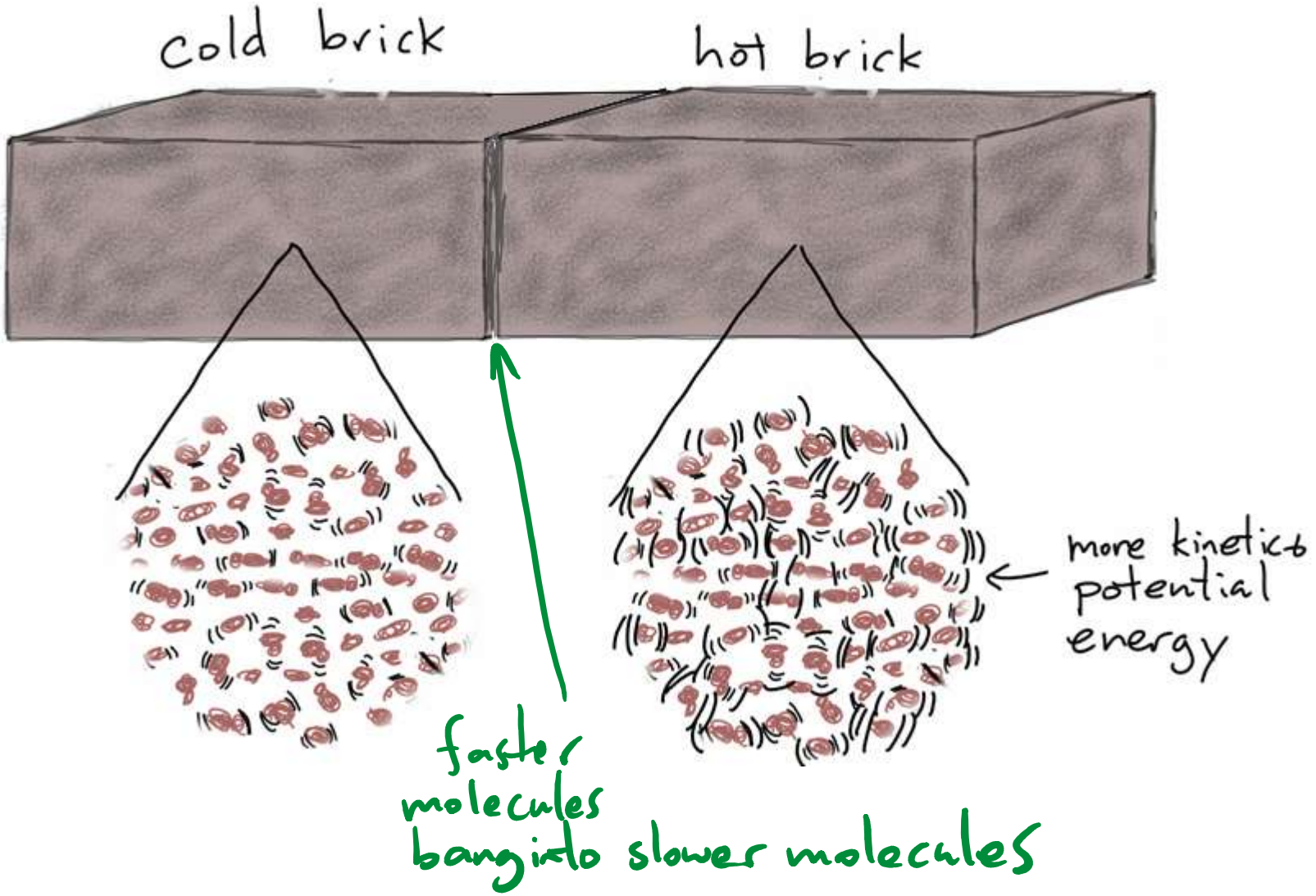
Tuesday 3:15-3:45
Wednesday 9:50-10:15
Wednesday 1:45-2:15

Bring your receipt (or some ID if you have lost your receipt)

