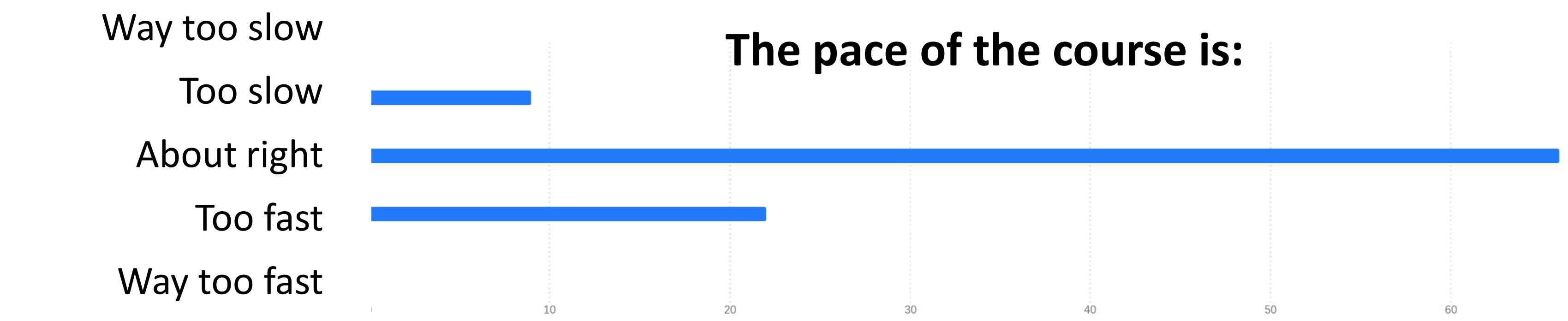
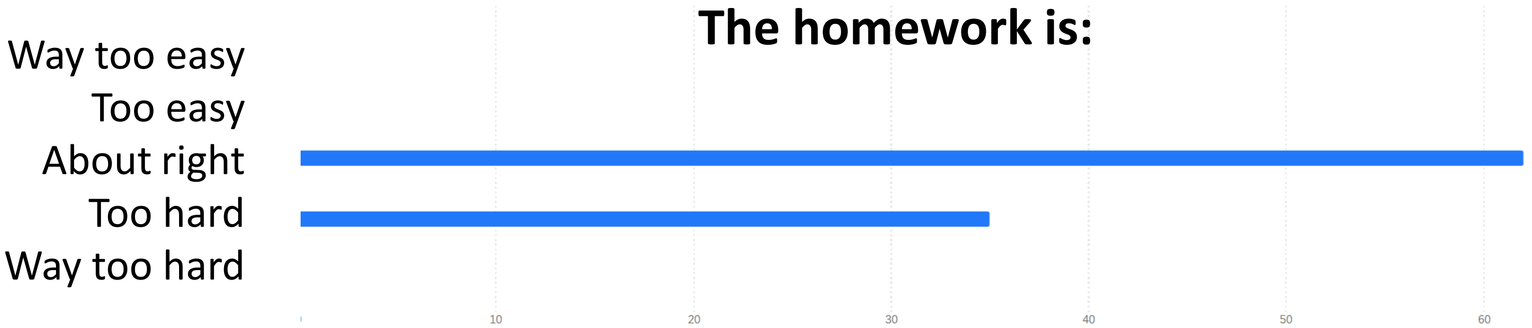
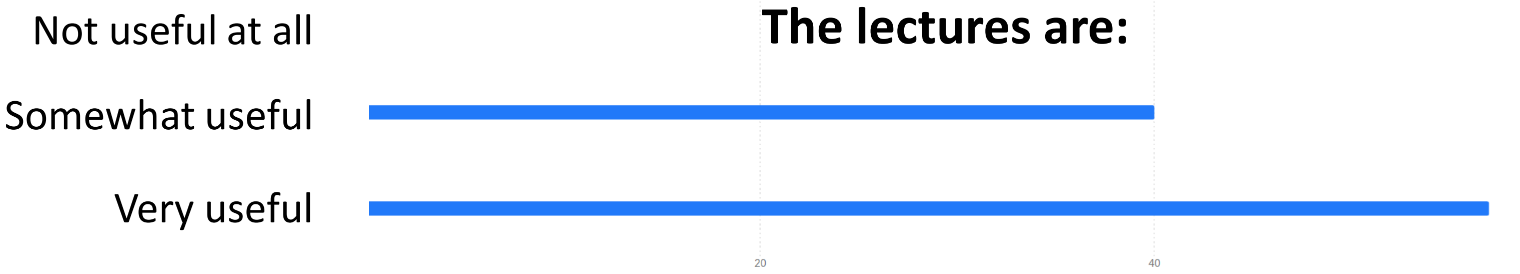
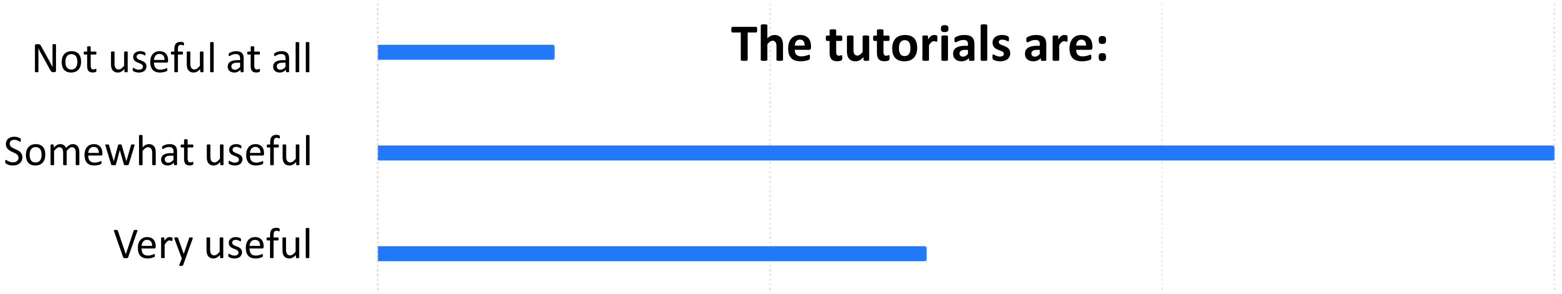
Survey Results









