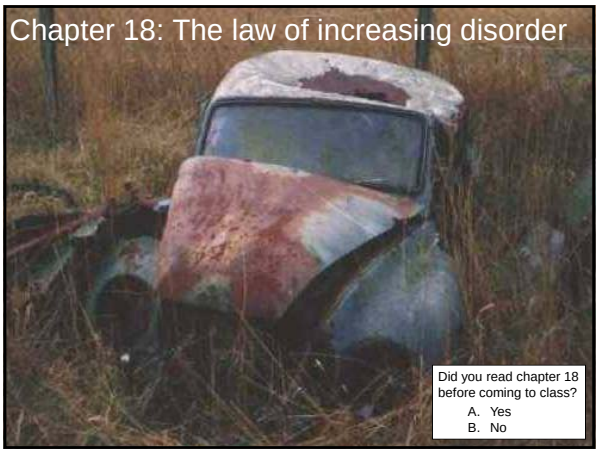
Chapter 18: The law of increasing disorder



Did you read chapter 18 before coming to class?

A. Yes
B. No

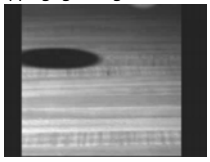
The arrow of time

- Which movie shows the natural order of events?
- Which is compatible with Newton's laws of motion, energy conservation, and inertia conservation (other than being slowed down)?

Klaus Dibiasi – final dive in 10m platform on the way to gold in the 1976 Olympics

Irreversible processes are all around us

- An irreversible process is one that occurs spontaneously in one way, but never in exactly the reverse way (i.e. the movie doesn't make sense when played backwards).
  - Examples: an ice cube melting on the counter, water flowing over Niagara falls, balloon popping, getting older.



Reversible processes can occur with equal ease in the forward and backward direction

- If a glass of ice water is held at exactly zero degrees Celsius and placed in an environment of the same temperature, the total amount of ice and water will remain constant. However, the shape of the ice cubes will change as water molecules become ice, and ice molecules become water.
- If the water or the environment is at a different temperature the process becomes irreversible
- Reversible processes occur under special circumstances, are almost always just approximately reversible, and do not usually occur in nature.

The second law of Thermodynamics

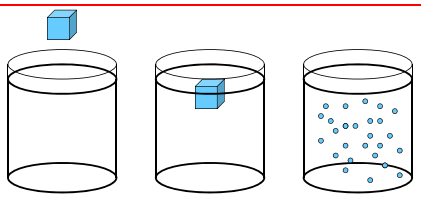
- Changes occurring in natural systems always proceed in such a way that the total amount of "disorder" in the universe either is unchanged or increased. If total "disorder" is increased, the process is irreversible.
- Entropy is the technical name for disorder, and it does not always have the same connotations that we associate with the word "disorder," so we will study it by example.

Getting a feel for entropy by example

- Allowing gas molecules to mix

Example: Dye in water, puff balls

Example: Ice in water

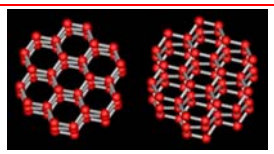


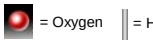
- Temperature difference destroyed
- Ice molecules mixed throughout the water
- We can refreeze the glass, but nature *by itself* will never recreate the blue cube separate from the frozen water.
- To recover the original "system" we must grab each original ice molecule, return it to the ice cube tray, and refreeze it.

Getting a feel for entropy by example

- Mining diamonds in Kimberly, South Africa

Molecules arranged in crystals have "order"
Example: Ice crystals



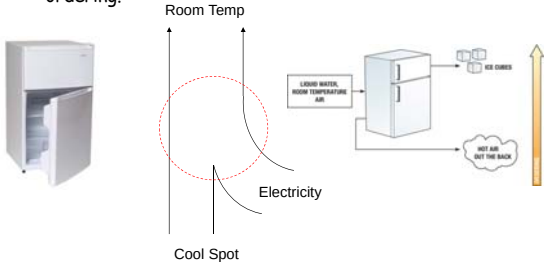


When water freezes into ice

a) The entropy of the universe goes down.
b) The entropy of the water/ice system goes down
c) The entropy of the water/ice system goes up
d) None of the above

Getting a feel for entropy by example

- A freezer performs the ordering process in making ice cubes
  - Extra energy (electricity) is needed to perform this ordering.



