by Maxim Mai

THERMODYNAMICS

”… the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, it will never be overthrown.”

A. Einstein

THERMODYNAMICS

** * * the laws * * **

I. When energy passes (work, heat, matter) into or out from a system, the system's internal energy changes in accord with the law of **conservation of energy**.

II. In a natural thermodynamic process, the **sum of the entropies** of the interacting thermodynamic systems **increases**.

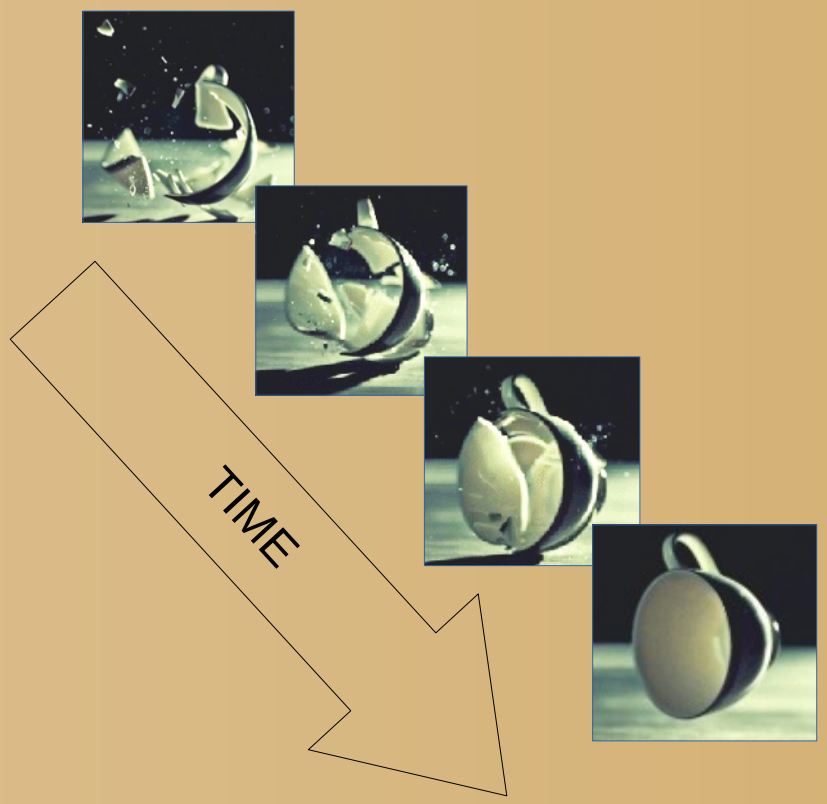
(+ two laws for consistency)

Q U I Z

WHICH IS MORE NATURAL?

A

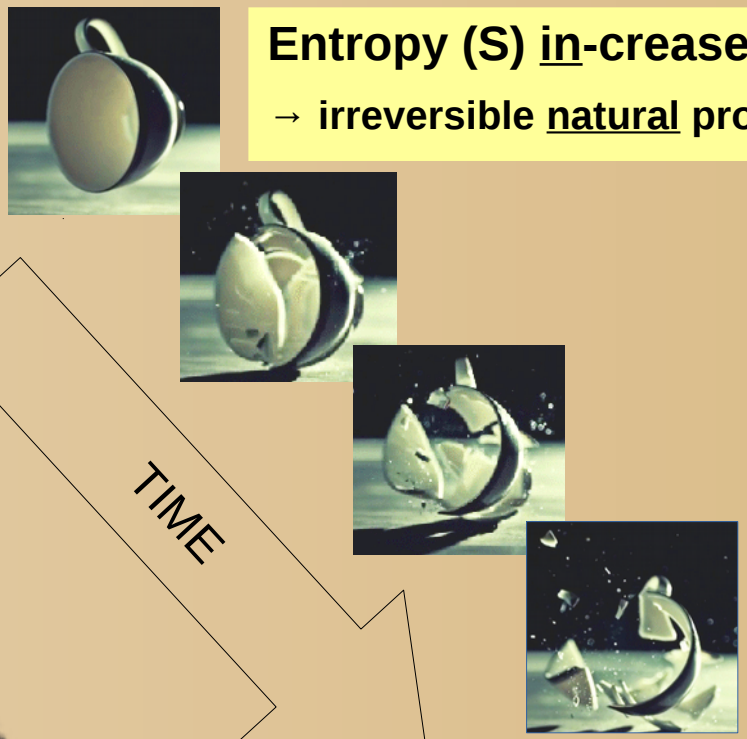
B



Q U I Z

WHICH IS MORE NATURAL?

