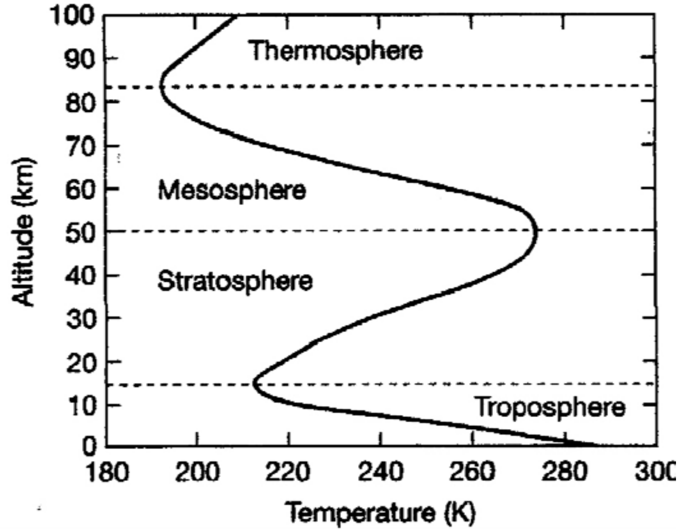
TOPIC # 9
LAWS OF THERMODYNAMICS: Keys to Energy Transfer & Conservation

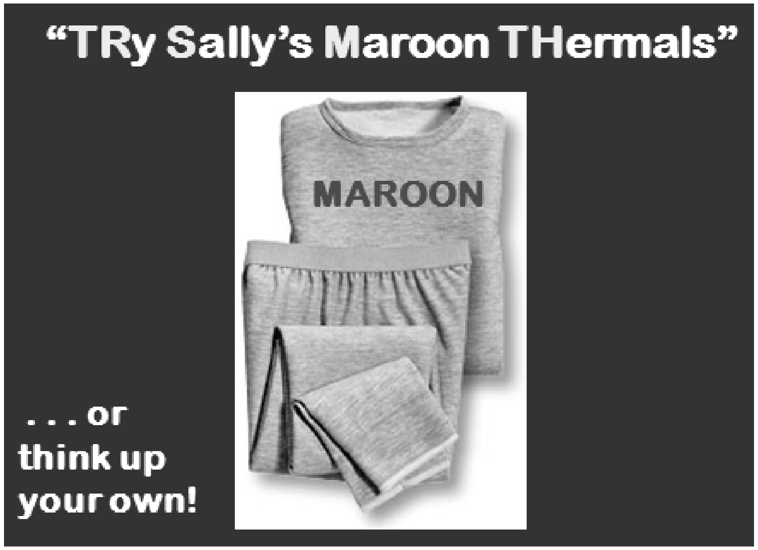
The Next Piece in the Puzzle to Understand Global Changes

CLASS NOTES: pp 43-46

TEST # 2 is coming up

-- Just in time, a memory device!





Trust **S**cientists' **M**inds & **Th**oughts

Courtesy of
one of your fellow NATS students

QUOTE OF THE DAY:

In this house, we OBEY
the laws of thermodynamics!

~ Homer Simpson

Forms of Energy - Review

- **Kinetic** (KE or KinE) = energy of *<u>motion</u> or* the ability of a mass to do work.

  KE = ½ (mass x velocity^2)

- **Potential** (PE) = energy a system possesses if it is capable of doing work, but is *not* doing work now
  - Includes: **gravitational, elastic, chemical, electrical, and magnetic**

review

Thermal Energy

Thermal energy (def) = the grand total of all energies inside a substance
(internal energy)

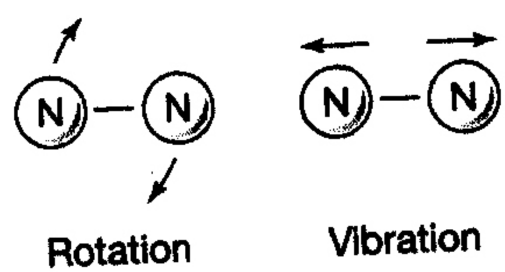
--also: a measure of the quantity of *atomic kinetic & potential energy* contained in every object;

-- also: the total kinetic energy of molecules in matter.

Thermal Energy

Atoms and molecules are constantly "jiggling" in some sort of back-and-forth vibratory motion.

The greater this molecular kinetic energy is in a substance, the <u>hotter</u> the substance is.



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THERMODYNAMICS

(def) = The study of the general properties of ENERGY.

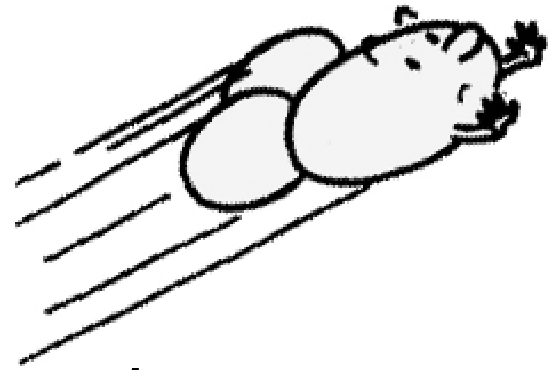
Thermal energy plays a central role in understanding these properties, hence the study of energy can also be called “thermodynamics.”

