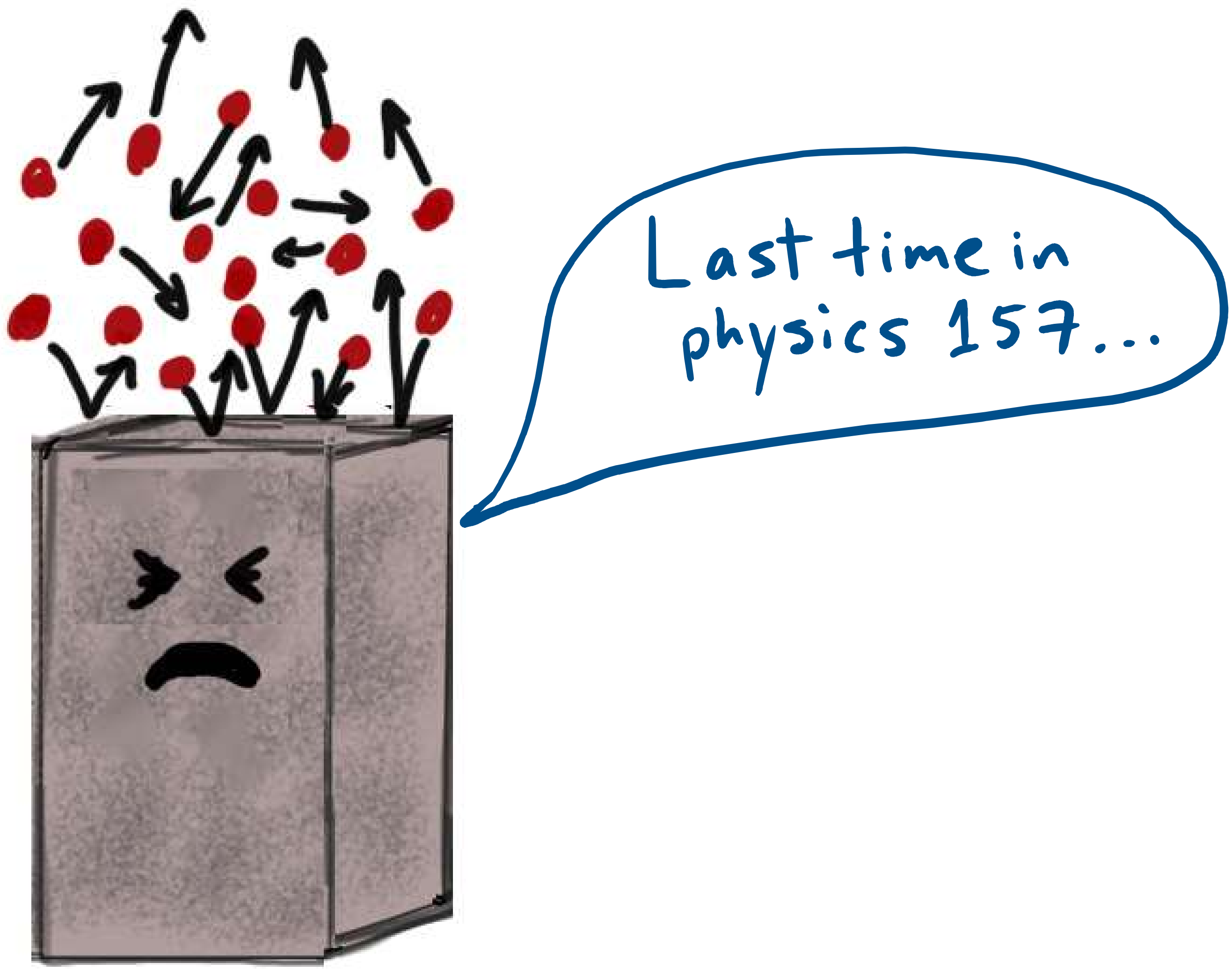
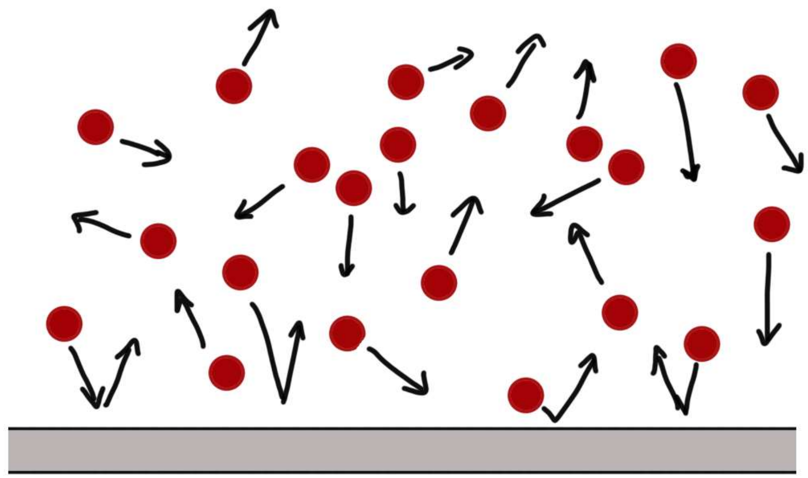
Office hours today: after class in Remo, 3:30pm in Zoom