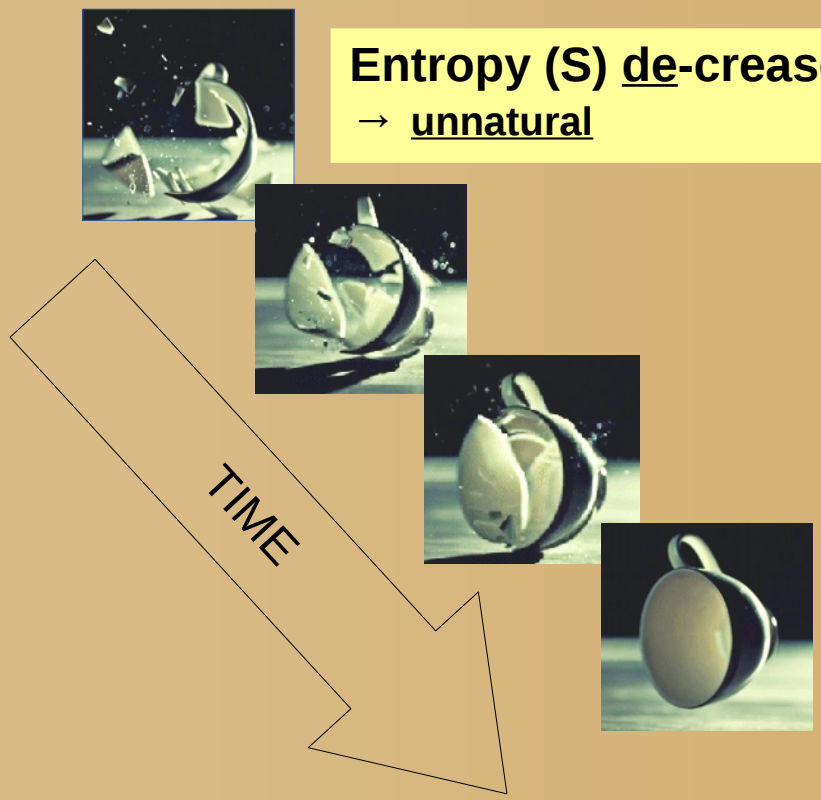
A



Entropy (S) in-creases

→ irreversible natural process

B

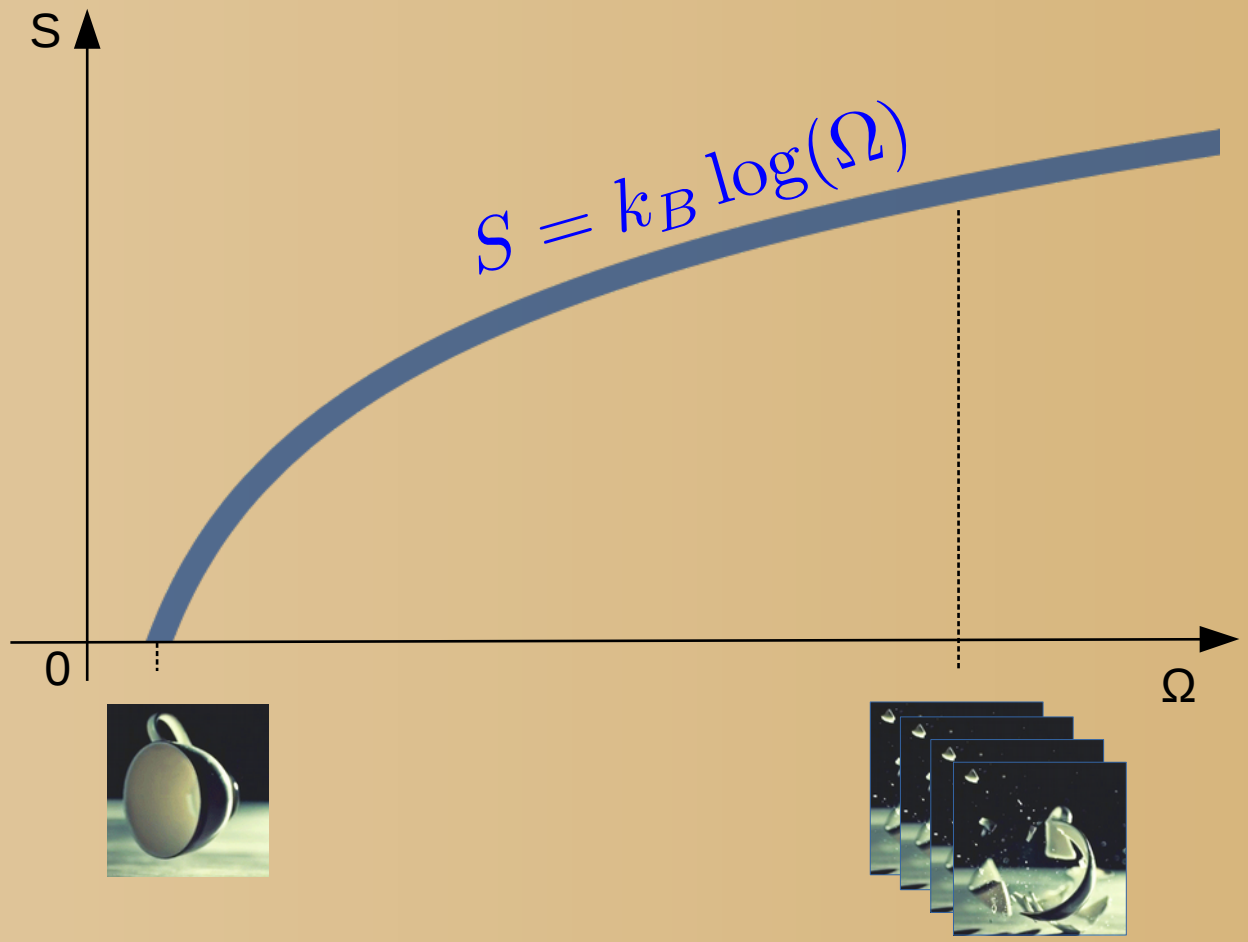


Entropy (S) de-creases

→ unnatural

ENTROPY

εν- *'in' and* ***τροπέ*** *'turning, transformation'*

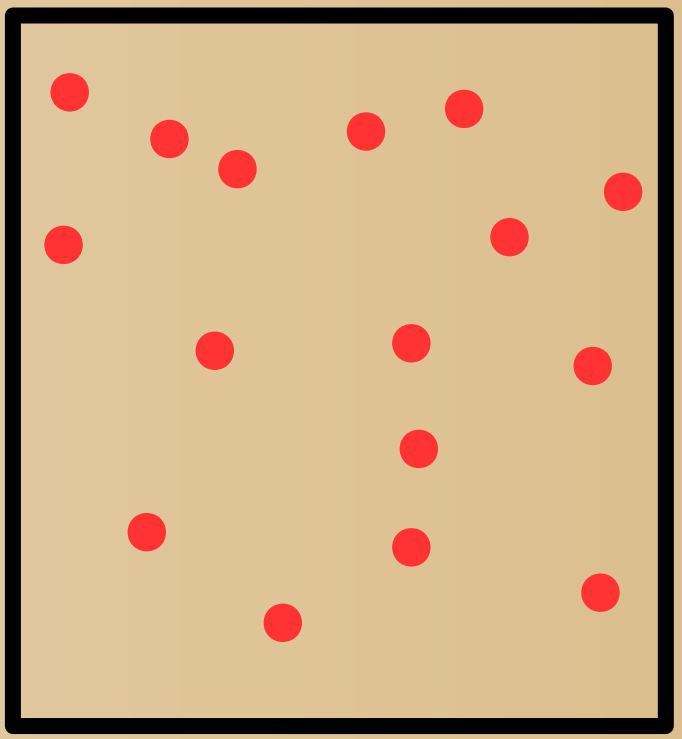


microscopic configurations of a system (microstates)

Many microstates = one macrostate