☺

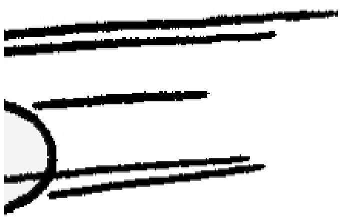
Thermal Energy & Temperature

- ***Temperature*** = tells how warm or cold a body is with respect to some standard (e.g., Fahrenheit (°F), Celsius (°C), or Kelvin (K) standard scales).

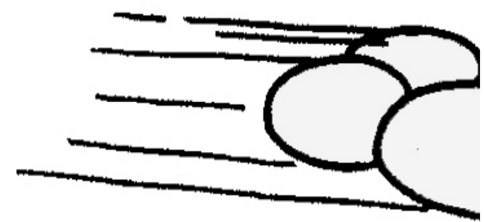
- **Temperature is a measure of the average kinetic energy of each molecule in a body.**

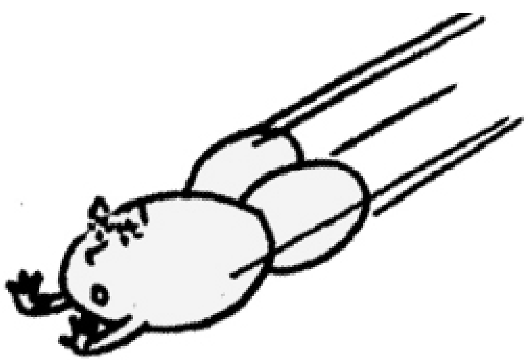


If a body has a high temperature, each of its molecules has, on the average, a large amount of kinetic energy.



e.g. water vapor -- H_2O molecule at high temperatures





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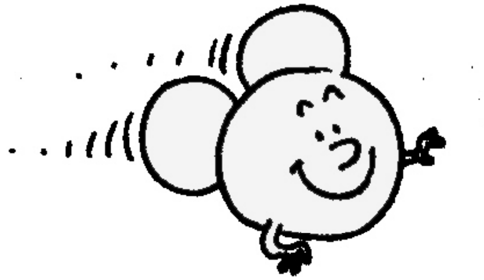
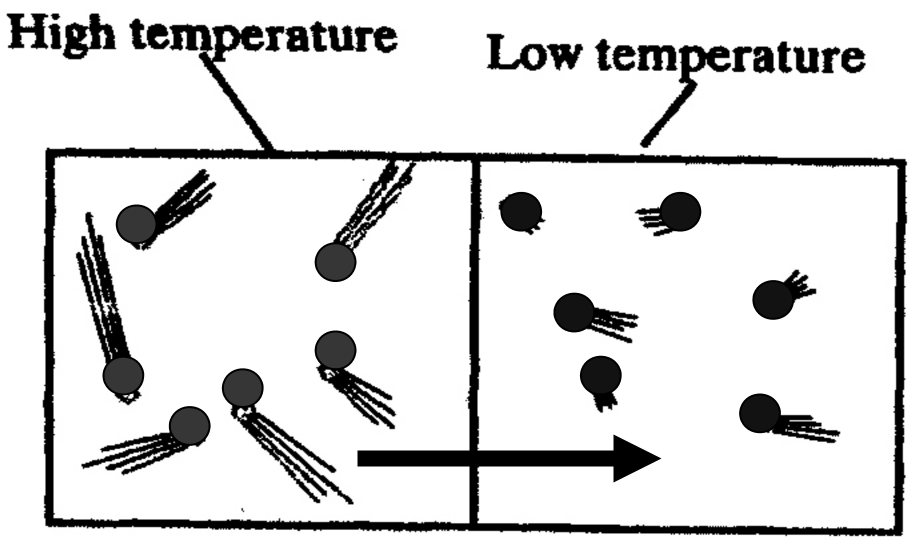
if a body has a low temperature, each molecule on the average has a small amount of kinetic energy.

e.g. water vapor molecule – H_2O at lower temperature



(and if atoms lose all their kinetic energy, they reach the **"absolute zero"** of temperature)

Thermal Energy Flow (Transfer)



(a) A hot box of gas and a cold box of gas, at the instant they are put into contact: Most of the molecules in the hot box move rapidly, while most of the molecules in the cold box move slowly.

In which direction will THERMAL ENERGY be transferred?