Learning goals for today

- Use the ideal gas law to provide a qualitative explanation for processes where gases move other parts of a system through mechanical forces
- Calculate the change in energy of a gas in situations where heat is transferred to a gas, but the gas also does work on its surroundings
- Explain why the first law of thermodynamics follows from the conservation of energy
- Relate the work done by a system to the force exerted by that system and the displacement caused by that force.


Last time in physics 157...



Force per area

density = # per volume

$$P = \text{const} \cdot \frac{N}{V} \cdot m \cdot v_{avg}^2$$

Avg. kinetic energy per molecule

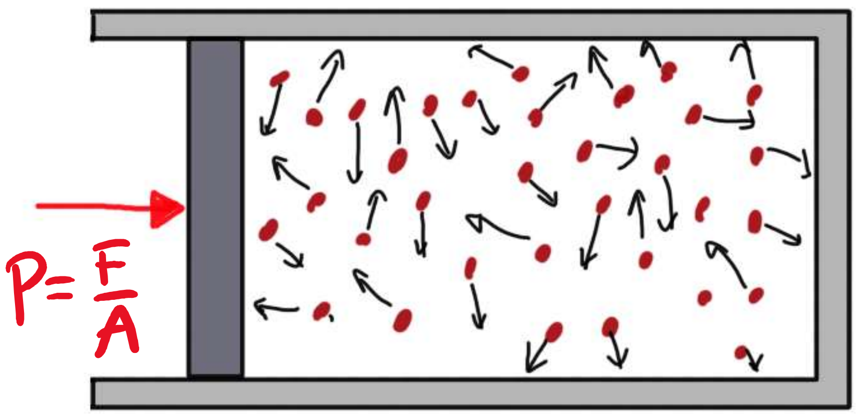
↓

$\text{const} \times T$

proportional to

TEMPERATURE

Ideal Gas Law



$$P = const \cdot \frac{N}{V} \cdot E^{kin}_{avg}$$

- $\frac{N}{V}$: molecular density
- E^{kin}_{avg}: avg. kinetic energy per molecule