# Last time in Physics 157...



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



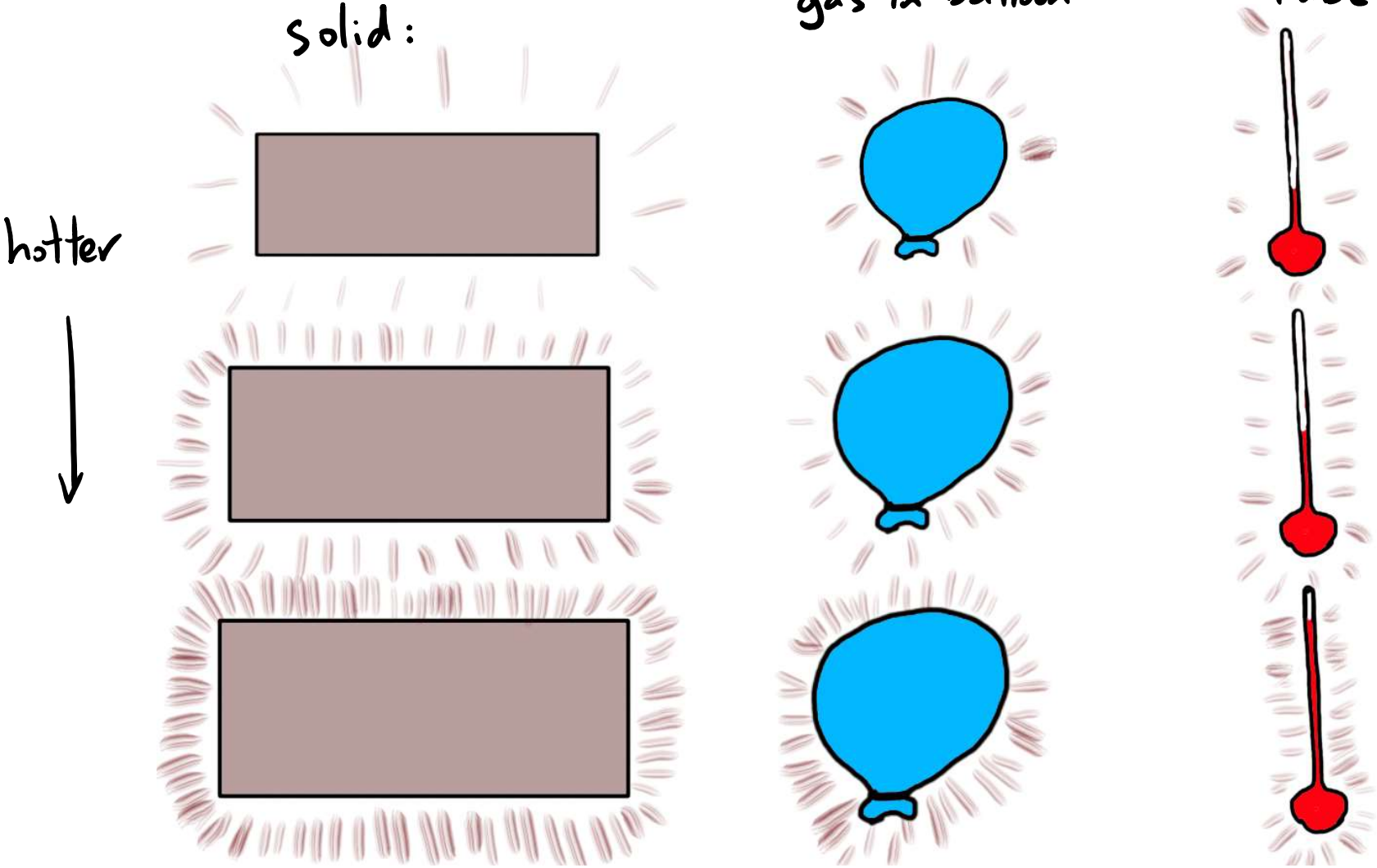
Macroscopic properties change as objects are heated/cooled.

solid:

gas in balloon

liquid in tube:

hotter



more IR radiation!

**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

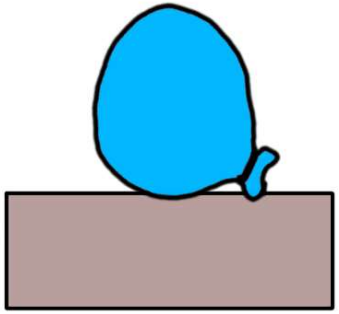
B) Object A initially had a higher temperature than object B.