Thermal energy flow = HEAT

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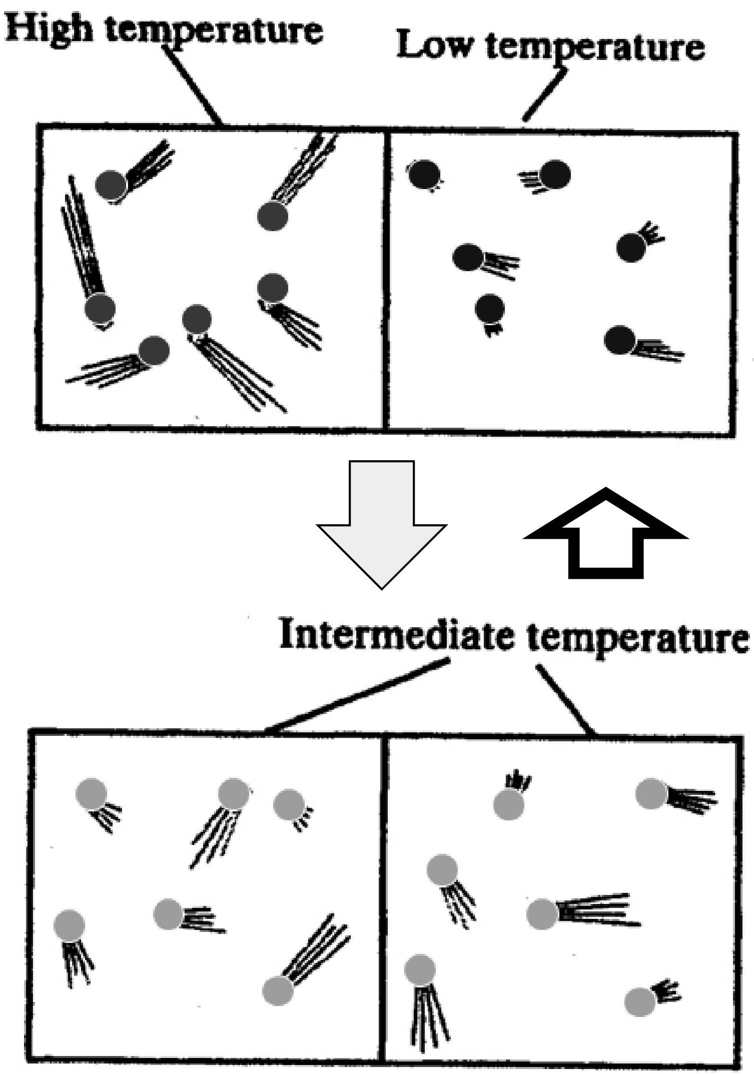
Thermal Energy vs. Heat

Heat = the thermal energy that is *transferred* from one body to another because of a temperature difference**.**

Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.

Higher T ➔ Lower T



Reaches equilibrium

Will not spontaneously return to previous condition!

http://jersey.uoregon.edu/vlab/Thermodynamics/index.html

Skip to p 46

THE LAWS!

"Everything that happens can be described as energy transformations"

A REPEAT! Discussed earlier under ENERGY *(p 22):*

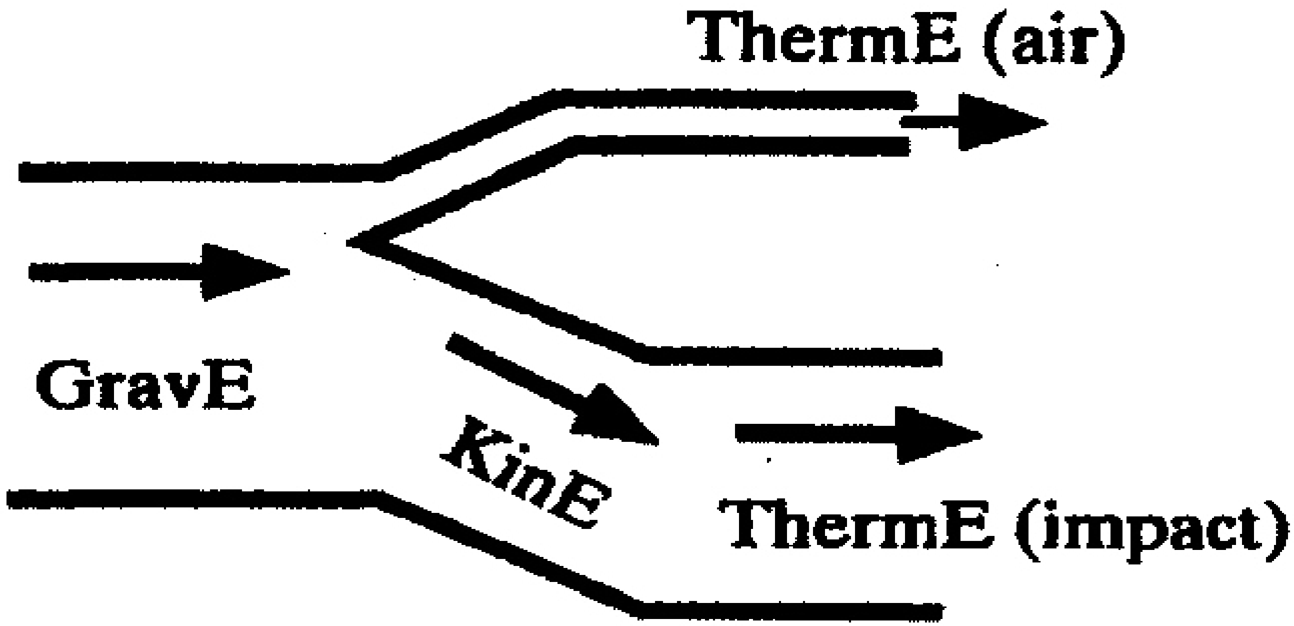
THE FIRST LAW OF THERMODYNAMICS
(stated as the "Law of Conservation of Energy")

The total energy of all the participants in any process must remain unchanged throughout the process. There are no known exceptions.

Energy can be transformed (changed from one form to another), but the total amount always remains the same.

Remember this example?

Energy flow for a falling book, with air resistance.