⇓

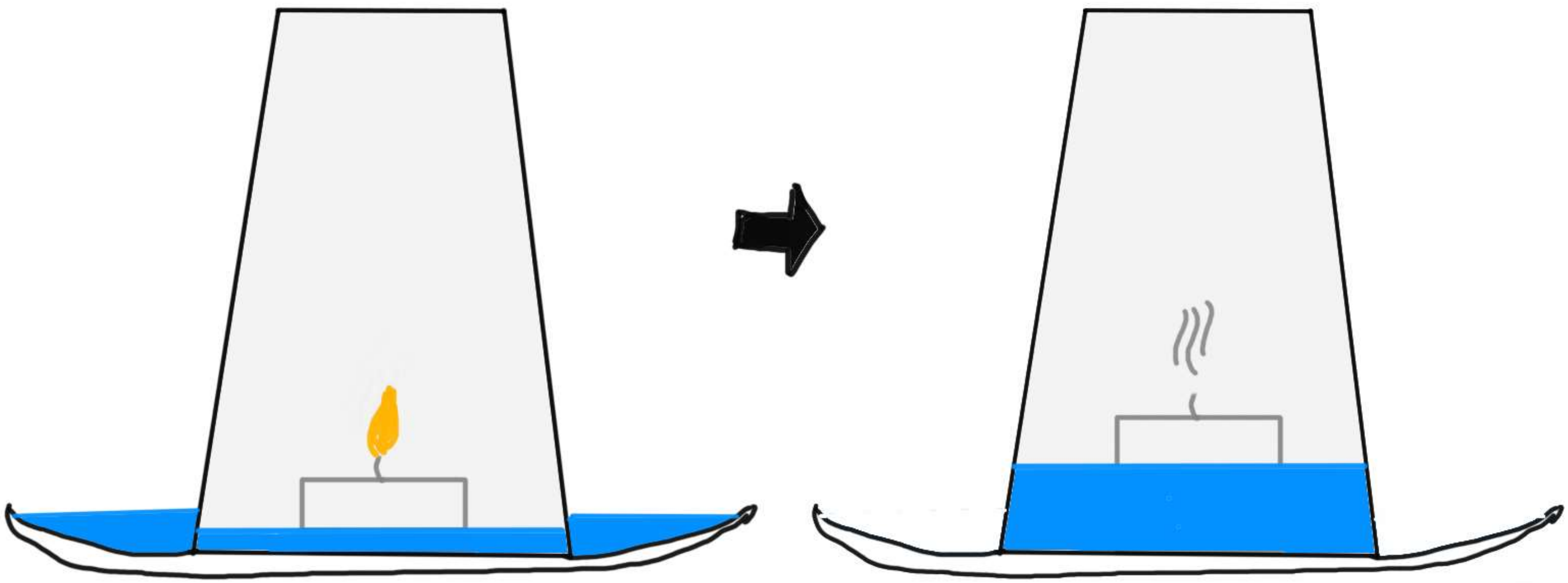
$$PV = n \cdot R \cdot T$$

- n: # moles
- R: $8.31 \frac{J}{mol \cdot K}$

Tells us how much force a gas exerts on the wall

Demo

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



Why?