Meet in person: after Mon / Wed lecture, or by appointment

Tomorrow at 13:00 in Hebb 100!!!

Midterm 1 Information

- 7:00-8:30 PM, Wednesday, Oct 18th
  - Class/midterm conflicts: fill out conflict form no later than Wed, Oct 11th 5:00 PM
- Location based on tutorial section:
  - Instructions in Midterm 1 Details posted on Canvas
- Format:
  - 6 Multiple choice questions + two written problems
  - 7:00-8:15 to work on exam; 8:15-8:30 to scan/upload exam to Canvas
- Content:
  - Material summarized in the Midterm 1 Resource Guide posted on Canvas
- Rules
  - Closed book but formula sheet will be provided (posted on Canvas)
  - Calculators allowed: any calculator without wireless capabilities
  - No communications or internet usage (except Canvas during upload period ONLY)

How to study for the midterm

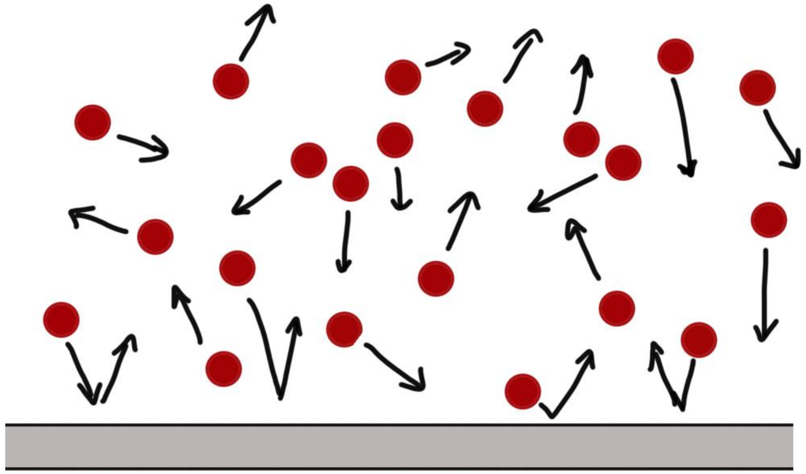
- Material summarized in the Midterm 1 Resource Guide posted on Canvas
- Review clicker questions from lectures and practice multiple choice questions posted on Canvas
- Do practice problems
  - Tutorials, homework, old midterm problems posted on canvas, back of chapters in text
  - Use text, lecture slides, problem solving tips, solutions posted on Canvas as reference
- Have a study group. Explain the steps that you make solving a problem out loud (to your study-group-mates, younger siblings, even to houseplants if you run out of listeners).
- Never look at posted solutions until you either want to check your answer or are really stuck.
- Sleep well, eat well, exercise, go out
- Smile

Lecture 14.

Ideal Gas Law.

1st Law of Thermodynamics

Ideal Gas Pressure



- The picture shows molecules of an ideal gas near the wall of a container.
- What properties of these molecules does the pressure on the wall (force per unit area) depend on?
- For each quantity you identify, what will happen to the pressure if you double that quantity?

  - Double density $\longrightarrow$ double P
  - Double mass $\longrightarrow$ double P
  - Double velocity $\longrightarrow$ quadruple P (twice as many collisions, twice as much impact)

- Therefore, on one hand:

