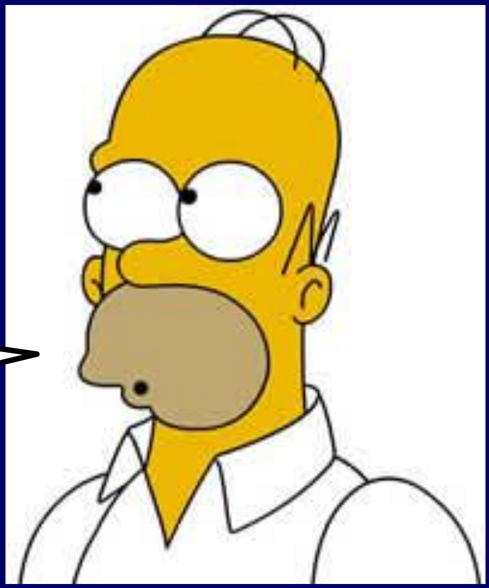
Ready for some more SCIENCE Homer?

**Alright brain,
you don't like me
and I don't like you;
but let's get through this
and I can get back
to killing you
with beer!**



Homer gives his brain a pep talk

Disclaimer: Homer's approach to learning science is not endorsed by Dr H!

TOPIC # 7 (cont.)

LAWS OF THERMODYNAMICS & MOTION

Keys To Energy Transfer & Energy Conservation

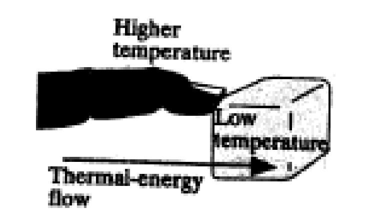
PART A - Thermal Energy Background

-- *Atoms & molecules are in constant motion*

-- *More molecular kinetic energy → hotter substance*

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.



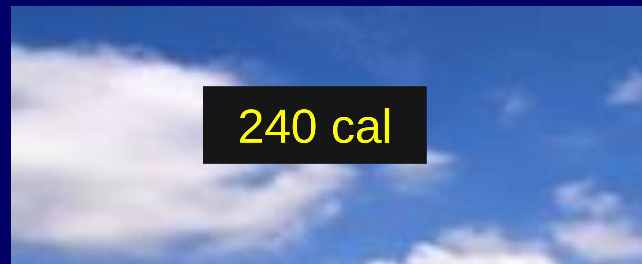
review

SPECIFIC HEAT = Heat needed to change temperature of a specified MASS of a substance

1 kilogram (kg) = 1000 grams (g) = a metric unit of mass

1000 cal

"2 lbs of water"
(~ 1 kg sand)



"2 lbs of air!"
(~ 1 kg air)

200 cal

"2 lbs of sand"
(~ 1 kg sand)

HEAT CAPACITY = heat needed to change temperature of a specified VOLUME of a substance (with a given MASS)

1000 cal

VERY HIGH DENSITY

"1 cubic meter of water"

LOW DENSITY

24 - 34 cal

"1 cubic meter of air"

HIGH DENSITY

100 – 600 cal
(more if wet sand)

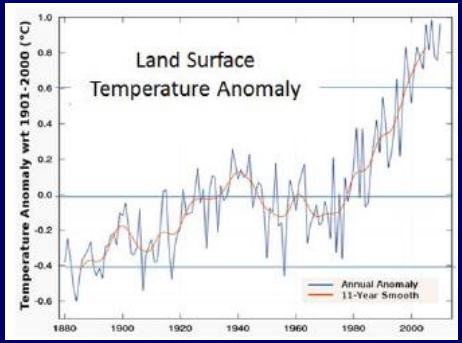
"1 cubic meter of sand"

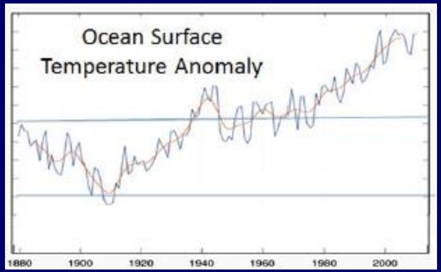
TOPIC # 7 (cont.)

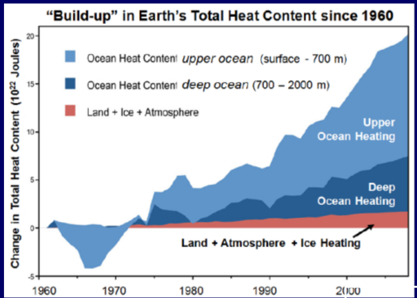
PART B – Temperature Responses & Thermal Energy Storage in Different Substances

Low Specific Heat / Capacity = heats up quickly, loses heat quickly, cannot store large amounts of thermal energy *(air, sand, continents)*

High Specific Heat / Capacity = heats up slowly, loses heat slowly, can store large amounts of thermal energy *(water, ocean)*