THERMODYNAMIC SYSTEMS

“enclosed system described by a set of variables”



VOLUME

spacial extension

TEMPERATURE

average kinetic energy

PRESSURE

force per area

ENTROPY

…

CLASSICAL DEFINITION

(change of entropy)

$$\Delta S = \frac{\Delta Q}{T}$$

Heat (energy) transfer

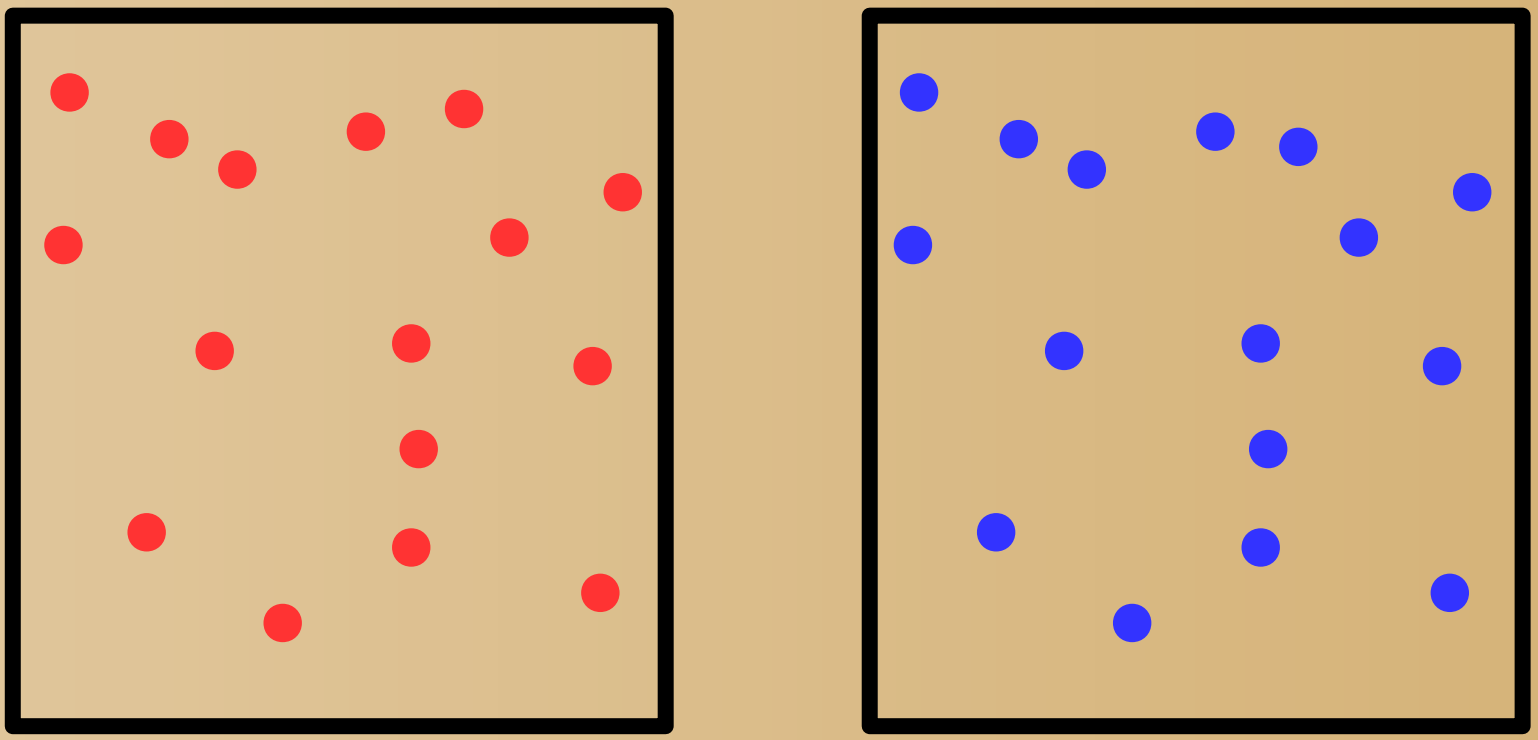
Temperature

Clausius (1865)