$$\boxed{P = \text{const}\,\frac{N}{V}\left(m\,v_{avg}^2\right)}$$

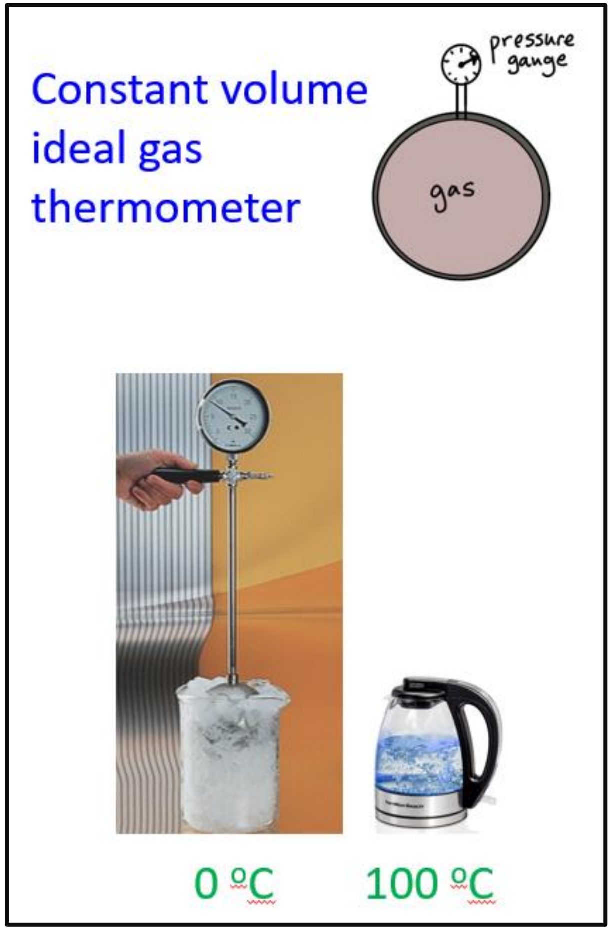
where

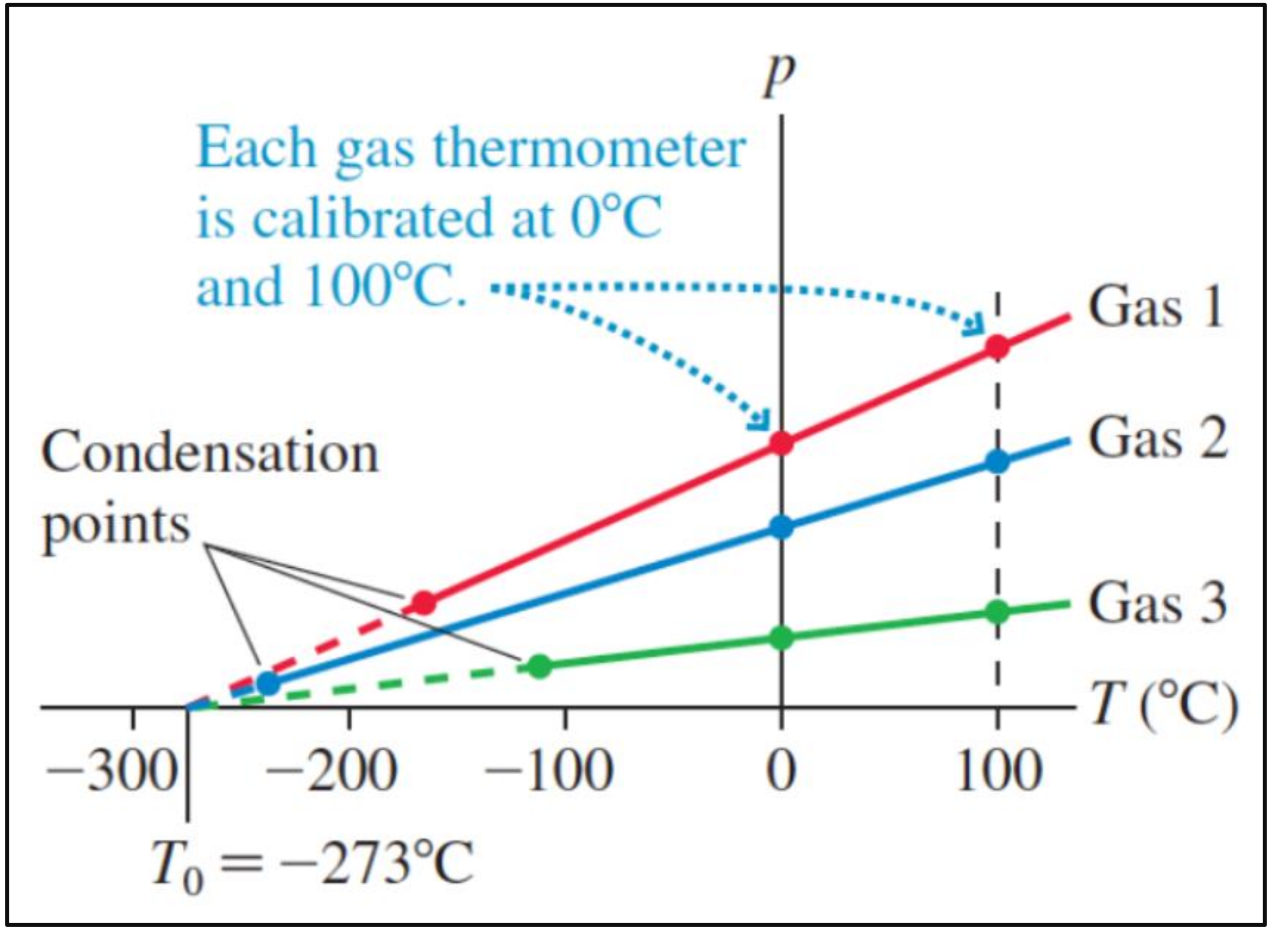
- $\frac{N}{V}$ = density
- $m\,v_{avg}^2$ = 2x kinetic energy per molecule

- On the other hand:

- Pressure of (any) ideal gas in a fixed volume appears to be a linear function of temperature

$P \propto T$





Temperature and Kinetic Energy of Molecules

- For constant N and V, molecular model gives: $P \propto E_{kin}^{avg}$

- We previously observed: $P \propto T$

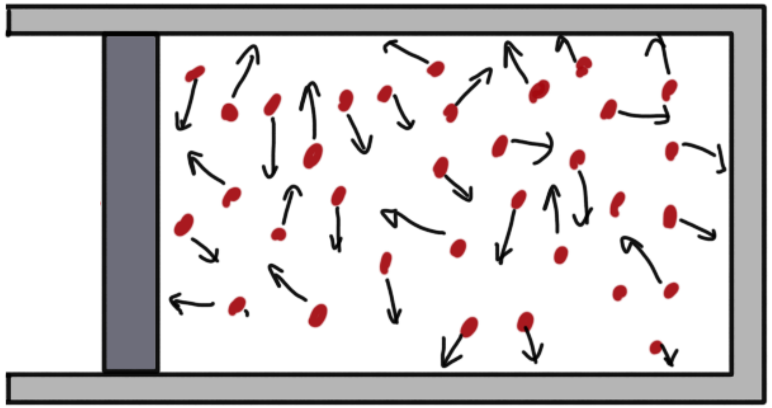
- These are consistent if: $T = \text{const} \times E_{kin}^{avg}$

Temperature measures the average kinetic energy of the molecules!

