Developing a conceptual model for both entropy and energy

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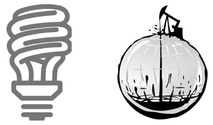
Interest in Energy Usefulness within Energy Representations

K-12 teachers desire to better understand the **connection** between everyday **sociopolitical energy** and **energy in formal physics** curricula

Sociopolitical Energy



Physics Energy

$E_{initial} = E_{final}$

Degradation statements and questions from teachers:

- The quality of the energy decreases as it dissipates.
- Energy's value has decreased.
- Energy degrades into a less useful form.
- Energy is used up and becomes less available.
- When is energy useful?

The above are consistent with research on student ideas (Watts, 1983; Solomon, 1992; Duit, 1984).

Theory

Learners' ideas always have some seed of correctness. Existing knowledge is the material out of which new knowledge is built (constructivism).*

Teachers know that energy is not only conserved, but also in an important sense used up (made less available for human purposes). Rather than seeing these teachers as at risk for misconceptions about energy conservation, we see them as having resources from which to build a sophisticated understanding of entropy and the second law of thermodynamics.

*(Gupta, Hammer, & Redish, 2010; Hammer, 2000; Smith, diSessa, & Roschelle, 1994)

Degradation of Energy

Textbooks define degraded energy as:

- Energy unavailable for the performance of work. (Cutnell & Johnson, 2009)

We define degraded energy as:

- Energy unavailable for the process of mechanical energy transfer
- Energy that cannot be converted to kinetic energy without the addition of outside energy or a change in the system
- Thermal energy at equilibrium

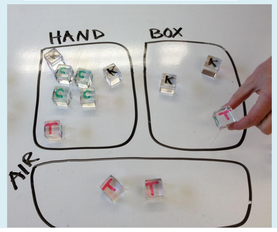
*In Energy Tracking Diagrams, degraded energy is a **T** (thermal energy) at the end of a track. If the **T** is not at the end of a track, then the energy is not degraded.*

GOAL: Create a K-12 conceptual model (statements, metaphors, and representations) **of energy *degradation,* including entropy and the second law of thermodynamics**

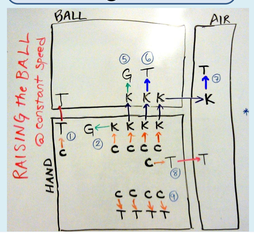
Energy Project K-12 Professional Development

Energy Theater

Energy Cubes



Energy Tracking Diagrams



Rules:

- Each **person** (cube, letter) is a '**chunk**' of energy
- **Objects** in the scenario correspond to **locations** on the floor (white board)
- Energy **forms** are indicated with **hand signs, movements, or letters**
- As energy **transfers and transforms** among objects, people (cubes, letters) **move** and **change label.**

For Energy Tracking Diagrams only:

- **Relative amounts of energy** may be represented by adding **coefficients** to the letters representing energy.
- **Energy transfers and transformations** are represented with **arrows**. All arrows have a letter at the head and the tail. Arrows that **have different letters** at the head and the tail **indicate transformations**. Arrows that **cross the boundaries** of object-areas **indicate transfers**.
- **Time order** of energy processes is represented by **sequences of arrows**. (The time order of processes that occur along separate tracks is not represented.)

Energy Theater emphasizes conservation of energy by requiring the total number of 'chunks' of energy to remain constant throughout the energy process.

Energy Tracking Diagram

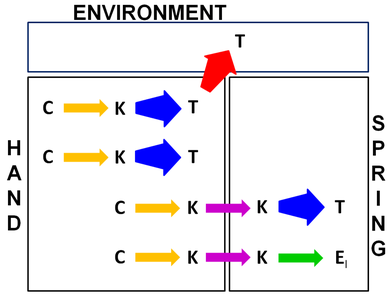


Figure 1. The compression of a spring by a hand moving at constant velocity. C, K, T, and E_l represent chemical, kinetic, thermal, and elastic energy, respectively.

Processes of Energy Transfer and Transformation

- Metabolism
- Thermal Conduction
- Elastic Compression
- Mechanical Work
- Dissipation

The process by which a transfer or transformation occurs (e.g., mechanical work, conduction) is indicated by the color or pattern of the arrow.

Why are these arrows different?

Principle of Energy Spreading

During Physical Phenomena, Energy Tends to Spread

Energy spreads spatially during processes

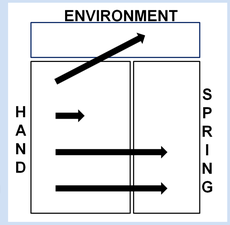
Large spread | Small spread

Conduction (red arrow)
Energy spreads to another object and expands spatially

Mechanical work (purple arrow)
Energy moves in bulk from the hand to the spring

Energy spreads to more and more objects

The energy spreads from the first object (the hand) to three objects (the hand, spring, and environment)



Energy spreads spatially within objects *(and in space)*

In general, tracks that end with thermal energy produce larger energy spread

Energy Degradation Principles

As Energy Spreads, Thermal Energy Never Decreases

K → T Thermal Energy Increases

T → T Thermal Energy Stays the Same

As Thermal Energy Increases, Other Forms Decrease

Energy conservation requires that in a system:

As **T**'s ↑, Other forms ↓

making the resulting energy configuration more and more unlike the original.

All of the energy is initially chemical; as the scenario progresses, a smaller and smaller fraction of the energy is anything other than thermal.

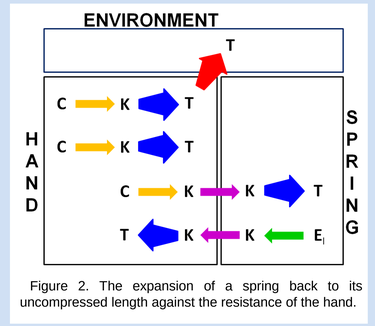


Figure 2. The expansion of a spring back to its uncompressed length against the resistance of the hand.

- All **C**'s have degraded to **T**'s
- All **T**'s are spread equitably in the system
- No more energy transformations will occur without additional energy supplied to the system

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