Understanding Energy

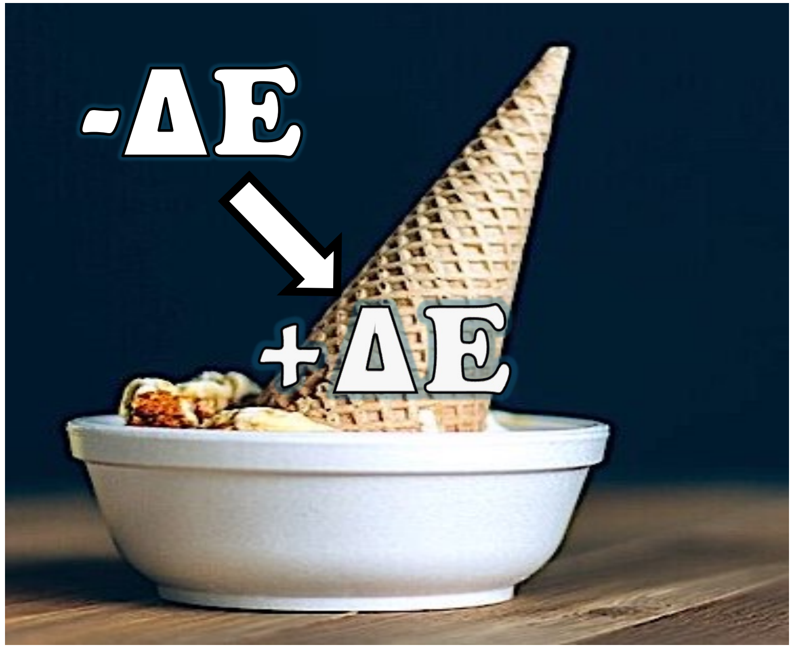
Since ancient times, people knew how to harness the energy of moving water.

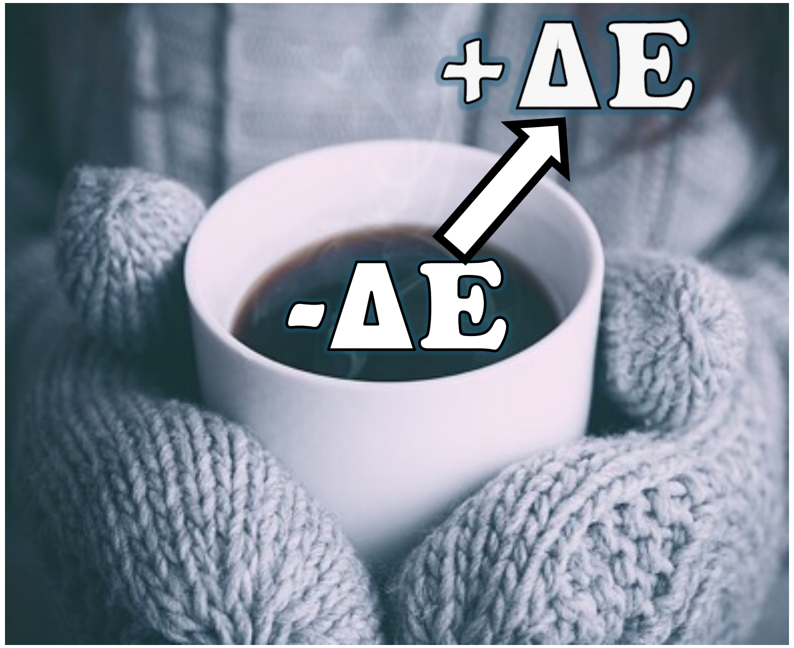
potential energy

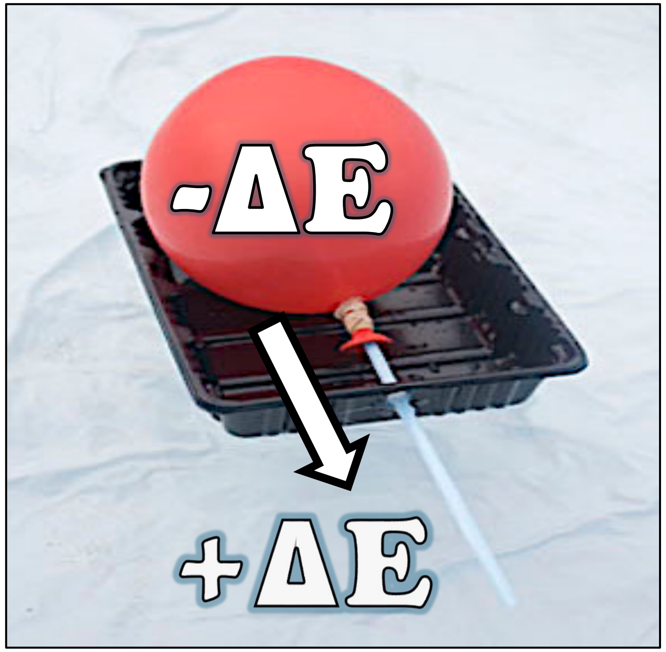
kinetic energy

First Law of Thermodynamics

The change in energy of an object plus the change in energy of the surroundings equals zero ($\Delta E_{object} + \Delta E_{surroundings} = 0$).