1^{st} Law of Thermodynamics

FIRST LAW OF THERMODYNAMICS

(another way of saying it)

In an isolated system
the <u>total amount of energy</u>
(including heat energy)

is <u>conserved</u>,

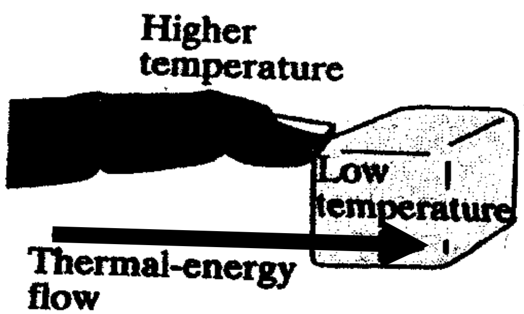
although energy may change from one form to another over and over again.

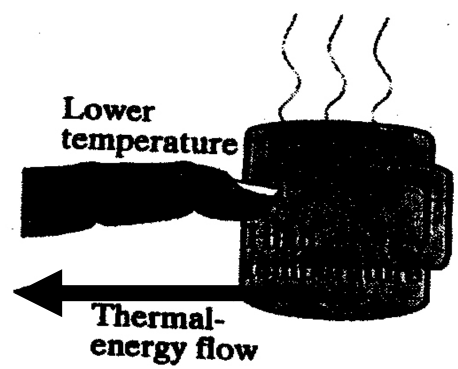
SECOND LAW OF THERMODYNAMICS (stated as the “Law of Heating”)

Heat will not flow spontaneously from a cold to a hot body.

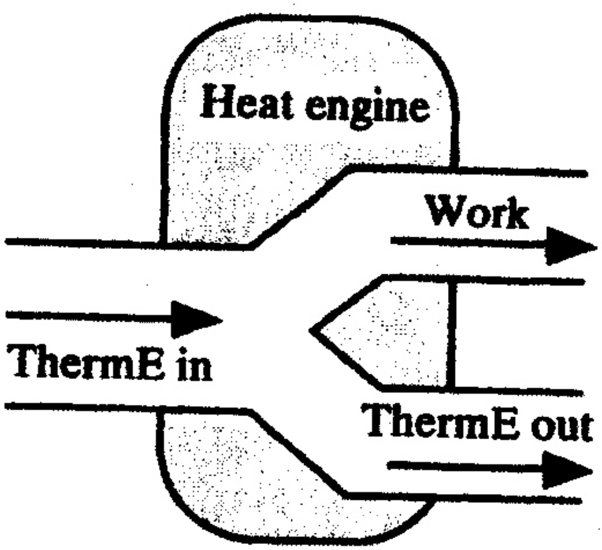
Thermal energy flows spontaneously
(without external assistance)
from a <u>higher</u> temperature object
to a <u>lower</u>-temperature object.

It will not spontaneously flow the other way!





The 2nd Law stated <u>another</u> way:



Energy flow diagram for a heat engine.

🡐

"2^{nd} Law" = Any process that uses thermal energy as input to do the work must also have thermal energy output (or exhaust)

WHAT TO REMEMBER: heat engines are always less than 100 % efficient! 🡐 **IMPROVED ENERGY EFFICIENCY IS A KEY ASPECT OF GREEN TECHNOLOGIES!**

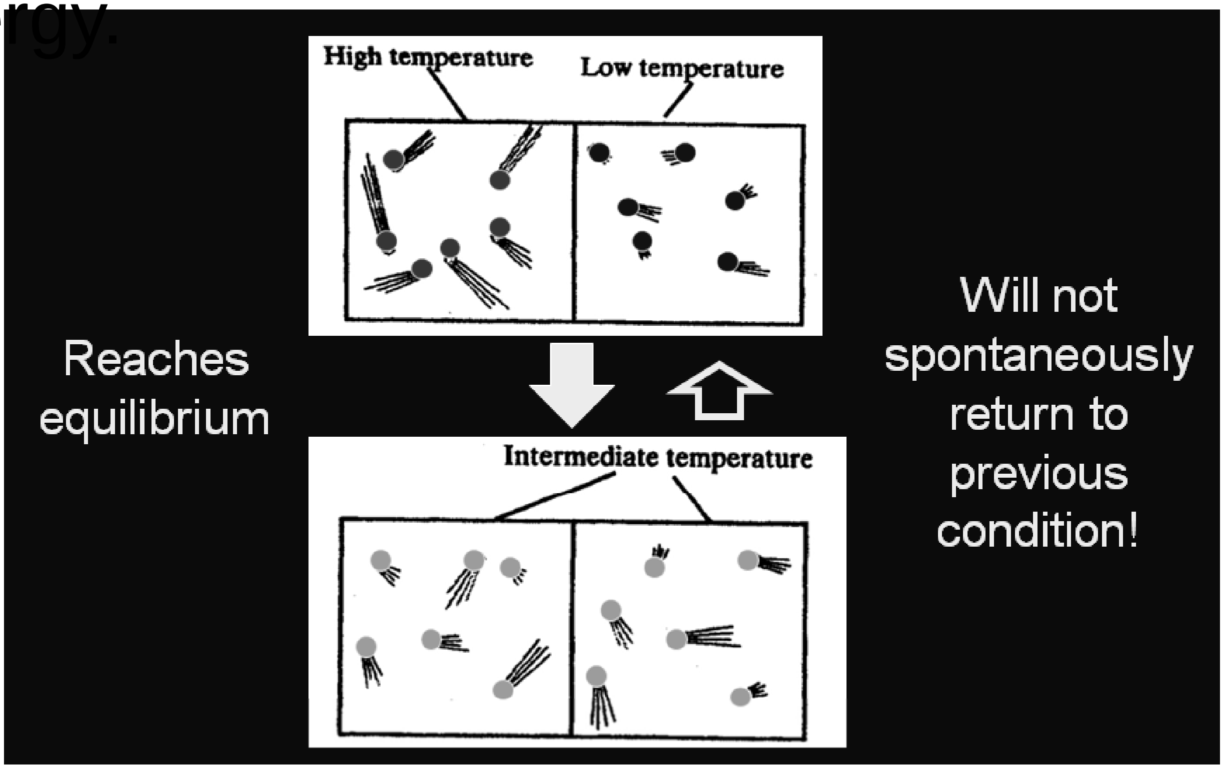
The 2nd Law stated a <u>THIRD</u> way:

Energy of all kinds in our material world disperses or dissipates if it is not hindered from doing so!

<u>**Entropy**</u> = the <u>quantitative measure</u> of this kind of spontaneous dissipating process:

i.e., how much energy has flowed
from being constricted or concentrated
to being more widely spread out
(at the temperature of the process)

Irreversibility: Once a system creates thermal energy, that system will never by itself (spontaneously) be able to return to its previous condition. There is an irreversibility about any process that creates thermal energy.



IN-CLASS
SELF TEST
TIME!!!

. . . . .→

Q1 - Which way is heat being transferred?

1. From the cold beer can into Homer's warmer beer belly

2. From Homer's beer belly to the colder beer can

3. From BOTH the beer can to Homer <u>and</u> Homer to the beer can

Think, pair, share!

Which way is heat being transferred?

1. From the cold beer can into Homer's warmer beer belly

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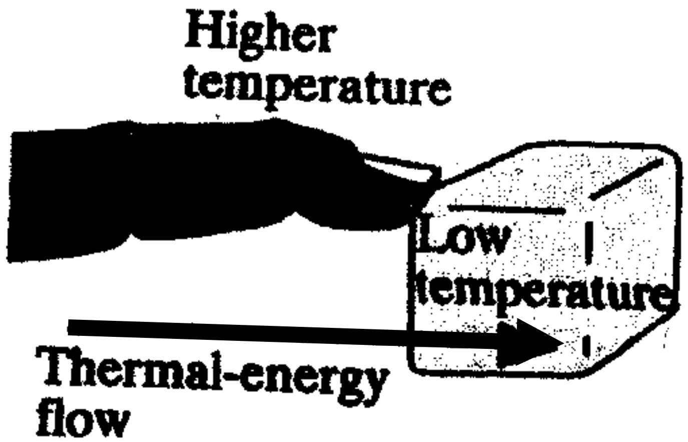
3. From BOTH the beer can to Homer and Homer to the beer can

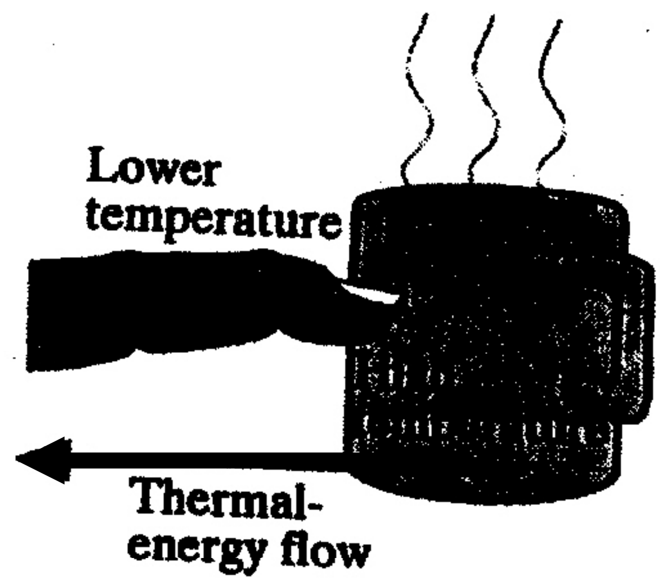
CORRECT ANSWER



Explanation for answer to Q1:

The 2nd Law of Thermodynamics!

Heat will always pass from a substance of higher temperature to a substance of lower temperature, until both come to a common temperature.



To prepare for the next few “CLASS SELF TEST” QUESTIONS, some background is needed . . . . .

- Unit of Measure of Thermal Energy
  (i.e., the joule or calorie)
- Specific Heat
- Heat Capacity
- Change of Phase
  (i.e., Latent Energy LE & Sensible Heat (H)
- Heat Transfer

Quick Review: Thermal Energy Units

Unit for Thermal Energy
= the *joule* or *calorie*.