Hint: $PV = nRT$

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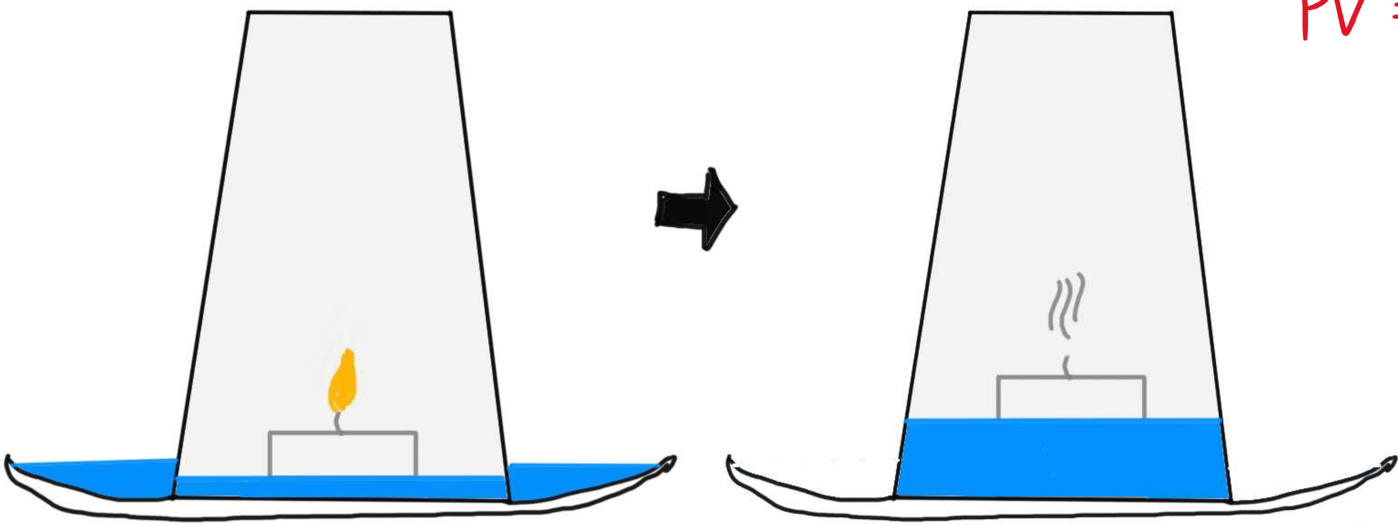
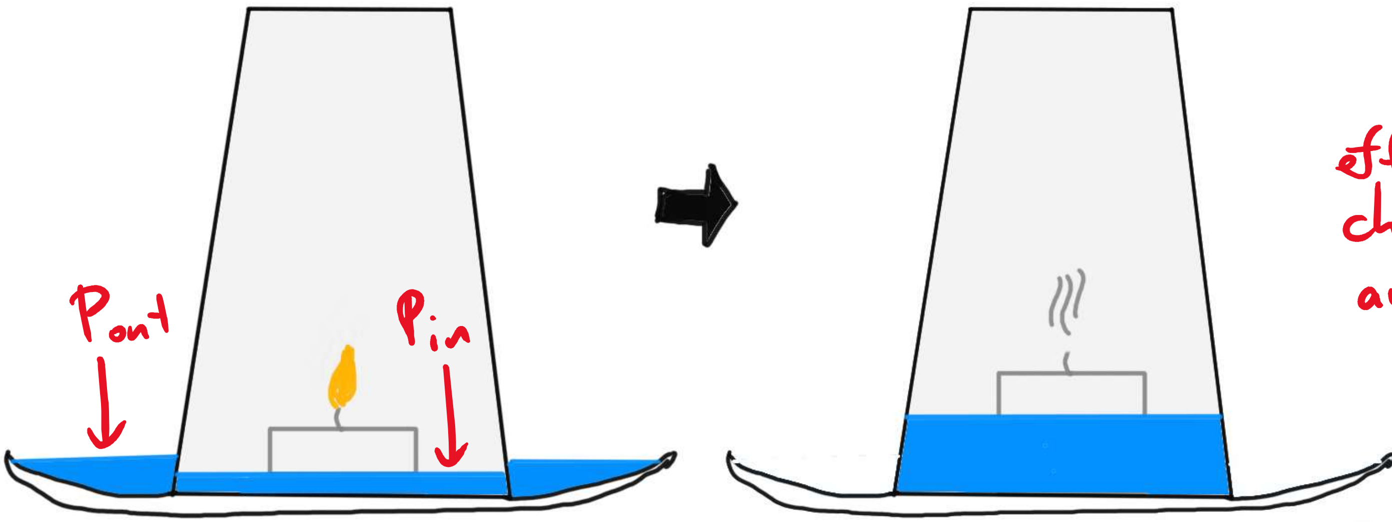


Which of the following is an "explanation" for why the cup sucks up the liquid?

A) $T\downarrow$ so $V\downarrow$
B) $P\downarrow$ so $V\downarrow$
C) $n\downarrow$ so $P\downarrow$
D) $n\downarrow$ so $V\downarrow$
E) $T\downarrow$ so $P\downarrow$



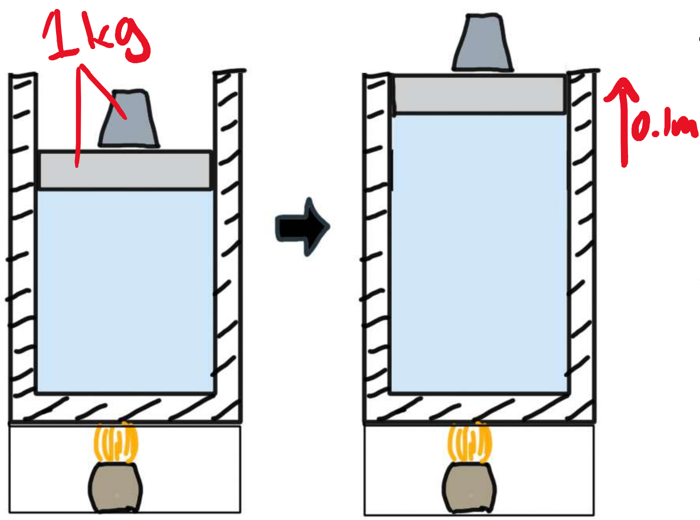
effects of changing n are small

Note: O_2 is being consumed, but it's being replaced by other molecules (CO_2, H_2O)

Which of the following is an "explanation" for why the cup sucks up the liquid?