CHANGE OF ENTROPY

Two isolated systems

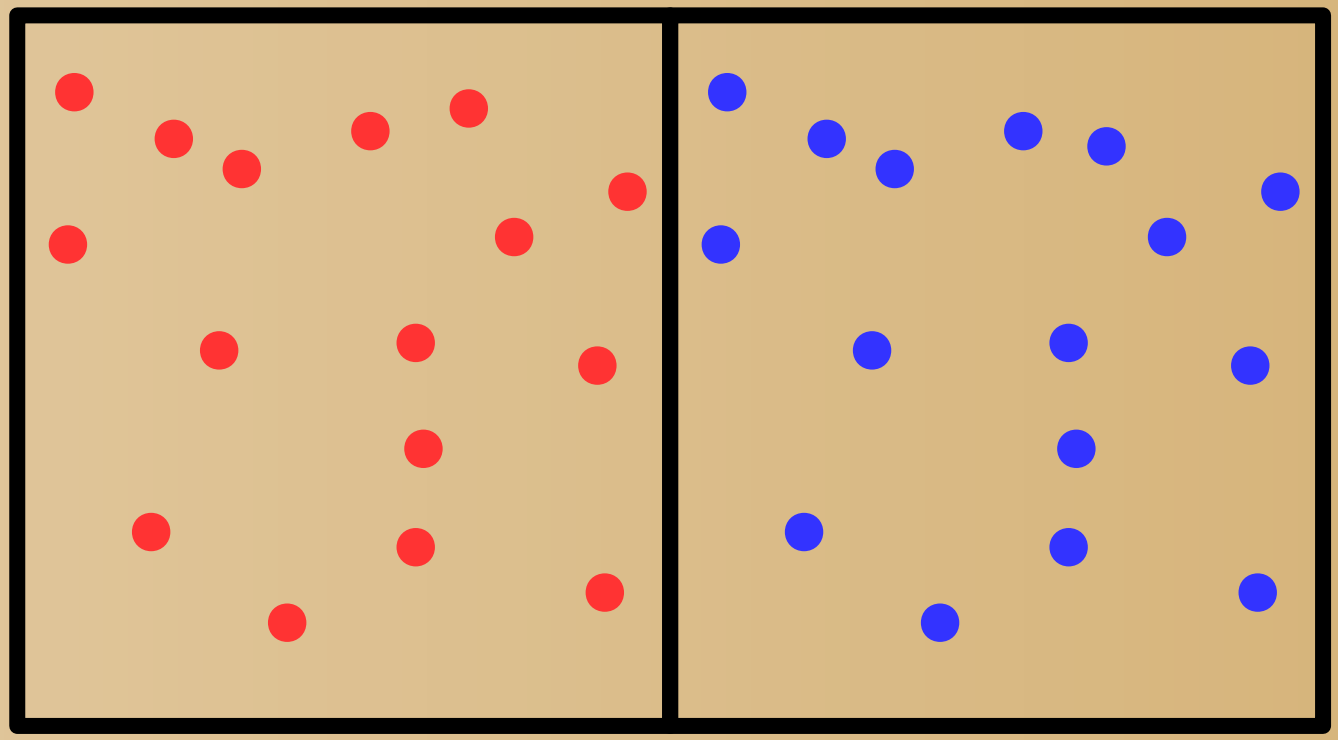
$$T_1 > T_2$$



CHANGE OF ENTROPY

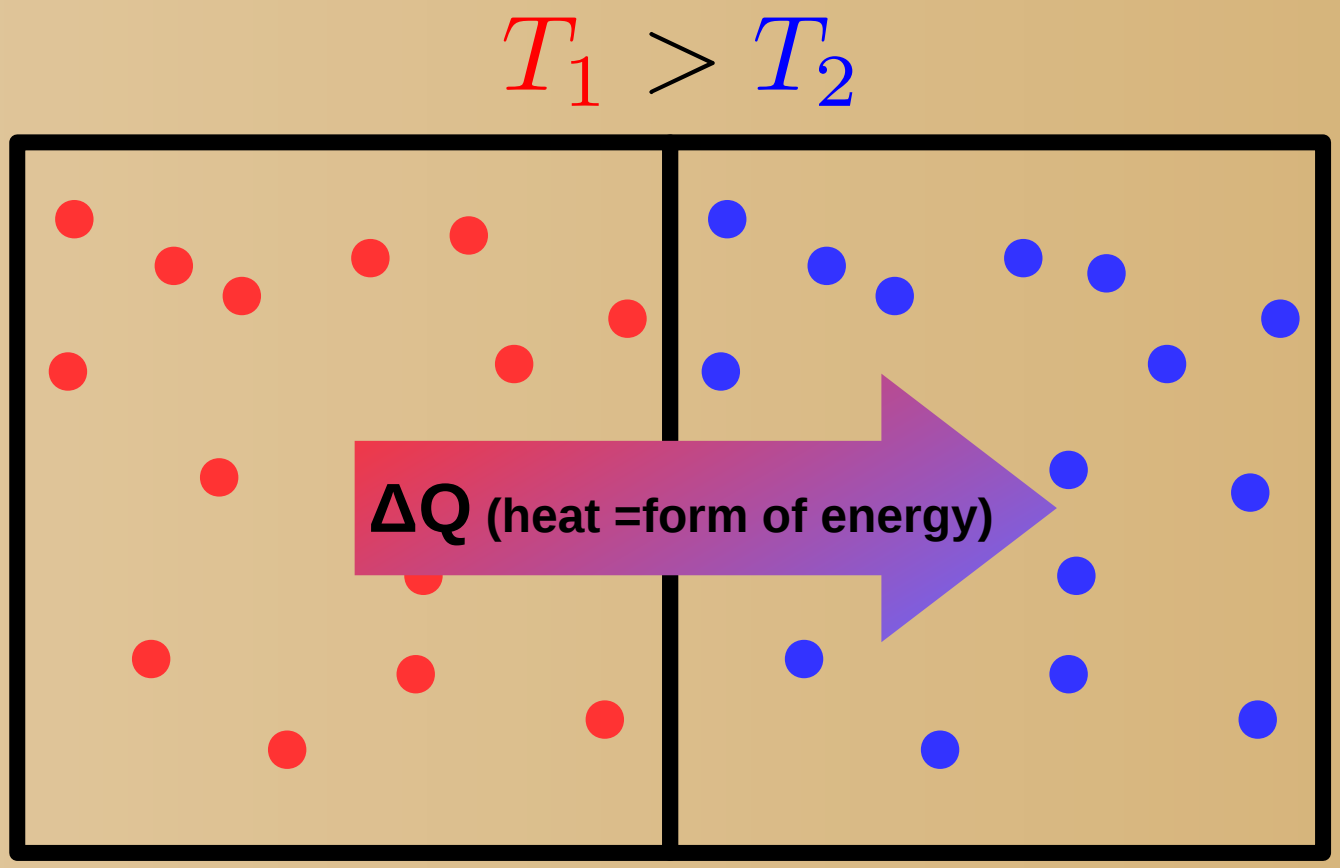
Two systems in contact

$$T_1 > T_2$$



CHANGE OF ENTROPY

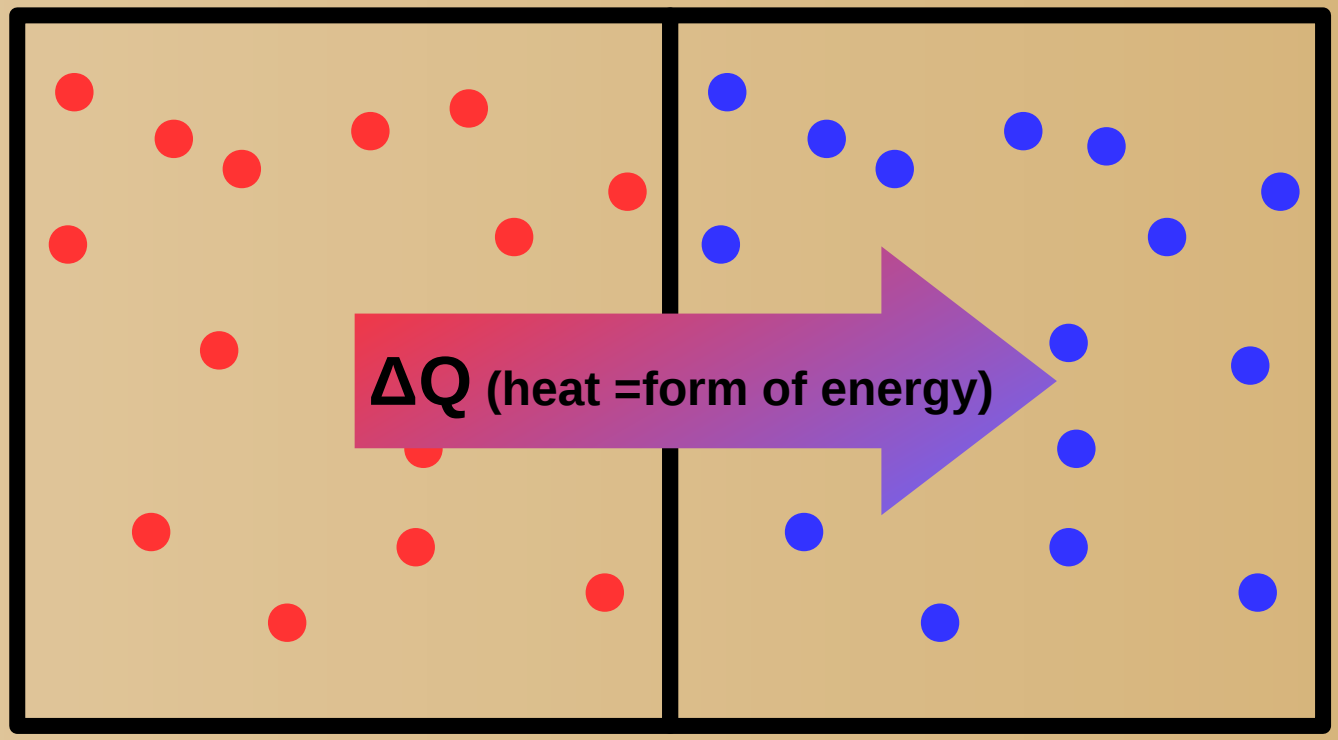