“Low Joule Cola”

A CALORIE is the amount of thermal energy required to change the temperature of 1 gram of water by 1°C (specifically from 14.5°C to 15.5°C)   1 calorie = 4.186 joules

(one gram of water is roughly equivalent to the weight of one cubic centimeter of water)

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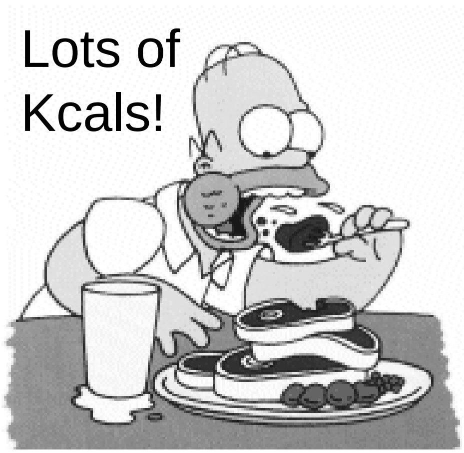
Thermal energy calorie
vs
“nutrition” kilocalorie:



1 “calorie” in nutrition context =
1000 calories
or 1 kilogram calorie
or kilocalorie (Kcal)

Other Important Terms:

Specific Heat = the amount of thermal energy (in calories) required to raise the temperature of 1 gram of ***any substance*** by 1°C.

One Other Important Term:

Heat Capacity =

specific heat x mass (density)
of a substance for a given volume.

(Density is measured in grams per cubic centimeter.)

(Heat capacity represents the capacity of a substance to absorb heat in relation to its ***volume*** and ***density***.)

Specific Heat & Heat Capacity for Different Substances

Substance	Specific Heat		Heat Capacity
	cal	*joules*	
water	1.00	4.186	1.00
air	0.24	1.005	0.00024 - 0.00034
concrete	0.21	.879	0.50
sand	0.20	.837	0.10 - 0.60 (higher if wet)
rock	0.185	.774	---
iron	0.105	.440	0.82
silver	0.056	.234	0.59

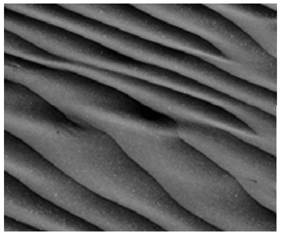
↑

Note the HEAT CAPACITY differences between higher density substances (like water, iron) vs. the low density substance of AIR.

Q2 - Assume you have an equal volume of WATER, AIR & SAND.

Which will <u>HEAT UP THE FASTEST</u> if the same amount of thermal energy is transferred into the substance?

1. WATER
2. AIR
3. SAND

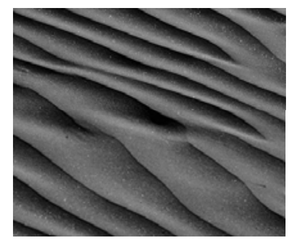


HINT: the greater the <u>heat capacity</u>, the longer it will take to heat up the substance.
To answer, check out the heat capacities in the table on p 43 of Class Notes.

Q2 - Assume you have an equal volume of WATER, AIR & SAND.

Which will HEAT UP THE FASTEST if the same amount of thermal energy is transferred into the substance?

1. WATER
2. $\boxed{\text{AIR}}$
3. SAND



Explanation:

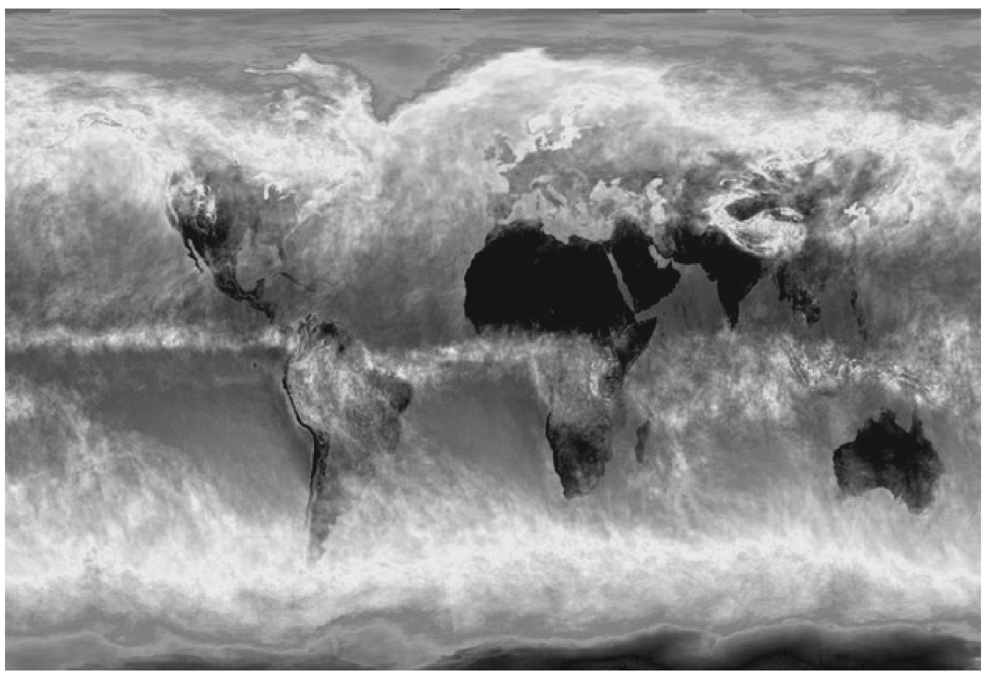
The lower the heat capacity, the quicker the response to a transfer of heat into the substance!