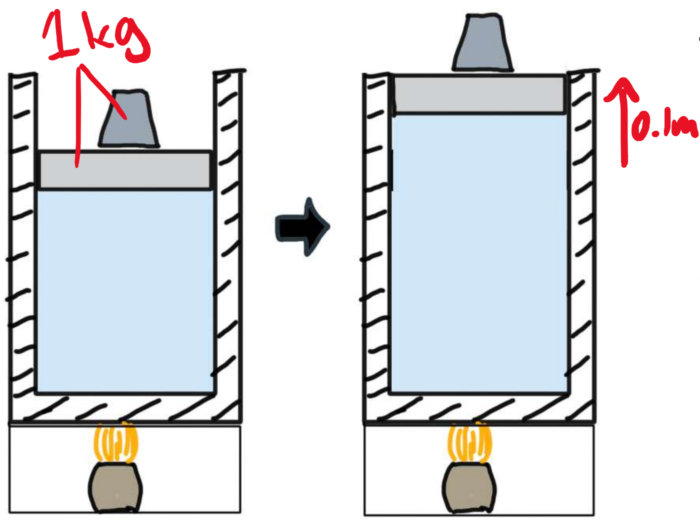
Flame extinguishes → temperature drops → pressure inside decreases → water is pushed into cup, since outside pressure is higher

A) T↓ so V↓
B) P↓ so V↓
C) n↓ so P↓
D) n↓ so V↓
E) T↓ so P↓



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

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



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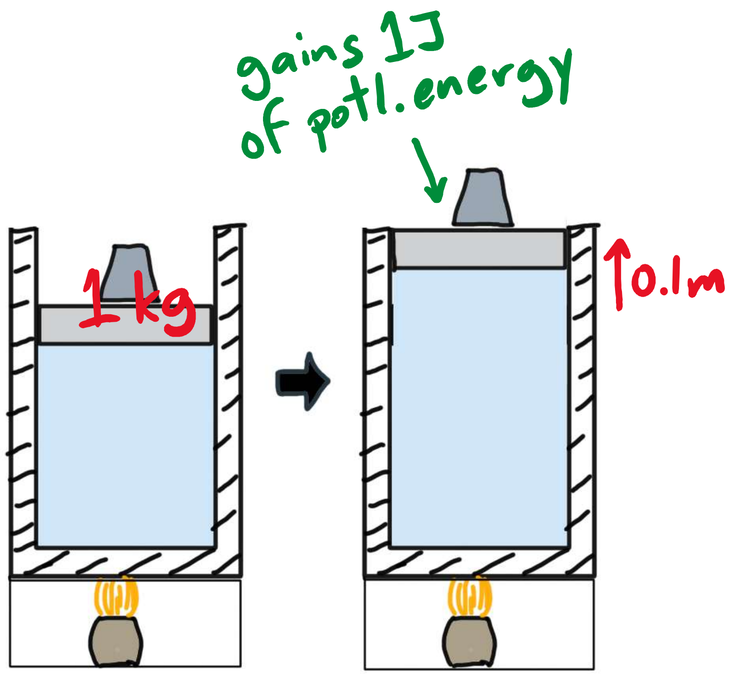
Change in potl. energy of weight + piston is $mg\Delta h \approx 1 \cdot 10 \cdot 0.1 = 1J$. This energy must come from the gas. So we have 10J in but 1J out leaving a change of +9J.