Ideal Gas Law

$N = 12 \cdot 10^{23}$ particles $\rightarrow$ 2 moles $n=2$

$$\boxed{P = \text{const}\ \frac{N}{V}\ E_{kin}^{avg}}$$



- N = number of molecules = amount of matter
- E_{kin}^{avg} = average kinetic energy per molecule = measure of the temperature of the gas

micro

$\hookrightarrow$ macro

- n = number of moles (1 mole = 6×10^{23} particles)
- R = "Gas constant" = 8.31 J/mole-K

1 mole = $6 \cdot 10^{23}$ particles

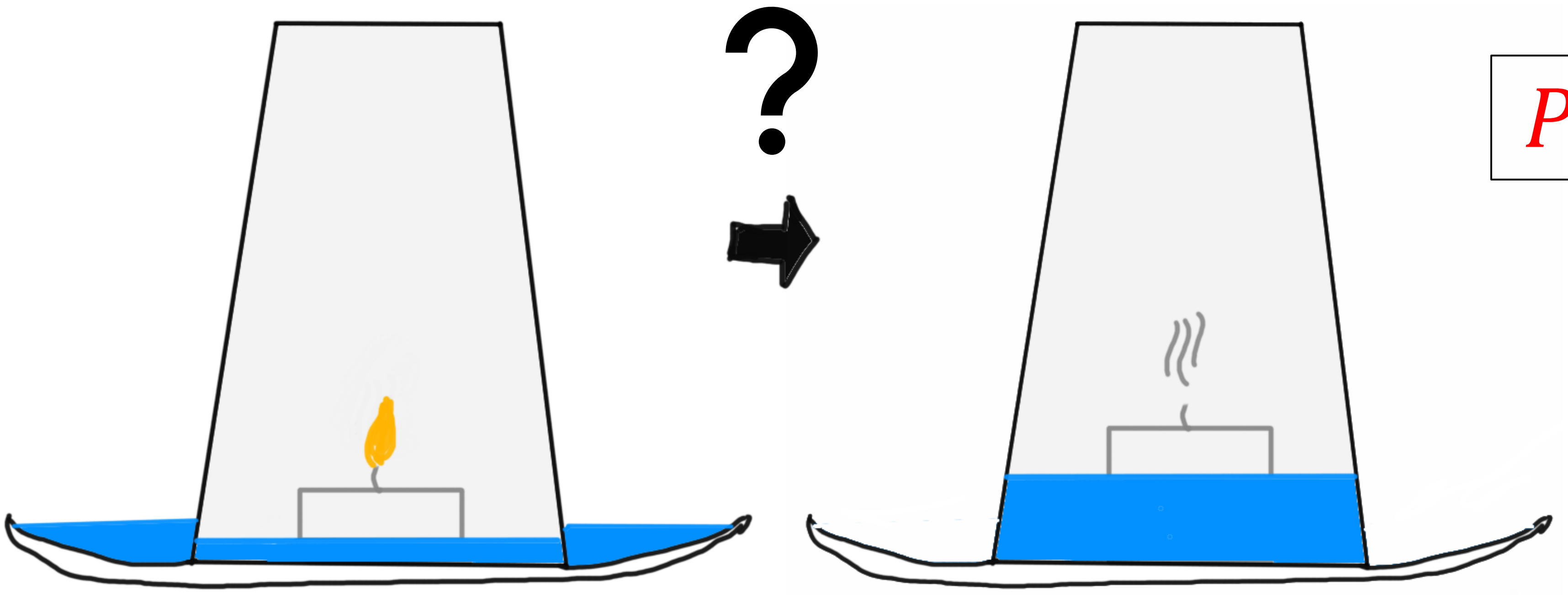
$$\boxed{PV = nRT}$$

- Describes how the parameters of the gas (P, V, T, n) are related

Thirsty Cup Demo

https://www.youtube.com/watch?v=3EGfqU_zBec

Q: Which of the following explains why the cup sucks up the liquid?