Q3 – As global warming is occurring we will be able to detect it <u>FIRST</u> where?

1 = the ocean temperature

2 = the land surface temperature (i.e., soil)

3 = actually, they will both heat up at the same rate



Q3 – If global warming is occurring we will be able to detect it FIRST in:

1 = the ocean temperature

2 = the land surface temperature (i.e., soil)

3 = neither, they will both heat up at the same rate

Note where the hottest temperatures occur

☺

Q4 - Why will he burn his tongue, even if the crust is cool enough to hold?

1 - Because due to the high specific heat & heat capacity of the water in the apple pie filling, the filling will hold the thermal energy longer

2 – Because, due to the high specific heat & heat capacity of the water in the apple pie filling, the filling will heat up faster and to a much higher temperature than the crust will

3 - BOTH

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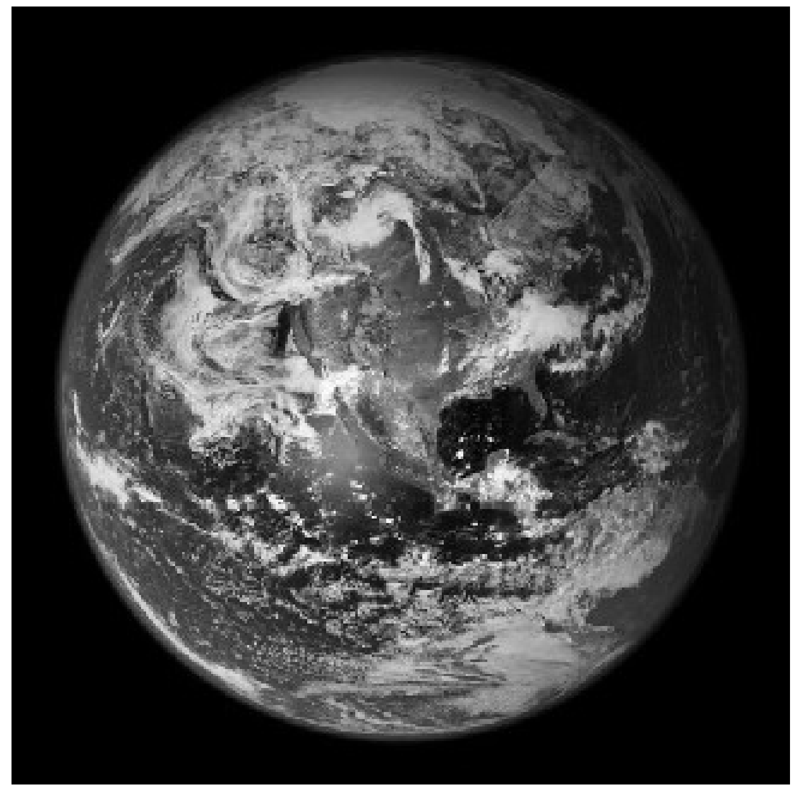
3 - BOTH

Q5 - Which component of the EARTH SYSTEM has the ability to <u>store</u> thermal energy the <u>longest</u> -- once it heats up?

1. The ATMOSPHERE
2. The CONTINENTS
3. The OCEAN



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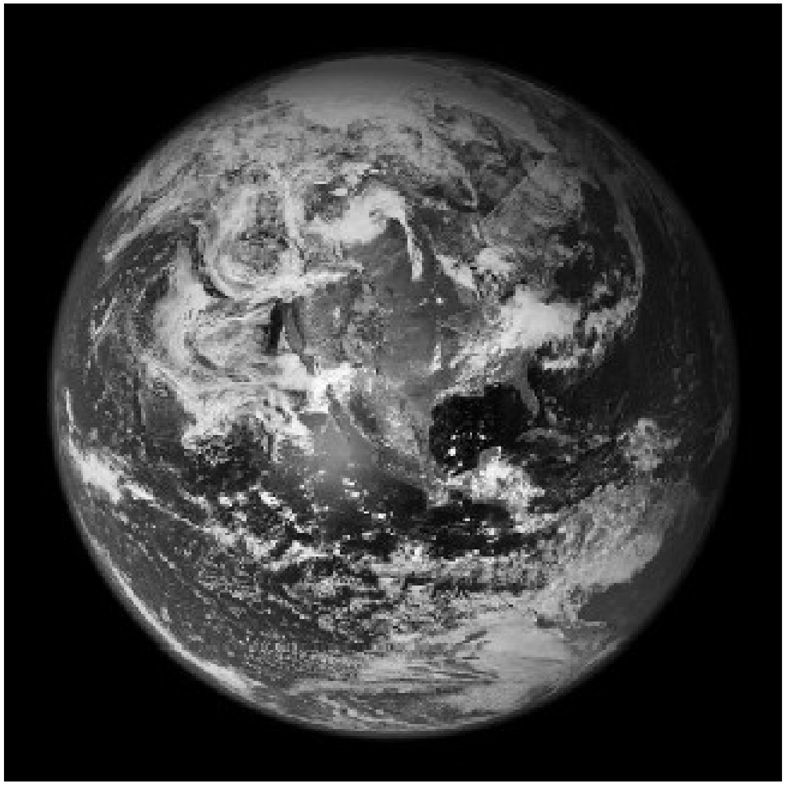

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One last quick review point . . . .