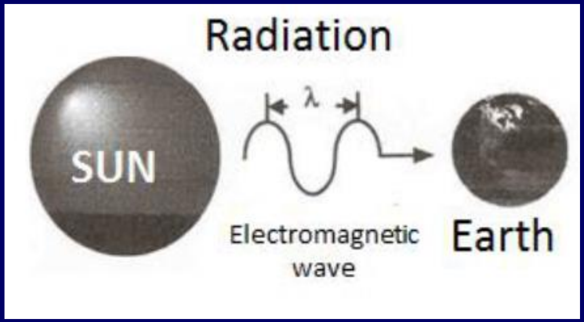




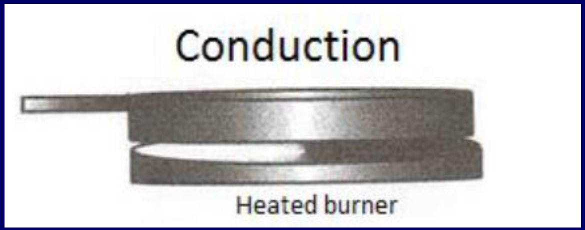
review

TOPIC # 7 (cont.)

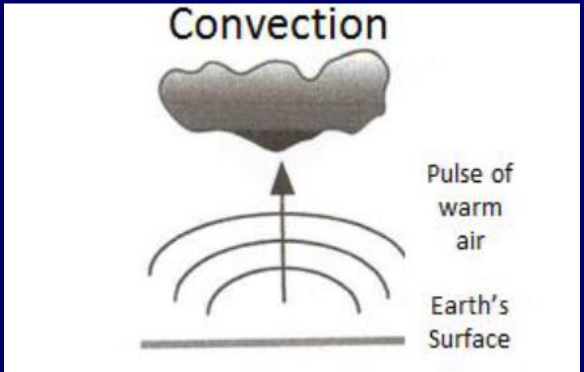
PART C – Thermal Energy Transfer



Matter is <u>not</u> needed for transfer of emergy in form of Electromagnetic radiation – the thermal energy is sensed only <u>after</u> matter absorbs the radiation



Molecule-to-molecule transfer of energy through matter (solids esp.) via kinetic energy at the molecular & atomic scale



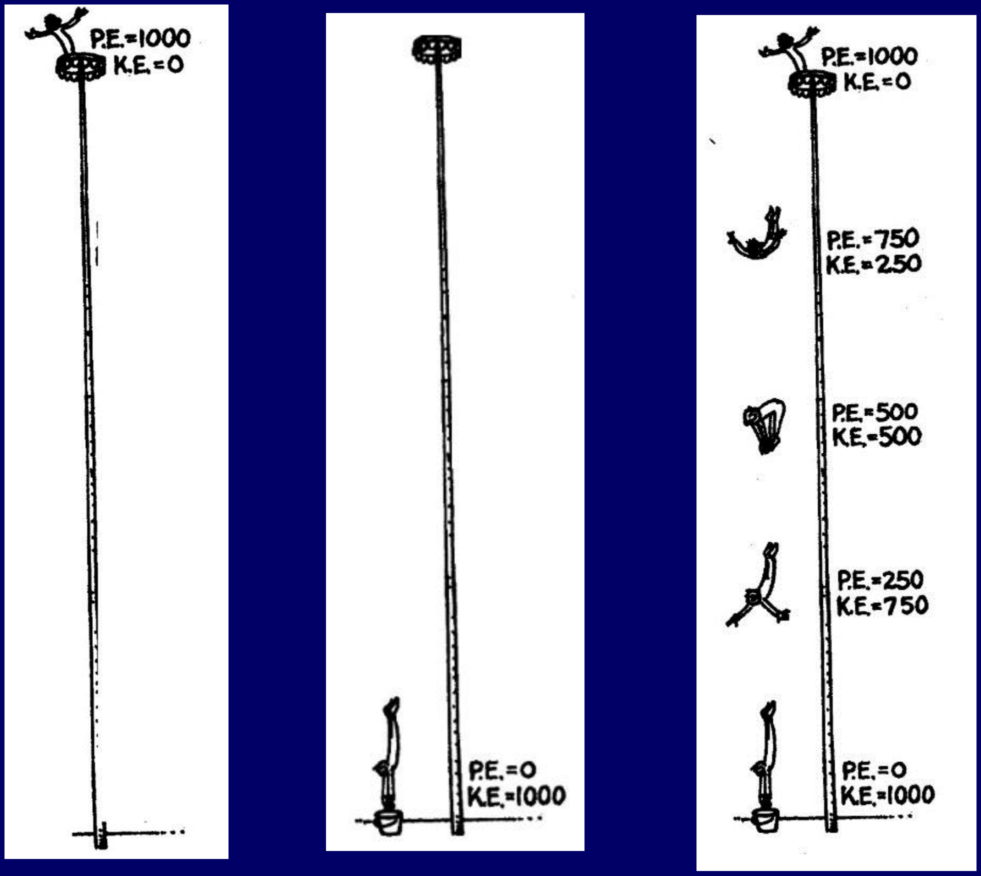
The matter itself moves – and the matter contains the energy (e.g., fast moving gas molecules)

review

CHECKPOINT

THINK . . . then share
What's still fuzzy . . .
what's now perfectly clear
about Topic #7 so far?