WORK = energy transferred by a mechanical process



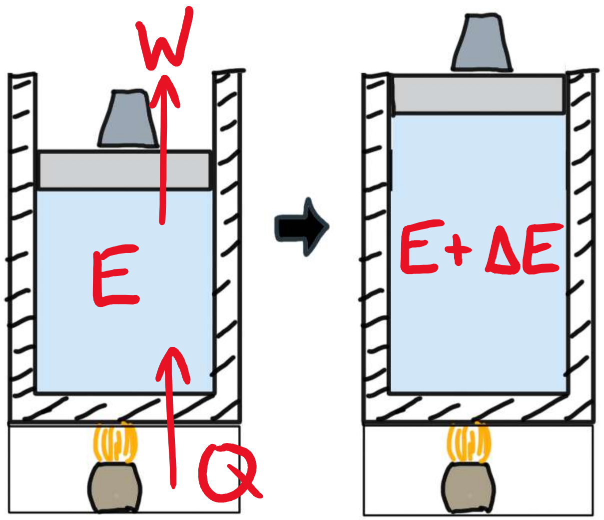
The gas did ~1 J of work on the piston.

$$W_{gas} = 1 J$$

↑ work done BY the gas

THE FIRST LAW OF THERMODYNAMICS

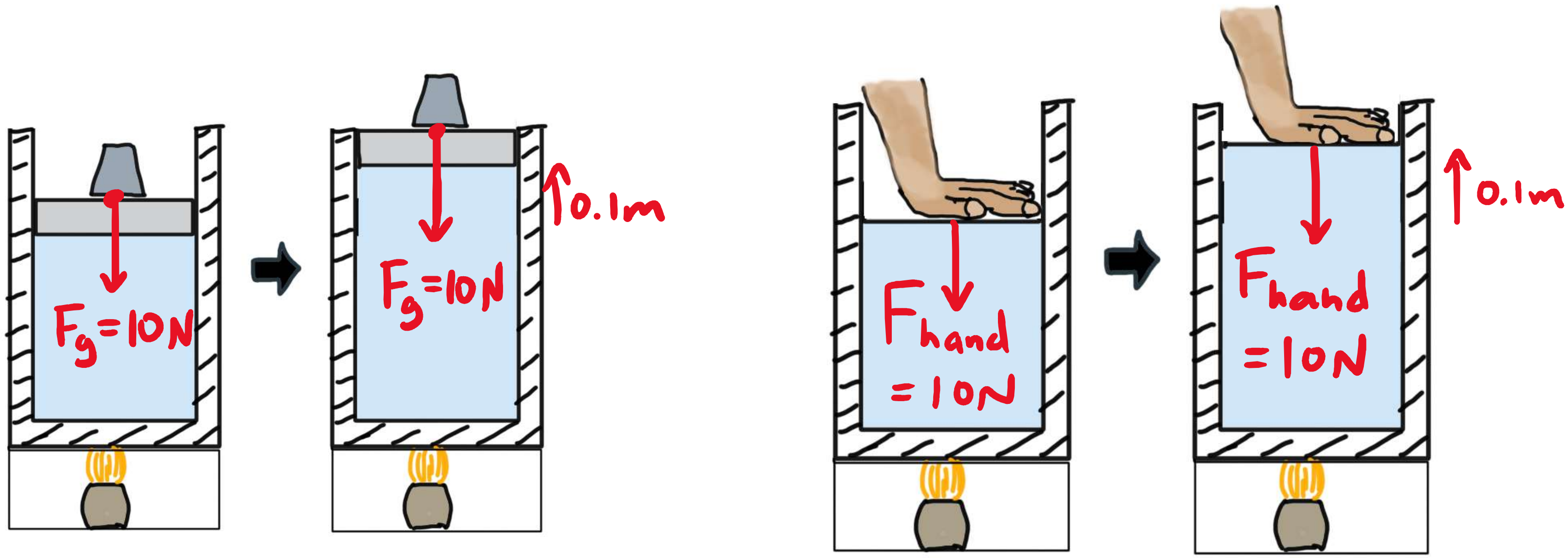
= Conservation of energy



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

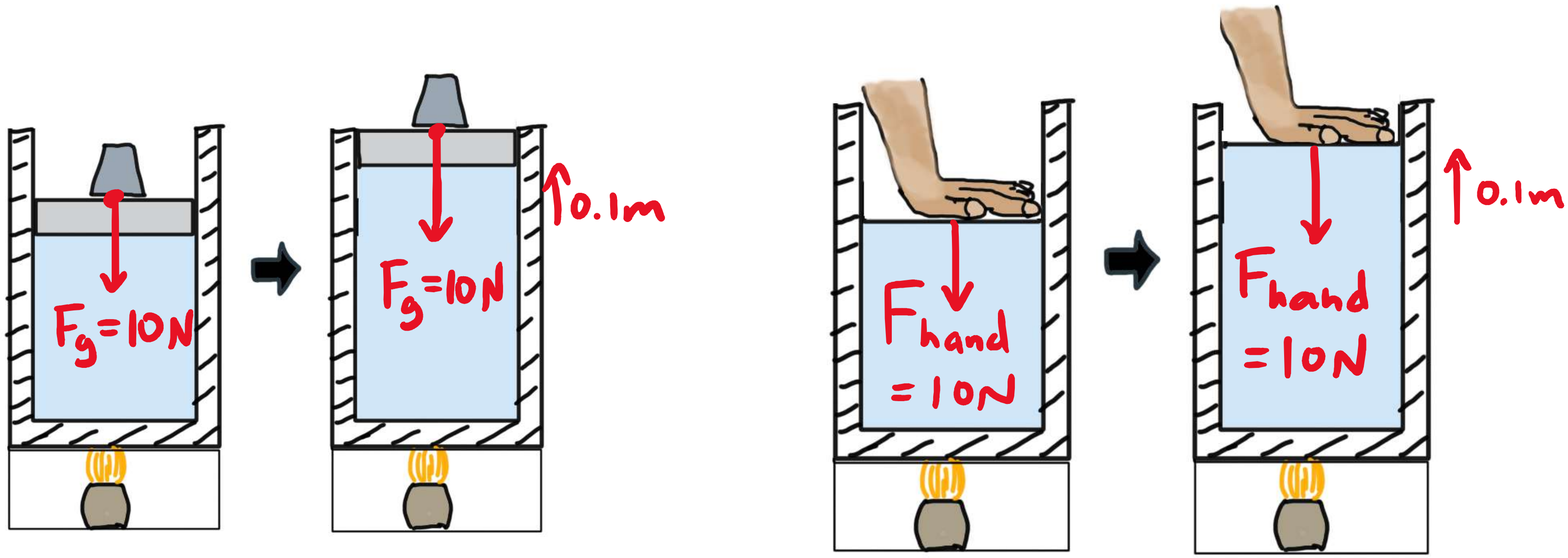
- ΔE_{gas}: net change in energy of gas
- Q: heat added to gas
- W: work done by gas

* E_{gas} is often called U *



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

A) Greater in the second case
B) Less in the second case