Heat flow



CHANGE OF ENTROPY

Heat flow

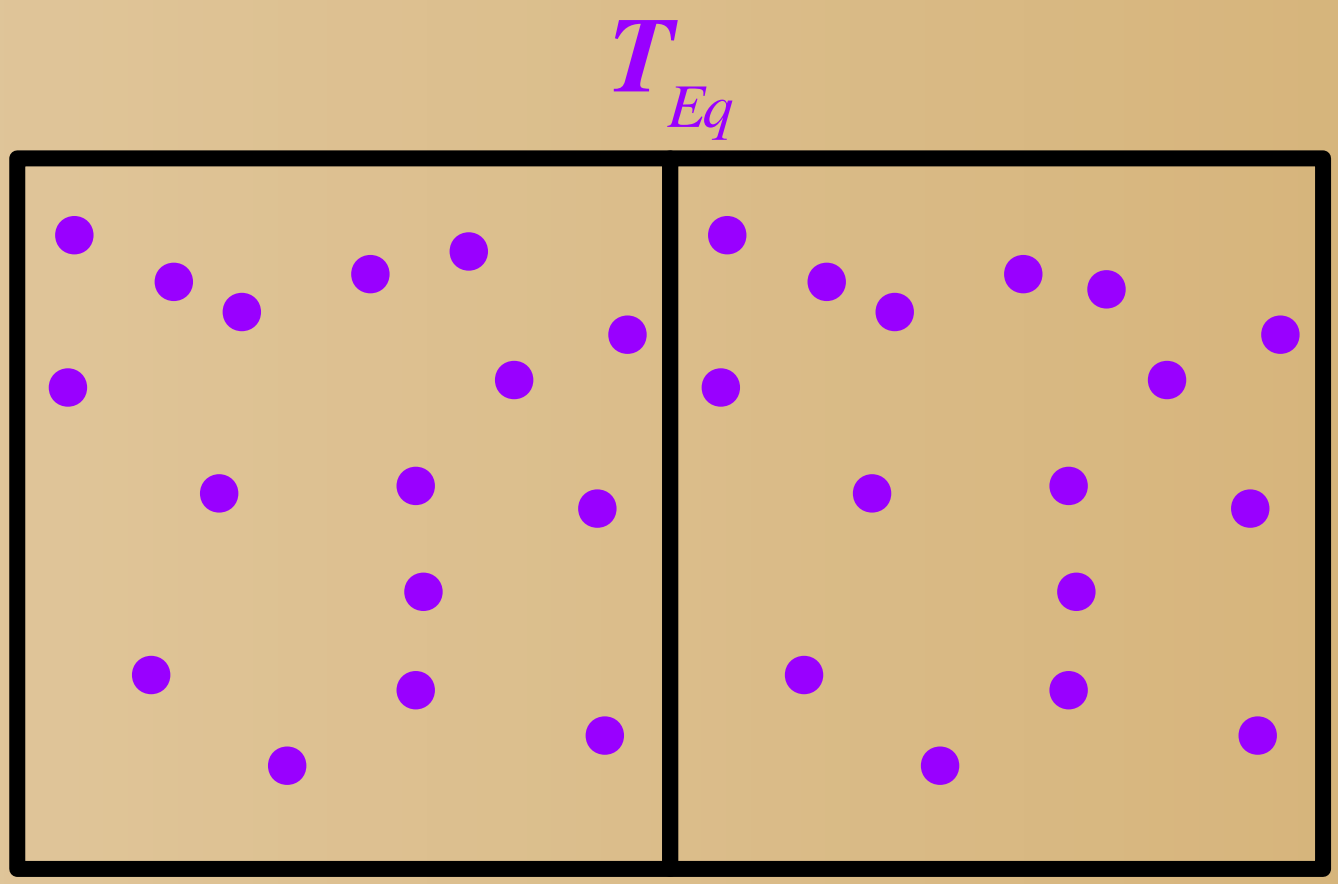
$$T_1 > T_2$$



$$\Delta S_1 = -\frac{\Delta Q}{T_1} \qquad \Delta S_2 = +\frac{\Delta Q}{T_2}$$

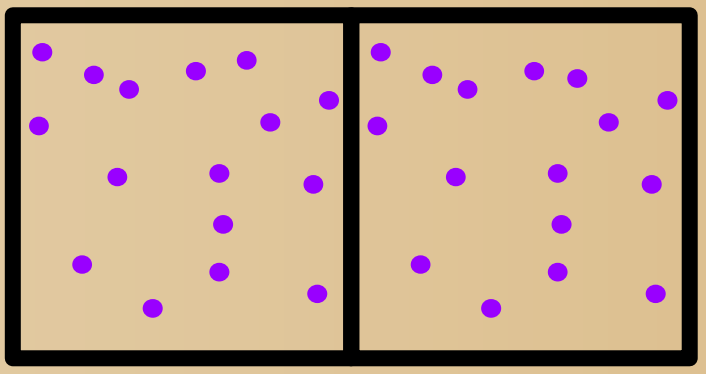
CHANGE OF ENTROPY

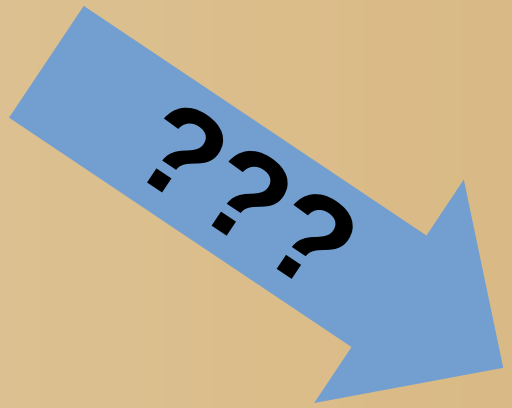