Take home lessons from the fridge

- The second law of thermodynamics says you have to plug in the refrigerator for it to work.
- The second law *does not* say that you can't create order. It says that when you do create order, you have to create a corresponding amount of disorder

So what does it mean to increase entropy?

- Increasing disorder (entropy)
  - An increase in random motion.
  - A greater physical mixing of types.
  - A reduction of temperature *differences*.
  - Conversion of energy to a lower order

Transforming Energy

- The Industrial Revolution was driven by the invention of the steam engine.
  - It changed chemical potential energy to kinetic with heat (thermal energy) as an intermediate form.
  - But how efficient could this process be?

Classification of the "order" of a form of energy

Decreasing Order

Macroscopic Kinetic / Gravitational

Nuclear Potential

Electrical Potential

Chemical Potential

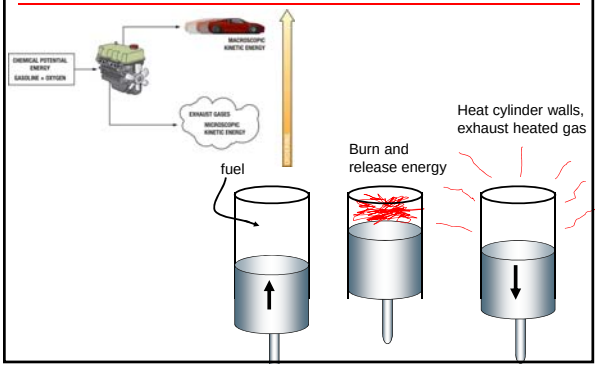
Ambient thermal (temperature)

Example: Ball on track

Limits to efficiency

- Energy can be completely converted into heat (random thermal/kinetic energy)
  - Most kinetic energy eventually ends up as heat (random kinetic).
- But heat ***cannot*** be completely converted into kinetic energy. Some will always remain as heat.

Car Engine



Trace the Order

- A pole vault.
- A car accelerates to 60 mph then coasts to a stop.
- A refrigerator freezes an ice cube.
- The sun warms the earth causing living things to grow.

Table 18.1 – Forms of Energy and Their Ranking in Terms of Organization

Gravitational Potential Energy and Macroscopic Kinetic Energy	ordered
Nuclear Potential Energy	
Electrical (Household)	
Chemical Potential Energy	
Thermal Energy (also known as Heat or Microscopic Kinetic Energy)	disordered

Why should you care about thermodynamics? We like to do things that take energy.

Per person U.S. daily energy use

90 lbs. Coal 

125 lbs. Wood 

8 gal Gasoline 

10 Therms Natural Gas 

1/6 Barrel of Crude Oil 

Energy and thermodynamics

1. Is there ever a **"total"** energy crisis?

   NO! - total mass-energy is always conserved

2. Is there a limitation on the **"useful"** available to us?

   YES! - burning fossil fuels loses order irreversibly

– resulting thermal energy is not very accessible

Equilibrium

- When left to themselves, all systems change to the arrangement with maximum disorder. No further macroscopic changes occur once the system is in equilibrium.
- As far as we can tell, the universe is a closed system …

"This is the way the world ends, not with a bang but a whimper."
T.S. Eliot

Thermodynamics and religion.

- I have my ideas, but mostly I don't know.
  - Believe in God; believe that he is, and that he created all things, both in heaven and in earth; believe that he has all wisdom, and all power, both in heaven and in earth; believe that man doth not comprehend all the things which the Lord can comprehend.
- Since the universe is continually winding down, at some point it had to be wound up
  - "In the beginning God created the heaven and the earth… the earth was without form, and void… and God divided the light from the darkness."
- "Time is no longer"

The second law of thermodynamics

A. Tells us that there organic evolution is impossible, since nature cannot create order.
B. Tells us that the creation of life is impossible
C. Tells us that there the ordering process involved with creating life must have created a larger amount of disorder elsewhere
D. Cannot be applied to the theory of evolution


The evolution of authority

Henry Eyring's take

"If you picked up a watch far from human habitation and found it running, you would ask not only 'Who made this watch?' but 'Who wound it up?' So it is with the universe. The universe is running down… In a very real sense, then, the universe is like a clock that has been wound up. If it is self-winding, it is unique in scientific experience."

-Henry Eyring

Reflections of a Scientist, pp. 75-76