$$PV = nRT$$

A. T↓ so V↓

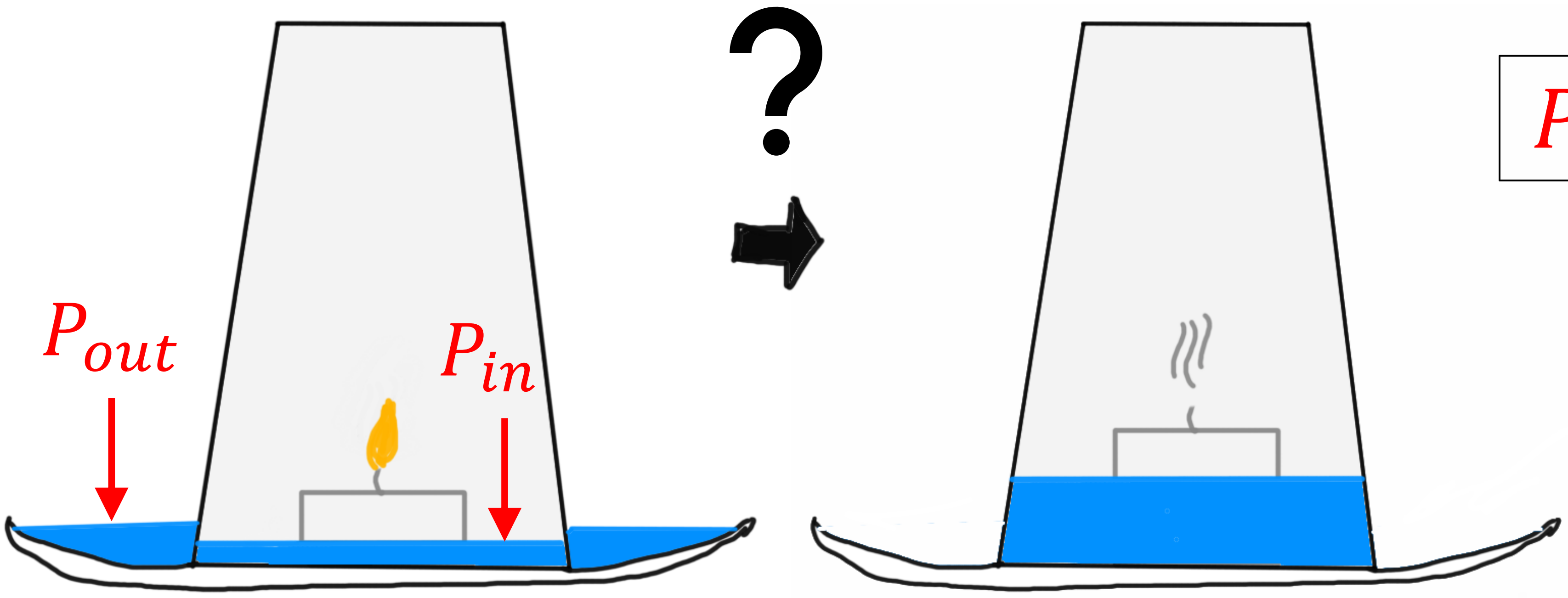
B. P↓ so V↓

C. n↓ so P↓

D. n↓ so V↓

E. T↓ so P↓

Q: Which of the following explains why the cup sucks up the liquid?



$$PV = nRT$$

A. T↓ so V↓
B. P↓ so V↓
C. n↓ so P↓
D. n↓ so V↓
E. T↓ so P↓ ✓

O_2 is consumed, but it's replaced by other molecules (CO_2, H_2O) so the effects of changing n are small

Flame extinguishes → temperature drops (heat leaks out through glass) → pressure inside decreases → water is pushed into cup, since outside pressure is higher

- Equation $PV = nRT$ is called ideal gas law.

- Now we are going to introduce the 1st law of thermodynamics. This law is a form of general principle of energy conservation, so we will start with a question in which it will be especially easy to trace involved energy bookkeeping.

- As a next step, armed with the ideal gas law, we will see how we can apply the 1st law of the thermodynamics to processes in gas.

Q: The picture shows gas in a cylinder with a movable piston on top. There is **no air** outside the cylinder. Heat 10 J flows into the gas via a burner at the bottom, causing the piston to move 0.1 m upwards. If the piston plus the weight on top have a mass of 1 kg, by roughly how much does the energy of the gas change during this process?

(E out)

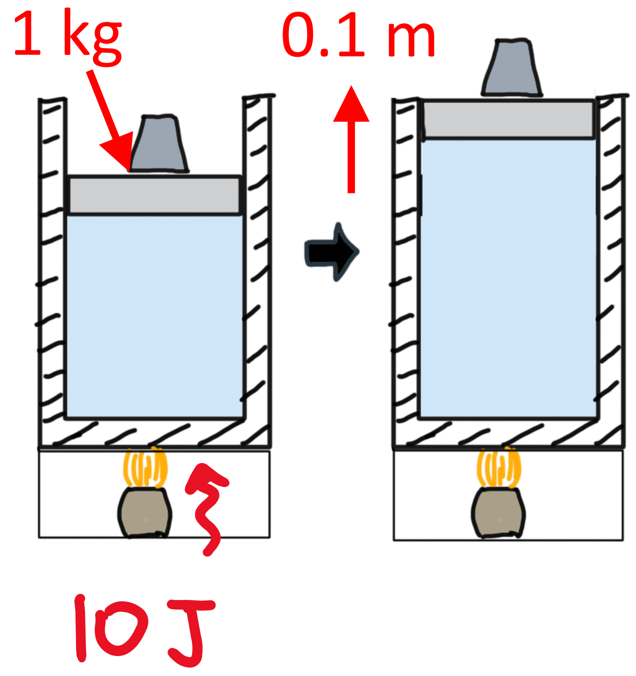
10 J

(E_{in} = 10 J)