equilibrium

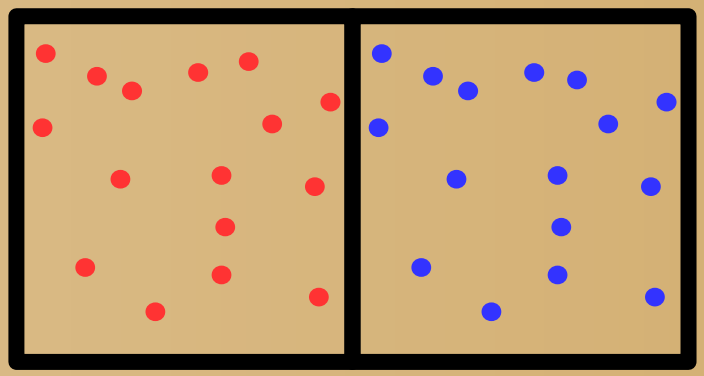


$$S_{Eq} > S_1 + S_2$$

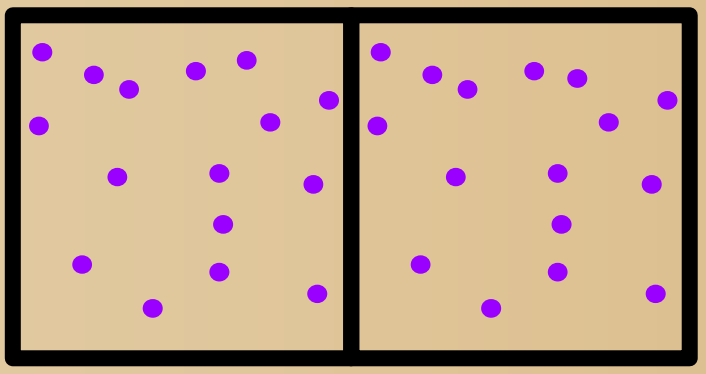
QUIZ





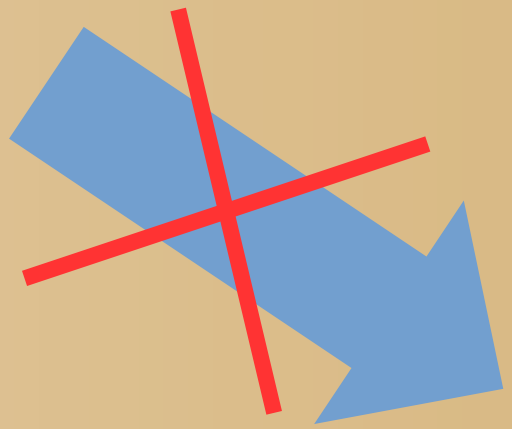


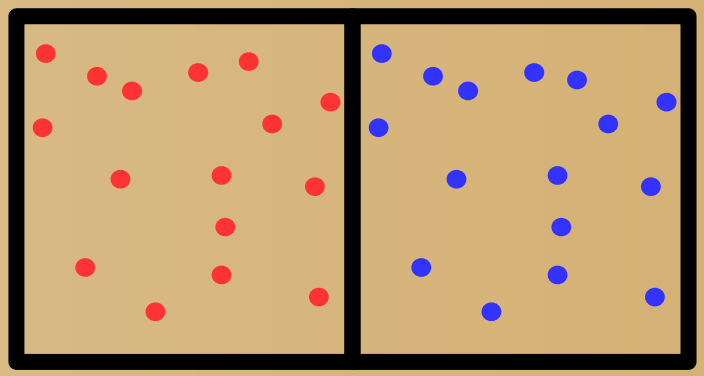
Q U I Z



