Name: _____

Period: _____

Laws of Thermodynamics

0th Law

If object 1 is in thermal equilibrium with two other objects, the other objects are in thermal equilibrium with each other. (**Objects at Thermal Equilibrium are at the same temperature.**)

This is called the "0th" Law because it was formulated after the other laws, as a logical precursor.

You know that objects I and III must be at the same temperature, even without checking.

Thermal equilibrium

	II	
I		III

Thermal equilibrium *Thermal equilibrium*

1st Law

The internal energy of a system can either be increased by adding heat or doing work. (**Conservation of Energy.**)

First Law of Thermodynamics

$$\Delta U = Q + W_{on\ system}$$

Internal Energy

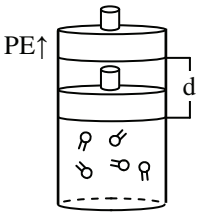
+Q → +ΔT

If Q is added, an object's temperature increases. The object's temperature can also be increased by work: rubbing (like two sticks making fire), shaking, or compressing a gas.

+W → +ΔT

Work Done on a Gas

As always, work is a force times a distance. A gas can do work by moving its surroundings. Any time a gas expands or contracts work is done.



When a gas pushes up a piston it does work on the piston, increasing the piston's potential energy and decreasing the gas's internal energy, causing a decrease in temperature: the gas cools.

–W on the gas: gas expands: –ΔT.

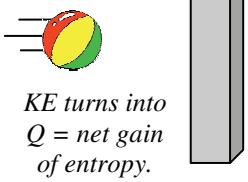
+W on the gas: gas contracts: +ΔT.

*When a fire extinguisher releases its gas, the canister gets very **cold because the gas is expanding**. A bike pump **gets hot because the gas is being compressed**.*

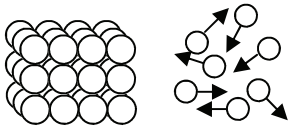
Entropy

Entropy is the amount of disorder of a system. The more organized a system is, the less entropy it has. Greater entropy usually means less useable energy.

The energy of a moving ball has low entropy because most of its energy is moving in the same direction (and is useable). After it hits, the system (ball and wall) gains entropy. Kinetic energy has turned into heat, which is more random internal motion of molecules (and less useable energy).



KE turns into Q = net gain of entropy.



Solids have less positional entropy than liquids or gases because solid molecules are more organized.

2nd Law—2 ways

1. Heat will travel from hot to cold on its own and never from cold to hot. (**Direction Heat Flows.**)

This happens naturally.

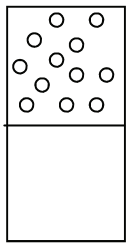
15ºC	40ºC
	← *Q*

This does not happens naturally.

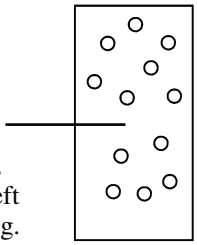
60ºC	20ºC
	← *Q*

Even though heat moving from cold to hot would not break the 1st Law (energy would still be conserved), it does not happen.

2. Using entropy: "In any natural process the entropy of a system increases OR the disorder of the system will increase."



Before the barrier is removed the molecules are all on one side and the disorder of the system is low. There is a high amount of useable energy, since the pressure in the left side could move something.



When the barrier is removed the molecules spread out and the disorder of the system increases and the amount of useable energy decreases.

Can entropy ever decrease?

NOT NATURALLY. External work could compress the molecules back into one side of the container. The gas's entropy would be decreased, but the universe's entropy would increase by a greater amount. By themselves, all natural processes are irreversible and result in an increase of entropy.

Name: _____

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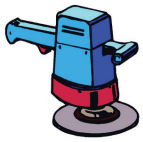
1. Increase or decrease in temperature?
   - A. ____ A gas is expanded.
   - B. ____ A gas is compressed.
   - C. ____ When air escapes from a balloon.
   - D. ____ When a piston moves up in an engine.
   - E. ____ When heat is added.
   - F. ____ When heat is removed.
   - G. ____ When sanding a piece of metal.



2. As you move higher up in altitude the amount of air decreases, meaning there is also less air pressure. Why then, does the air get cooler?

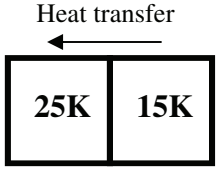
3. You have 6 dice.
   - A. When you roll the dice is it possible that you will roll all 6's?
   - B. It is probable (likely) that you will roll all 6's?
   - C. Is there more entropy with six 6's or a mix of numbers?
   - D. If you start will all 6's and roll the dice will the entropy like increase or decrease?
   - E. Explain.

4. A person does 15 joules of work compressing a gas. 25 joules of work is also added as heat.
   - A. Does the work that is done increase or decrease the energy of the gas?
   - B. Will W be + or – in the equation?
   - C. What is the total change of the gases internal energy?

5. A gas expands so that the gas does 35 joules of work to lift a piston.
   - A. Does the gas want to increase or decrease in temperature due to the expansion?
   - B. Will W be + or – in the equation?
   - C. If the internal energy of the gas does not change (T remains constant), was heat added or removed from the gas?
   - D. How much heat was added or removed?

6. Which Law of Thermodynamics?
   - A. ____ Compressing a gas causes an increase in energy of the gas.
   - B. ____ Entropy will always increase in a natural process.
   - C. ____ Defines what thermal equilibrium is.
   - D. ____ Naturally, heat always moves from hot to cold.
   - E. ____ Just a restatement of Conservation of Energy.

7. A broken glass moves up to a table and puts itself back together.
   - A. What kind of energy is the object gaining?
   - B. Does this break the 1st Law of Thermodynamics?
   - C. Explain.
   - D. What Law does this break?



8. Comment about the diagram at the left. Be sure to mention the Laws of Thermodynamics.

9. Two gases are mixed together. Does the total entropy of the system increase or decrease?

10. A moving box slides to a stop.
    - A. What kind of energy does it start with?
    - B. What does the energy become?
    - C. Is this process reversible or irreversible?
    - D. What happens to the entropy of the object?
    - E. What happens to the entropy of the universe?

Note: Heat is almost always the most chaotic type of energy, so it has the highest entropy.