Piston up

$\Delta U_G \uparrow$ = 1 J

ΔE_{gas} = 9 J



A. 0 J

B. +1 J

C. +9 J

D. +10 J

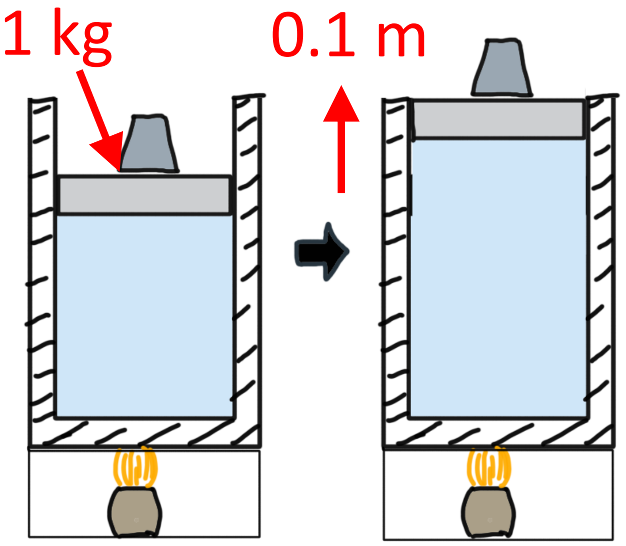
E. +11 J

$U_G = mgy \rightsquigarrow \Delta U_G = mg\Delta x$

Q: The picture shows gas in a cylinder with a movable piston on top. There is **no air** outside the cylinder. Heat 10 J flows into the gas via a burner at the bottom, causing the piston to move 0.1 m upwards. If the piston plus the weight on top have a mass of 1 kg, by roughly how much does the energy of the gas change during this process?

Energy in: $Q = 10$ J → To the gas (the added energy we need to find)

→ To change the potential energy of the weight



$$\Delta P = mg\Delta h = (1\text{ kg}) \times \left(10\,\frac{m}{s^2}\right) \times (0.1\,m) = 1\text{ J}$$

A. 0 J

B. +1 J

C. +9 J ✓

D. +10 J

E. +11 J

Energy in: $Q = 10$ J → ΔE_{gas}

→ $\Delta P = 10$ J

$$\Delta E_{gas} = 9\text{ J}$$

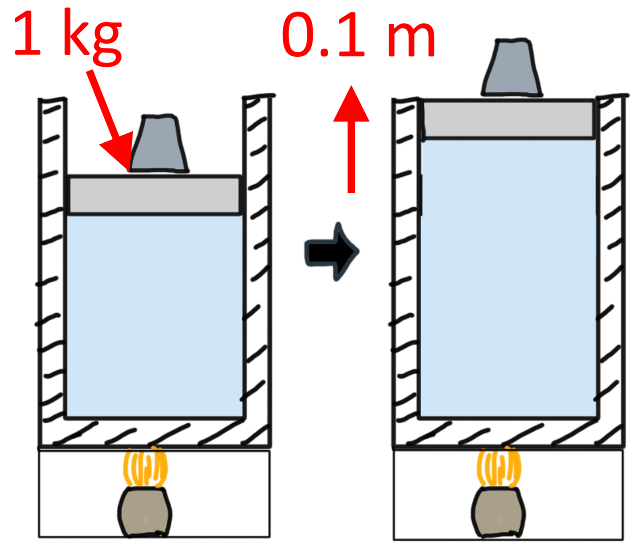
Q: The picture shows gas in a cylinder with a movable piston on top. There is **no air** outside the cylinder. Heat 10 J flows into the gas via a burner at the bottom, causing the piston to move 0.1 m upwards. If the piston plus the weight on top have a mass of 1 kg, by roughly how much does the energy of the gas change during this process?

Change in potential energy of weight & piston is

$$mg\Delta h = (1\text{ kg}) \times \left(10\frac{m}{s^2}\right) \times (0.1\ m) = 1\text{ J}$$

This energy must come from the gas

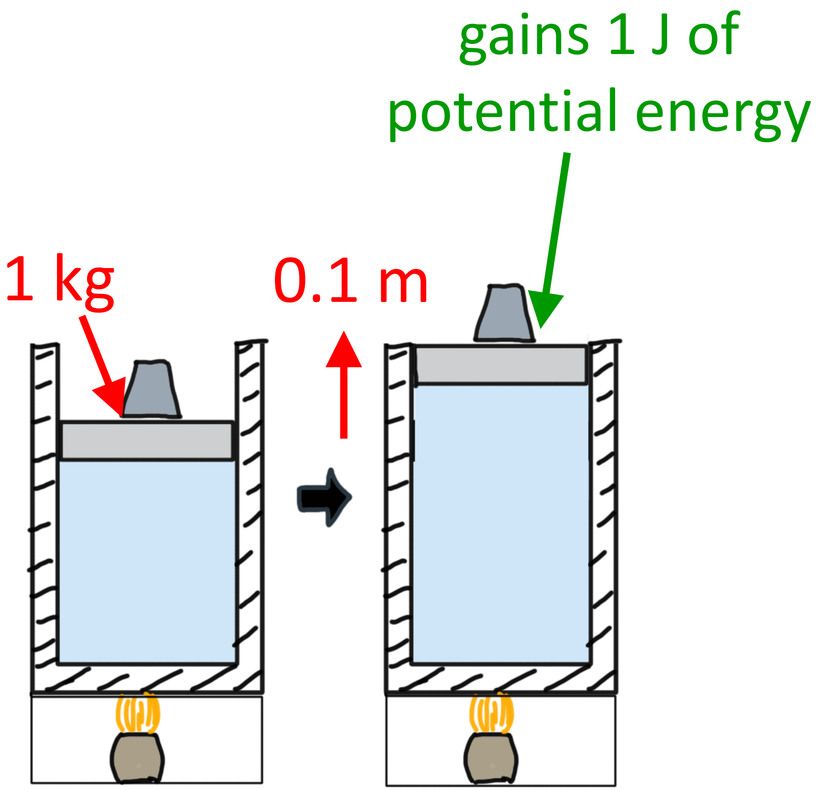
So we have 10 J in but 1 J out, leaving a change of +9 J



A. 0 J
B. +1 J
C. +9 J ✓
D. +10 J
E. +11 J

WORK = energy transferred by a mechanical process

- Q: Why does the change in the potential energy of the weight & piston matter, if we look at this process “through the eyes” of the gas? How does the gas “pass energy over” to the weight & piston?