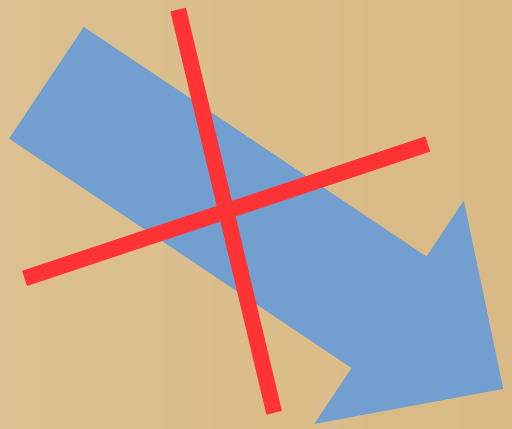
Overall entropy would decrease

→ **violates II. law**



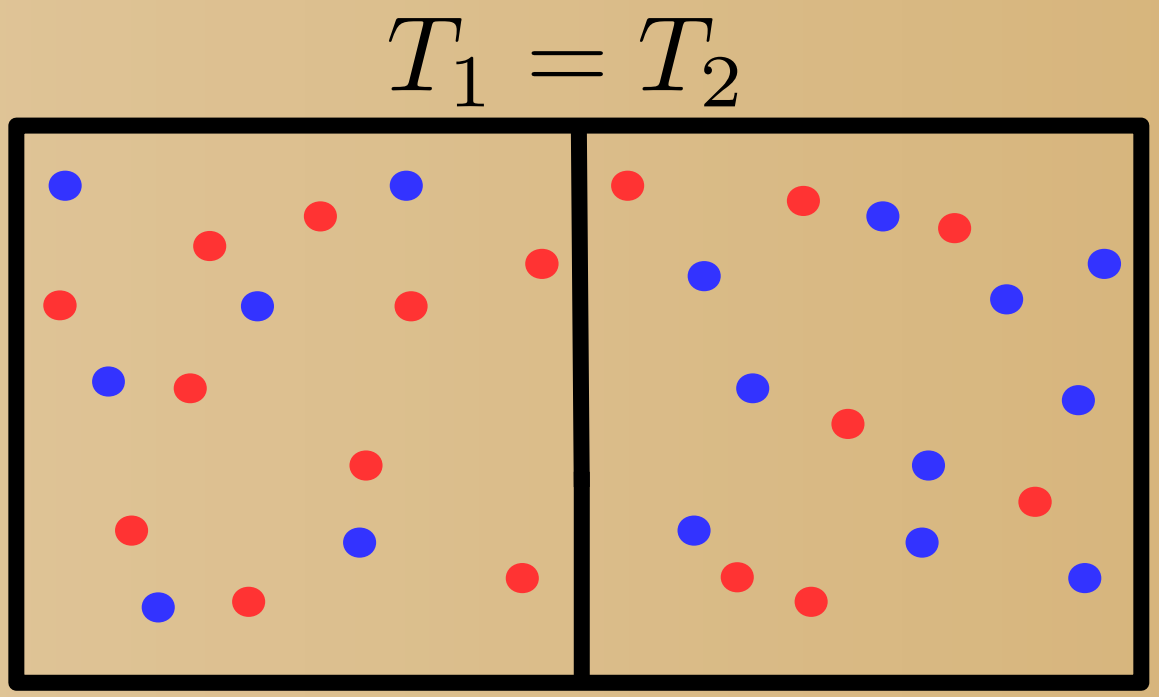


QUIZ



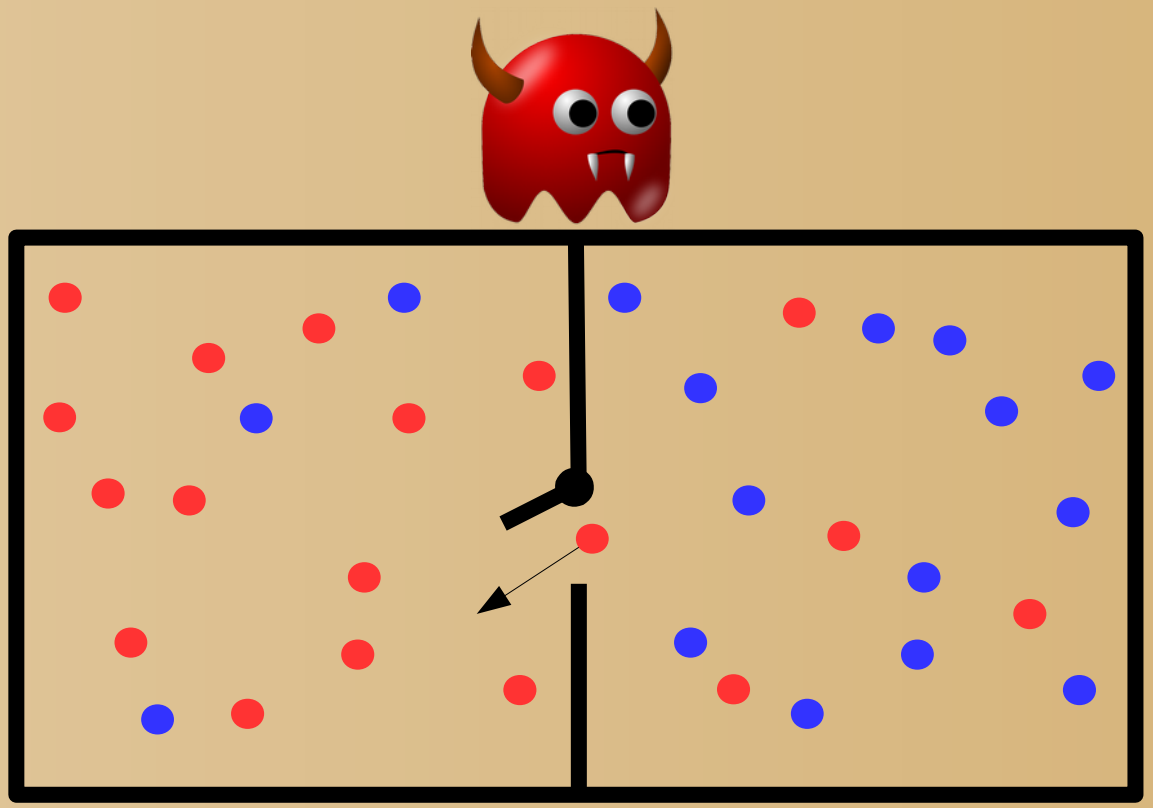
GEDANKEN-EXPERIMENT

“Maxwell-demons” (1867)



GEDANKEN-EXPERIMENT

"Maxwell-demons" (1867)