C) The same in the second case



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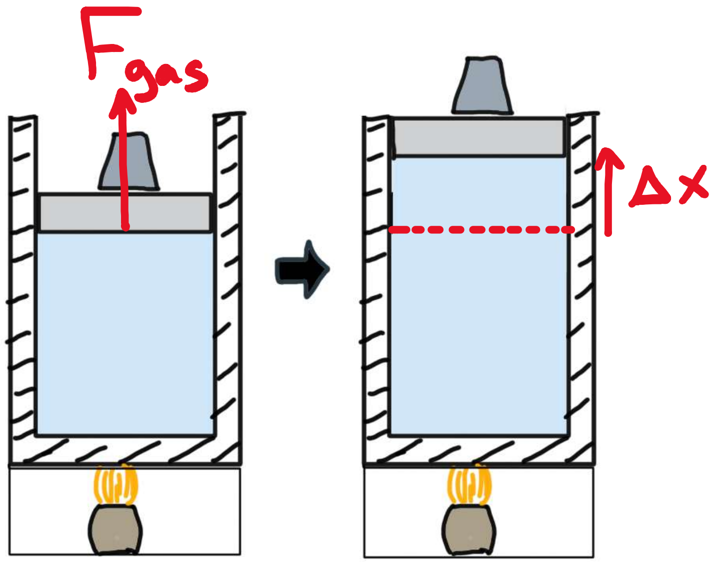
Gas can't tell what is pushing down. Exactly the same situation from the point of view of the gas, so same energy lost via work.



First example:

$$W = (mg) \cdot \Delta x$$
$$= F_{gas} \cdot \Delta x$$

This is ALWAYS the work done by the gas, regardless of what it is pressing against.

$$W = F \cdot \Delta x_{\parallel}$$ (constant force)

F: Force exerted by gas

$\Delta x_{\parallel}$: displacement in direction of force

general expression for work.