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:

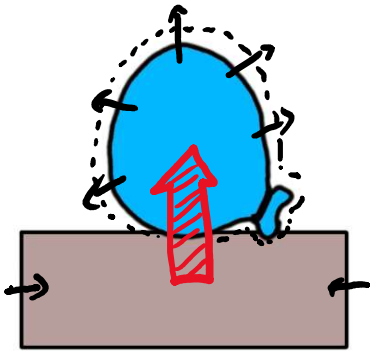
no HEAT flows

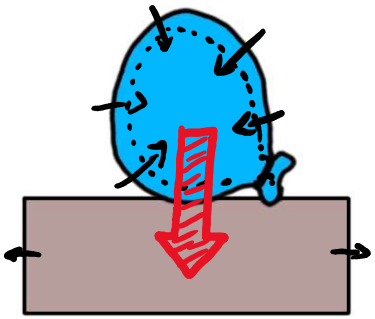
=

objects are in EQUILIBRIUM

=

objects have same TEMPERATURE



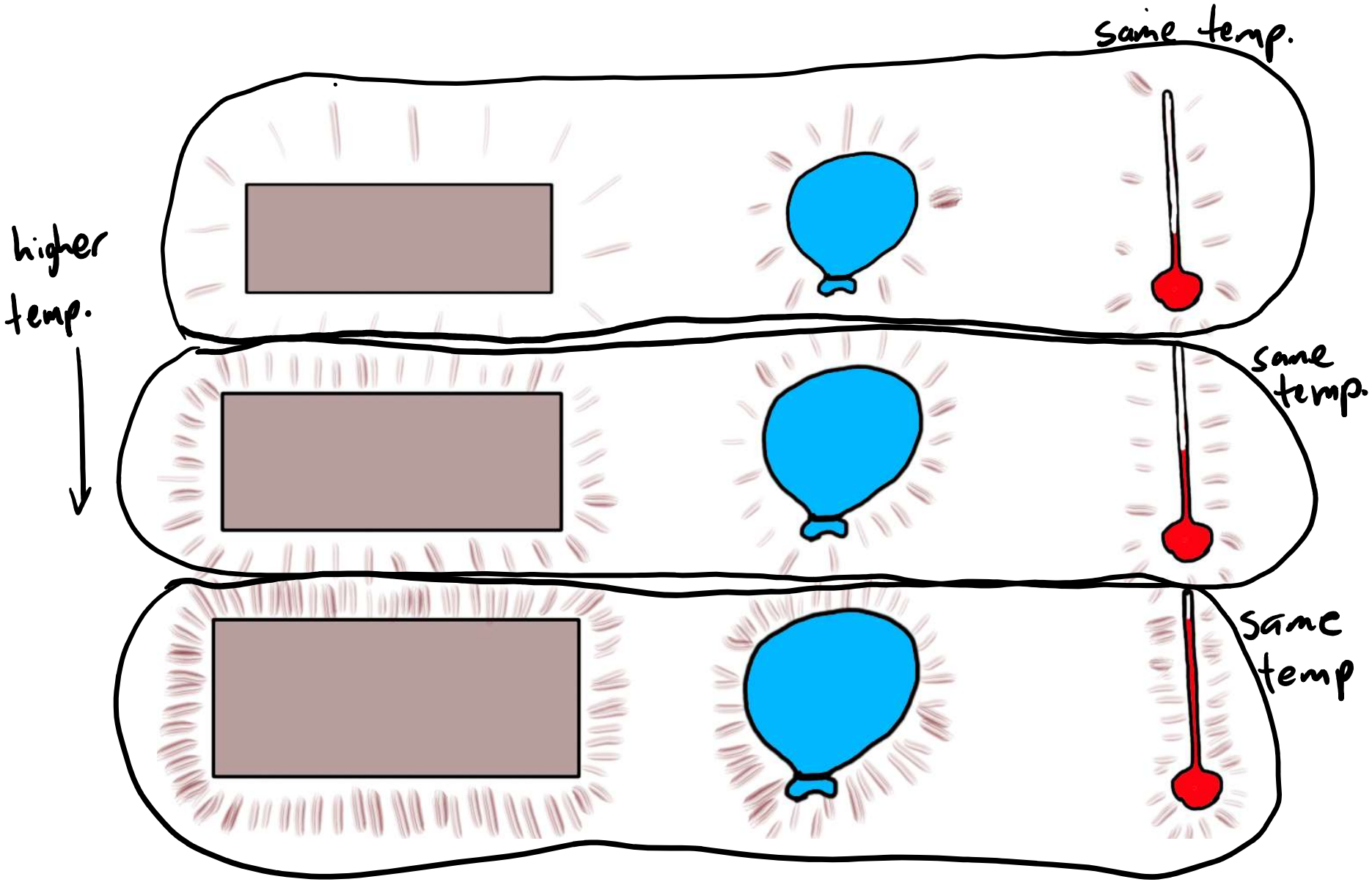


or:

thermal energy is transferred

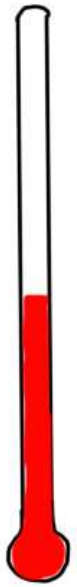
=

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

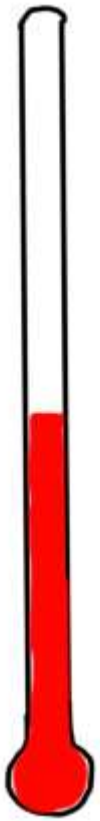



How can we assign a number to temperature?

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

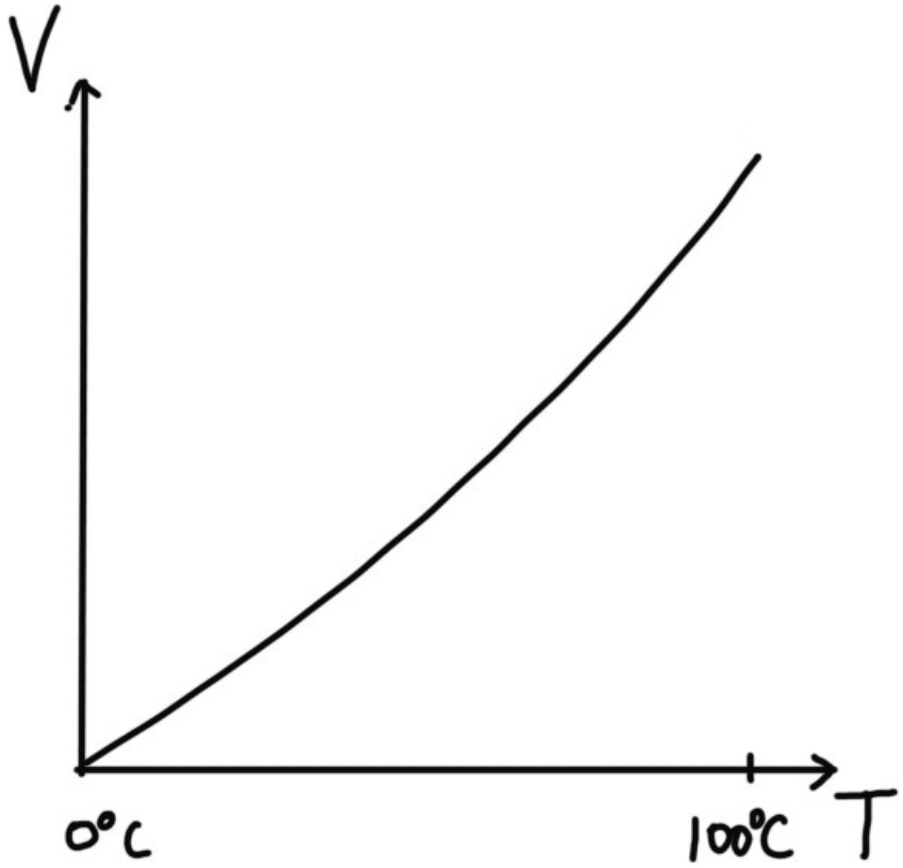
Place equally spaced markings between 0 and 100°C and label these with the intermediate temperatures