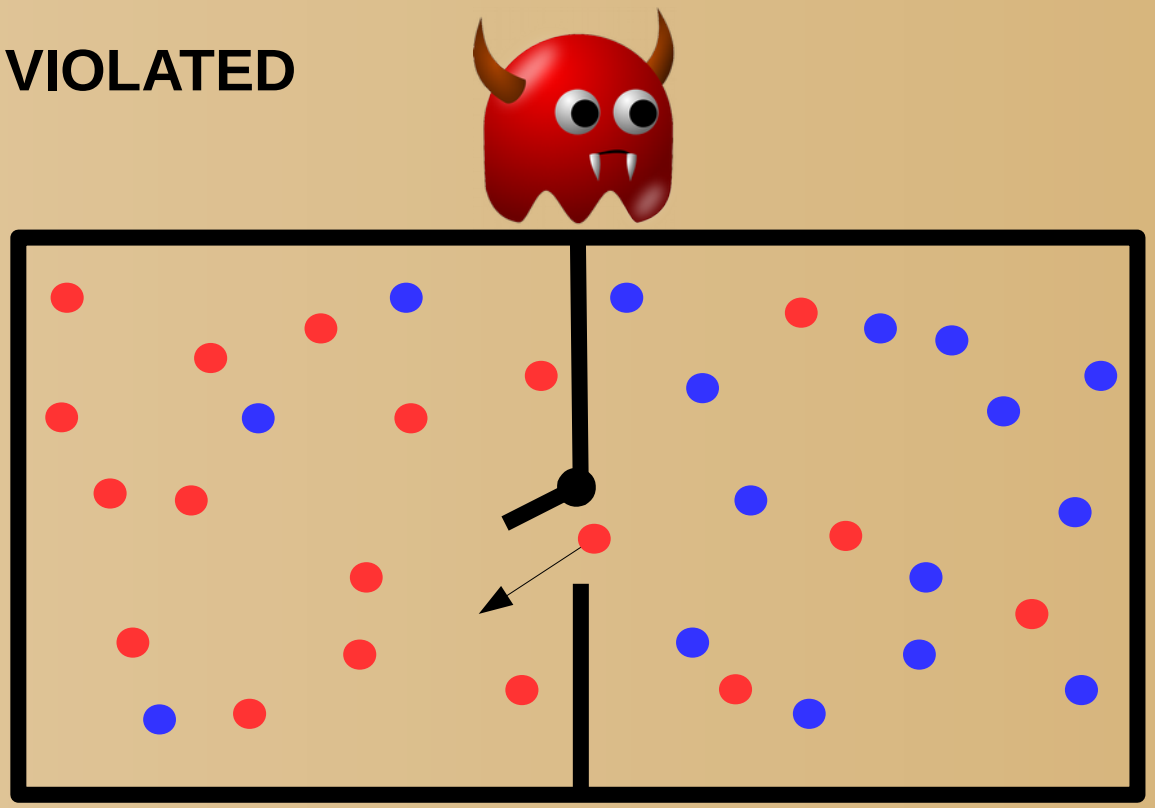
$T_1 > T_2$

GEDANKEN-EXPERIMENT

"Maxwell-demons" (1867)

Maxwell-demon is part of the system.
→ his entropy increases (demon heats up)
→ the total entropy rises

II. LAW IS *NOT* VIOLATED



$T_1 > T_2$


thank you