Heat generally causes *EXPANSION* of a substance.

WHY?

When the temperature of the substance increases:

-- the molecules jiggle faster

-- more energetic collisions occur between the molecules

-- molecules are forced to move farther apart

-- thereby expanding the substance and making it LESS DENSE.

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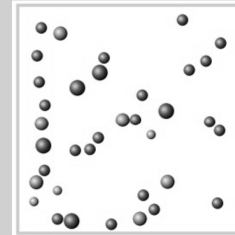
As air heats up, it expands, hence hot air is less dense than cold air & tends to RISE.

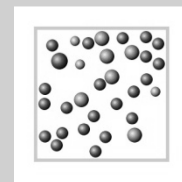
Likewise, cold air is more dense than hot air & tends to SINK

These thermal differences play an important role in driving ATMOSPHERIC CIRCULATION, WEATHER & GLOBAL CLIMATE PATTERNS . . . . .

HOT

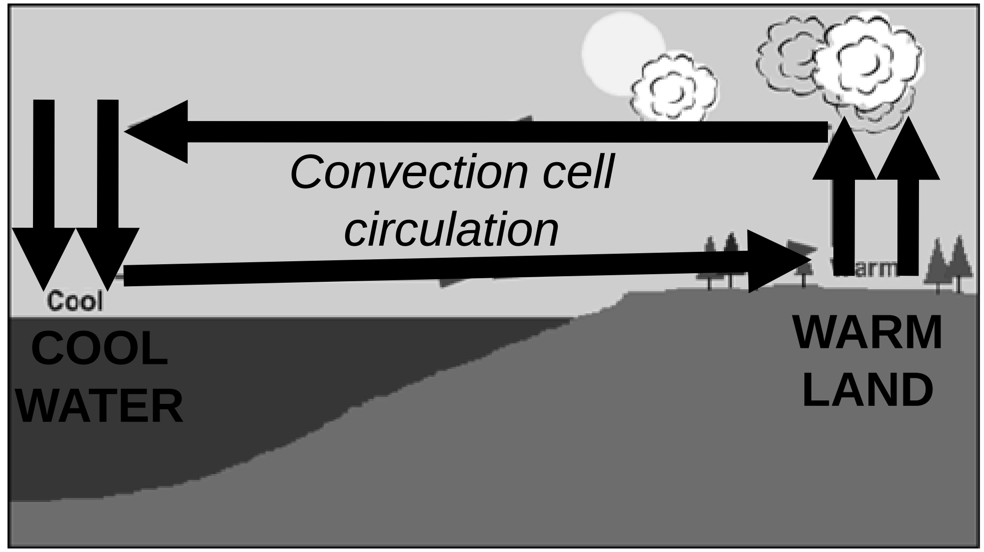


COLD



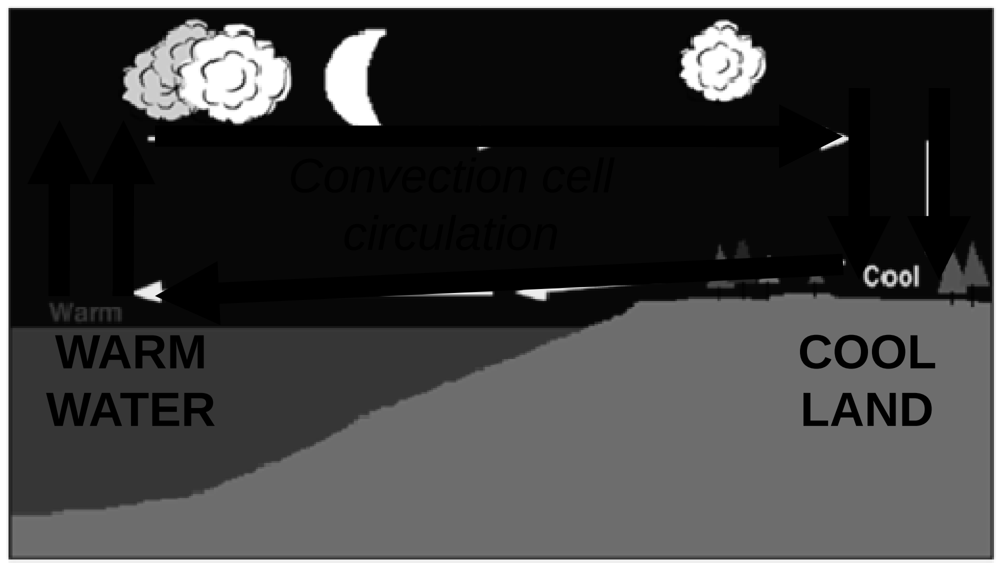
Example: **Sea Breeze & Land Breeze**

Thermally driven density differences of air



+ differences in the specific heat / heat capacity of LAND vs. WATER

➔ atmospheric circulation



On large continental scale = MONSOON CIRCULATION!

Got it all down Homer?
We'll finish up with a quick review of
PHASE CHANGES (p 44)
& HEAT TRANSFER (p 45)
next class!

NOW ONTO THE WOOD!!!!