**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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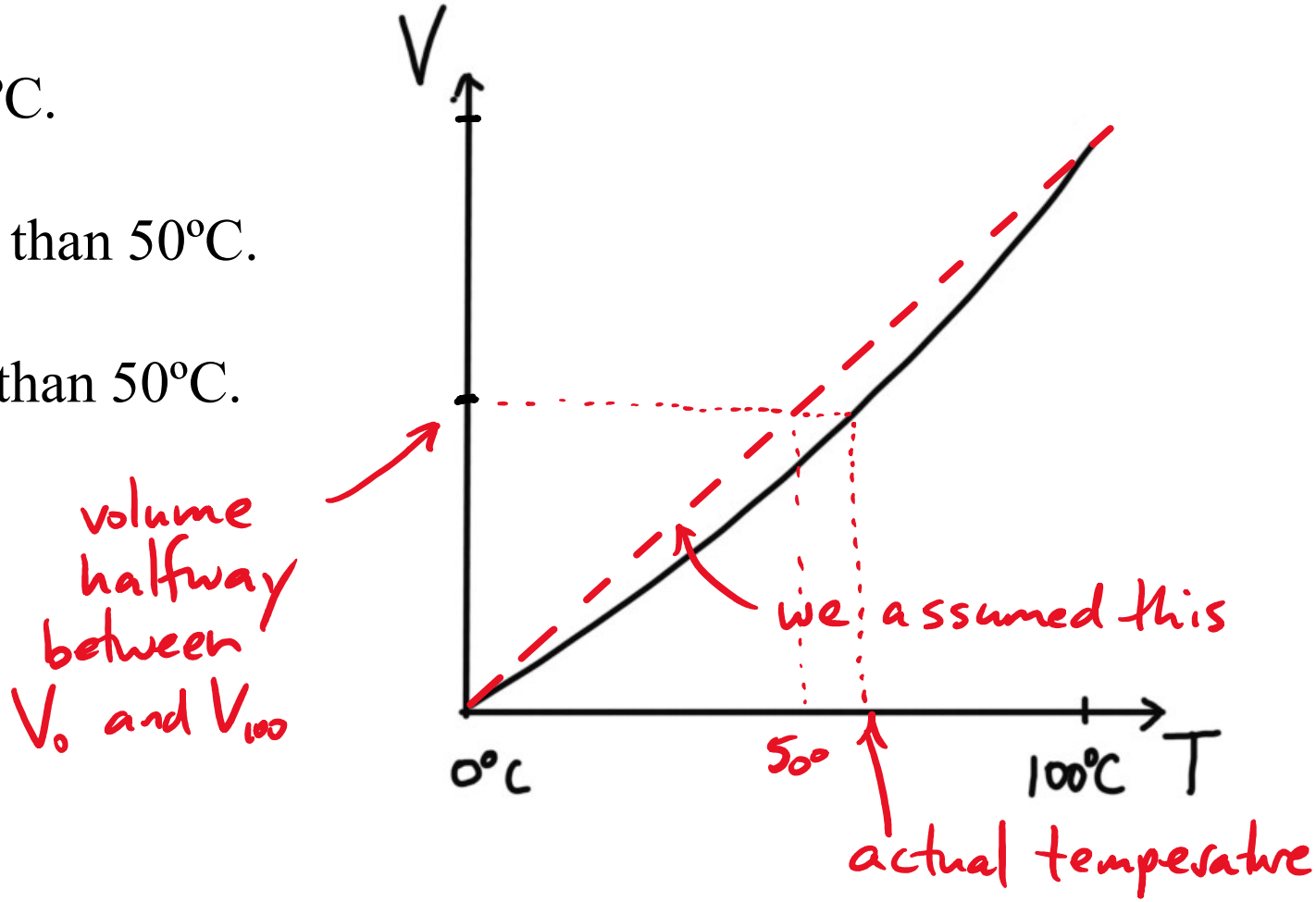
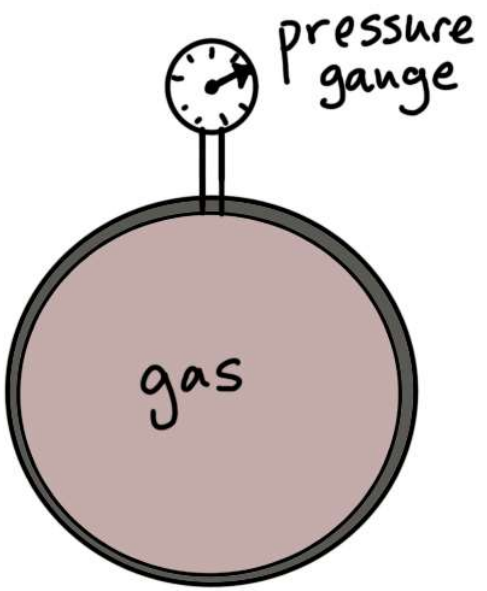


Many materials ⟶ Many possible definitions of T.