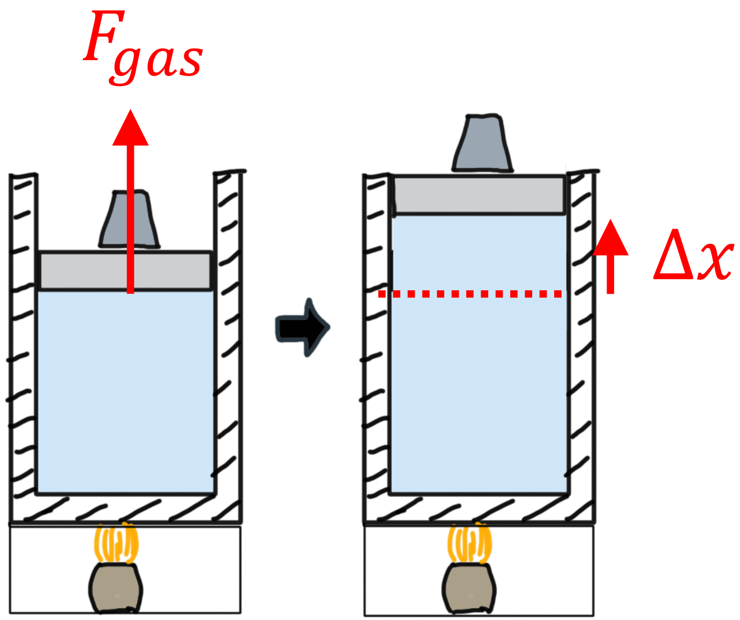


- A: The gas did 1 J of work on the piston

$$W_{gas} = 1\text{ J}$$

work done BY the gas

WORK = energy transferred by a mechanical process



- In mechanics, force & displacement produce work (units: Joules):

$$W = F\Delta x_{\parallel}$$

force exerted (const force)

displacement in the direction of the force

- Work done by the gas:

$$W = F_{gas}\Delta x_{\parallel}$$

- Gain in the potential energy of the weight & piston:

$$\Delta(PE) = mg\Delta h$$

- Energy bookkeeping: $\Delta(PE) = W$

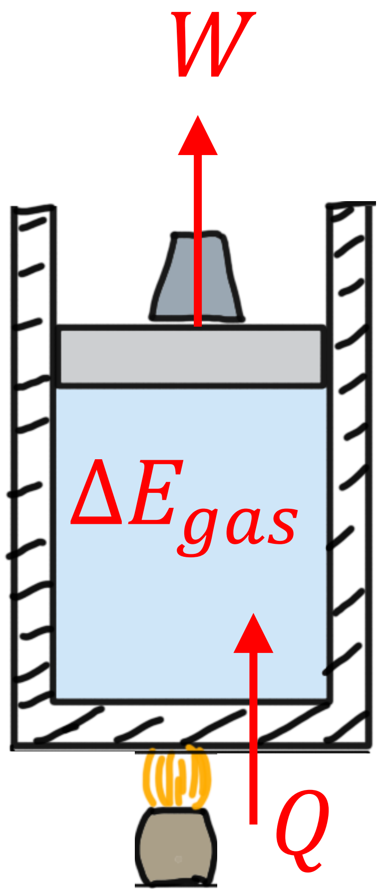
Gas pressure P tells us how much force gas exerts on the walls: $P = \frac{F_{gas}}{A}$

First Law of Thermodynamics

(conservation of energy)

$Q < 0$, heat is released by object

$W < 0$, work is done <u>on</u> the object



$$\boxed{\Delta E_{gas} = Q - W}$$

net change in the energy of the object*)

heat supplied <u>to</u> the object (thermodynamics)

work done <u>by</u> the object (mechanics)