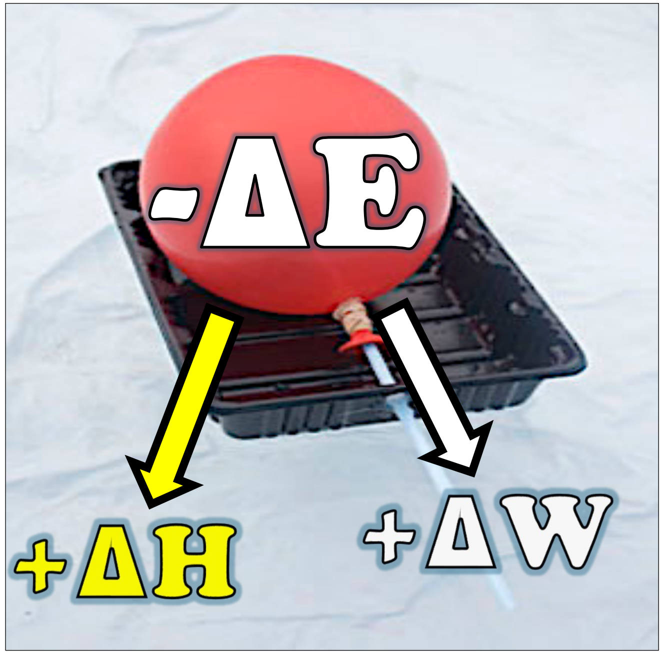


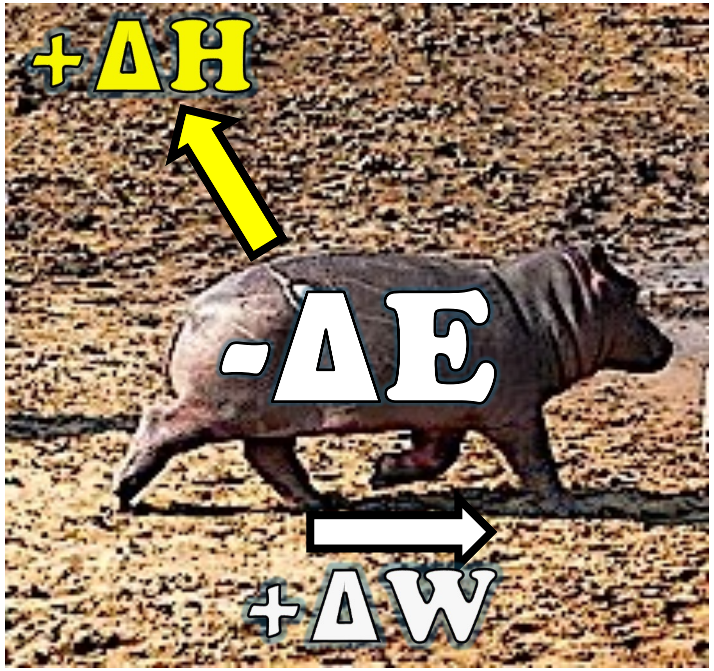
In other words, the total change energy in an object will always have the **opposite sign** as that of the surroundings, and **the magnitude of this change is the same** ($\Delta E_{object} = -\Delta E_{surroundings}$).

Ballon boat image from *Life with Moore Learning* https://www.lifewithmoorebabies.com/2012/09/balloon-boats.html

Second Law of Thermodynamics

All changes increase entropy. This is often expressed as dissipated heat. This "waste heat" cannot be harnessed to do work because it is too spread out.





In other words, **no work can be accomplished with 100% efficiency** because dissipated heat makes up a significant portion of the energy that is spent. Since entropy is always increasing, **all material objects decay over time**.

Ballon boat image from *Life with Moore Learning* https://www.lifewithmoorebabies.com/2012/09/balloon-boats.html

Combustion

sugar	+	oxygen	→	carbon dioxide	+	water
100 g		108 g		148 g		60 g
400 Cal.				*0 Cal.*		*0 Cal.*

Produces about 400 Cal. heat & light energy

Due to the first law of thermodynamics, the energy released from the combustion of sugar equals the energy that goes into the surroundings.

The equation for respiration is identical to that of combustion.

Due to the second law of thermodynamics, more than half the energy from respiration is dissipated heat.

Cellular Respiration

sugar	+	oxygen	→	carbon dioxide	+	water
100 g		108 g		148 g		60 g
400 Cal.				*0 Cal.*		*0 Cal.*

Produces about 160 Cal. of cellular energy

...and about 240 Cal. of heat energy

$$\frac{160\ Cal.}{400\ Cal.} \text{ X } 100\% = 40\% \text{ efficiency}$$

For comparison, the efficiency of an internal combustion engine is 20%.

Requires about 1570 Cal. light energy to generate 400 Cal. Sugar*

Photosynthesis

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide + water → sugar + oxygen

Since the equation for **photosynthesis** is the **reverse of respiration/combustion**, it requires an energy input. This input is provided in the form of sunlight.

The efficiency of converting this light energy into chemical energy is 25%.

*Source: https://www.britannica.com/science/photosynthesis/Proteins

Review Questions

1. What is the purpose of cellular respiration?
2. What process provides the energy needed for cellular respiration?
3. What process synthesizes sugar from carbon dioxide and water?
4. What provides energy for the synthesis of sugar?
5. Why does the consumption of 400 calories of sugar only generate 160 calories of cellular energy?

Review Questions

1. What is the purpose of cellular respiration? **It generates energy for our cells.**
2. What process provides the energy needed for cellular respiration? **the breaking down of sugar**
3. What process synthesizes sugar from carbon dioxide and water? **photosynthesis**
4. What provides energy for the synthesis of sugar? **sunlight**
5. Why does the consumption of 400 calories of sugar only generate 160 calories of cellular energy? **The the remaining energy is expressed as dissipated heat because second law of thermodynamics limits the level of efficiency that is possible.**

Acknowledgement:

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