Simplest is based on the simplest material: ideal gas

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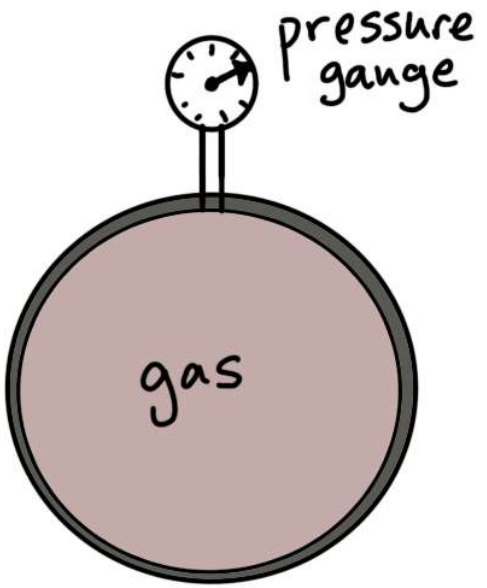
molecules with negligible interaction
(good approx. at low density)

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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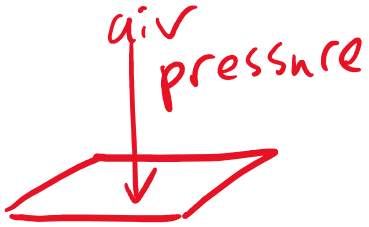
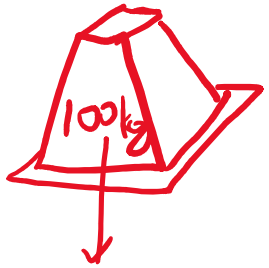



$F = P \cdot A$

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

$= 1000N$

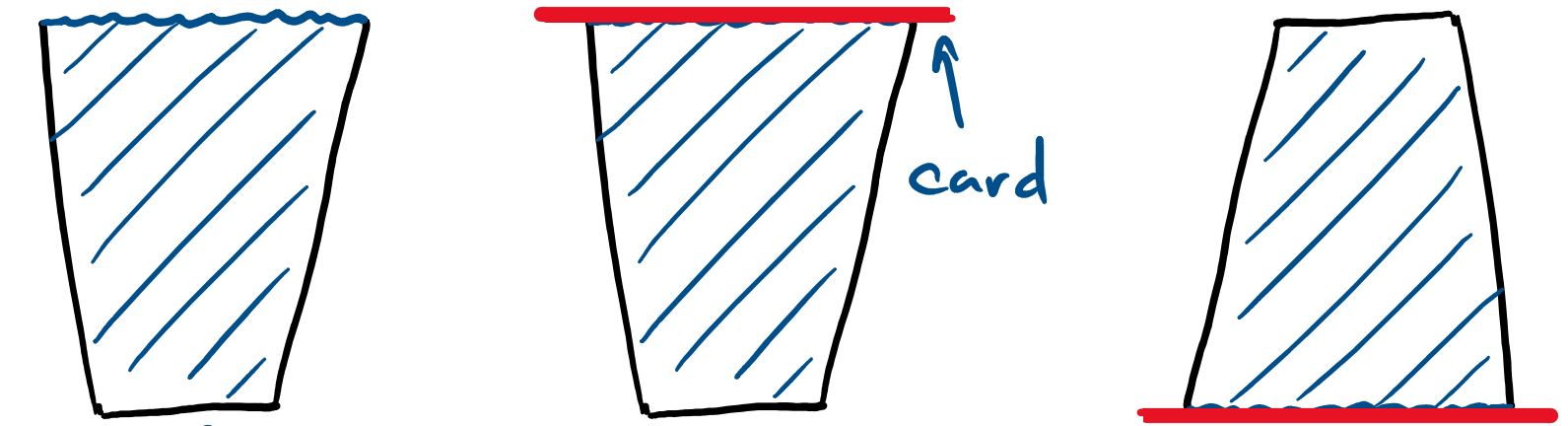



same as from a 100kg mass:

$F = mg$

$\approx 1000N$

DEMO: (try this at home!)