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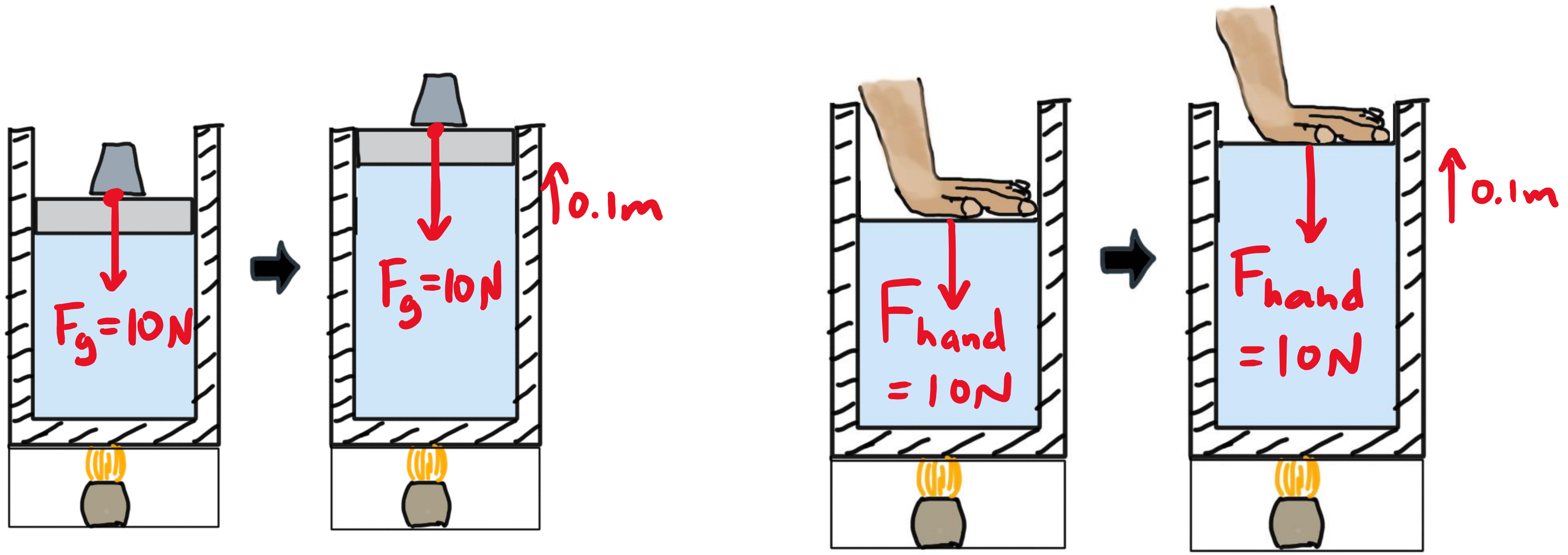
*) This is actually the change on the internal energy of the gas, which is denoted ΔU. We will define it properly soon.

Q: In the second picture, the hand exerts a constant 10 N force opposing the expansion of the gas. The person uses up 2 J of energy in order to exert this force. We can say that the work done by the gas is

$W = F\,\Delta x$



$\Delta PE_g = 1J$

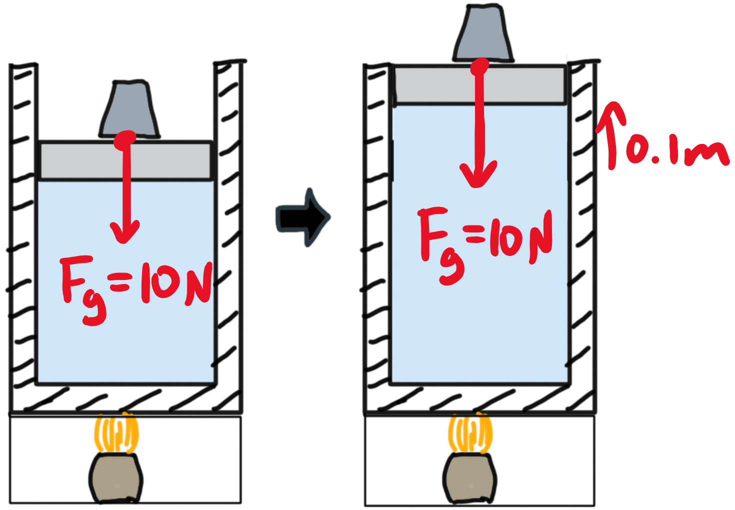
$\Delta E_{person} = 2J$

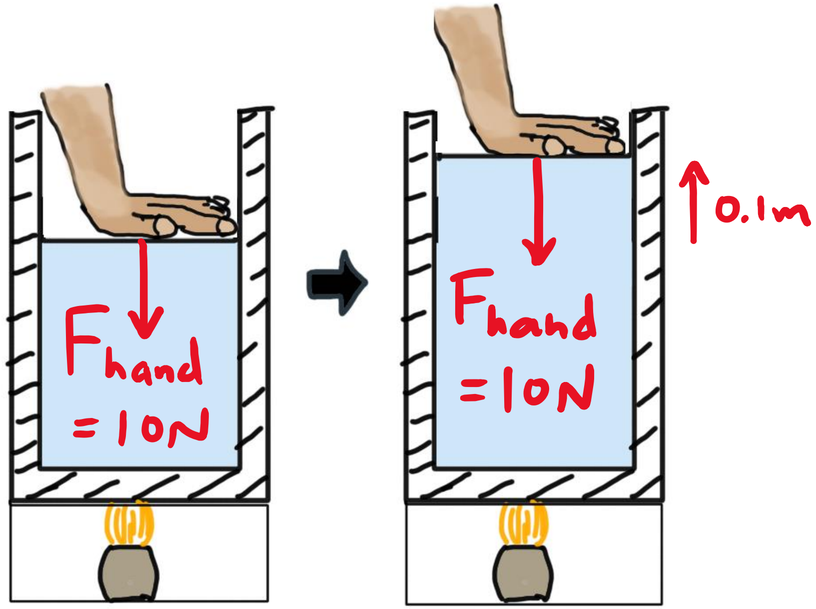
A. Greater in the second case

B. Less in the second case

C. The same in the second case

Q: In the second picture, the hand exerts a constant 10 N force opposing the expansion of the gas. The person uses up 2 J of energy in order to exert this force. We can say that the work done by the gas is





Gas can't tell what is pushing down.

Exactly the same situation from the point of view of the gas, so same energy lost via work.

You can study the energy balance of the person to find out how they spent an extra 1 J of energy.

A. Greater in the second case

B. Less in the second case

C. The same in the second case