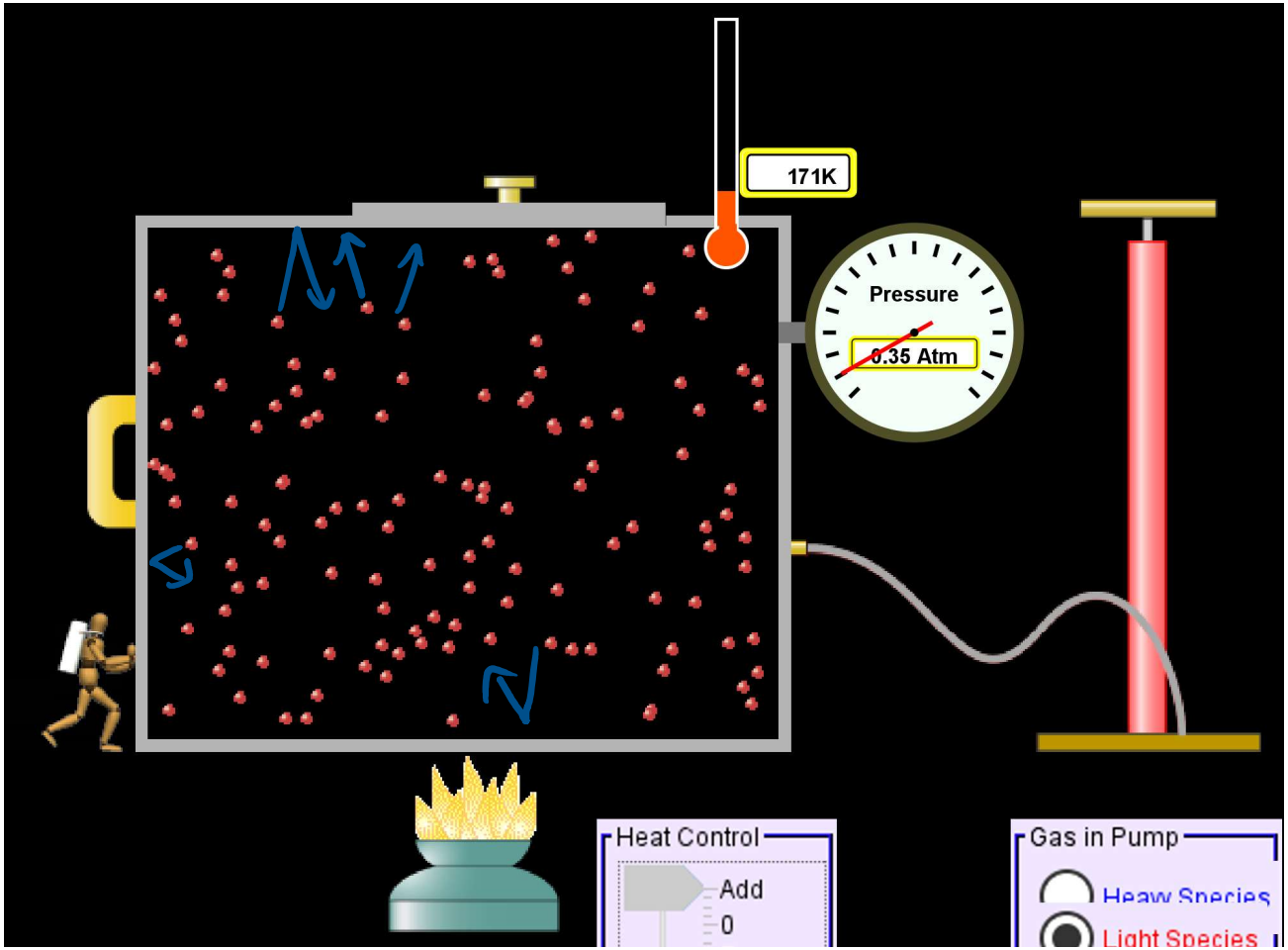



cup of water

easily holds up the water!

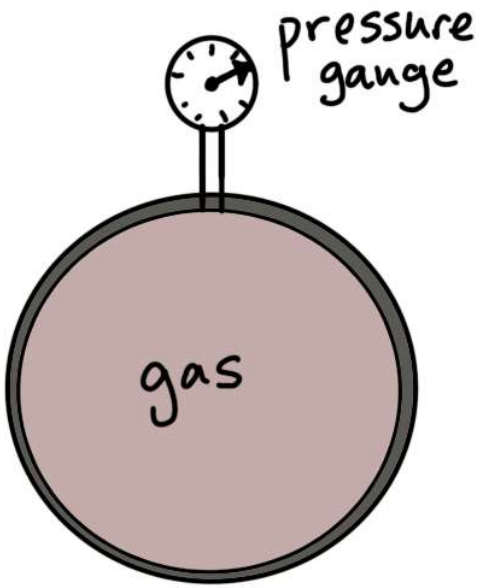
What is really holding the water up?

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

P ↑ pressure

will discuss calibration later