"Everything that happens can be described as energy transformations"



Energy is <u>conserved</u> at each point during the dive

Law of Conservation of Energy

(seen earlier on p 18)

THE
FIRST LAW
OF THERMODYNAMICS

(It's the same as the "Law of Conservation of Energy")

Energy can be transformed
(changed from one form to another),
but the **TOTAL AMOUNT**
always remains the same.

Whoops! Homer just dropped his Global Change textbook . . .

The falling book illustrates
The 1st Law of Thermodynamics
which is also known as
The Law of Conservation of Energy

HOW???

Gravitational Potential Energy (GravE)

Has potential energy due to its elevated position

Also jiggles the air molecules as it falls through the air

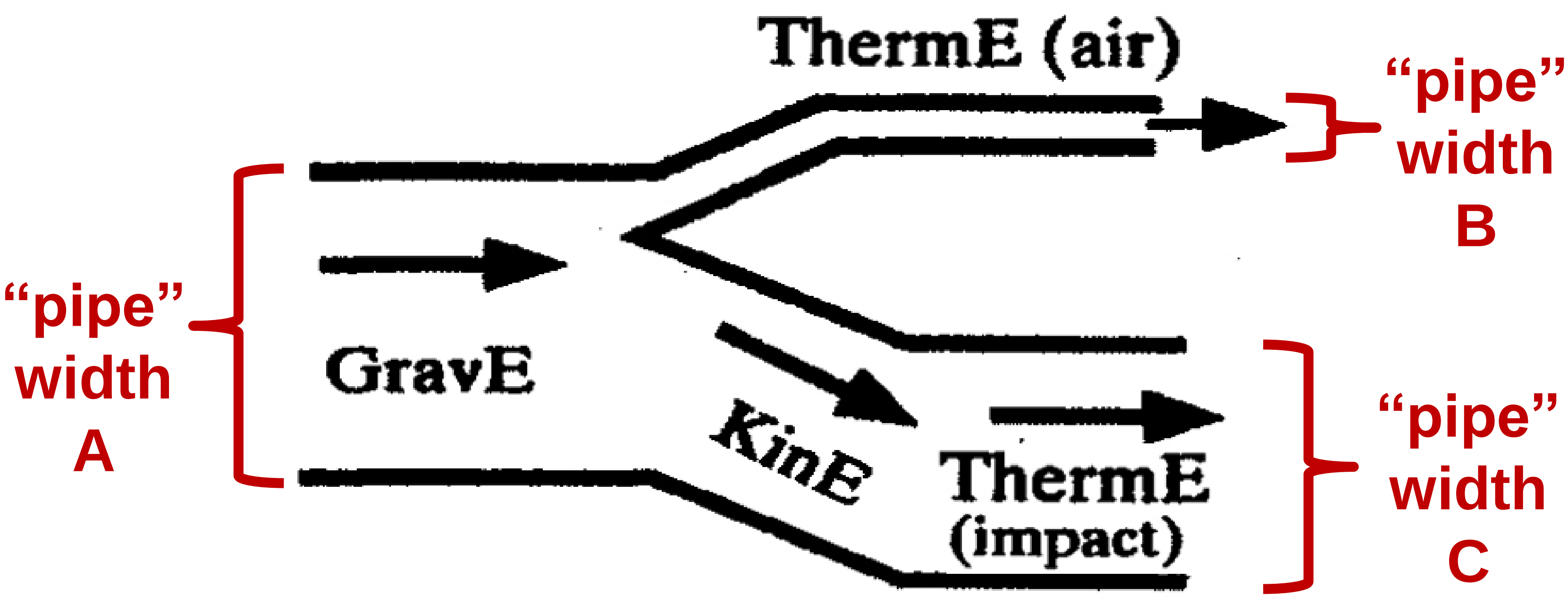
Kinetic Energy (KinE)

Converts to energy of motion as it falls

Thermal Energy (ThermE)

Converts to thermal energy on impact by jiggling the molecules of the floor it hits
➔ slight increase in temperature

This "Energy Flow Diagram" demonstrates the 1st Law:



Width A = Width B + Width C

Energy flow for a falling book, with air resistance.

FIRST LAW OF THERMODYNAMICS

(another way of saying it)

The total energy of all participants in any process must remain unchanged . . .

. . . no known exceptions

THE
SECOND LAW OF THERMODYNAMICS

There are 3 different ways
to state or describe this Law . . . .

1st way to state it: **as the "Law of Heating"**

Heat will <u>not</u> flow spontaneously
from a cold to a hot body

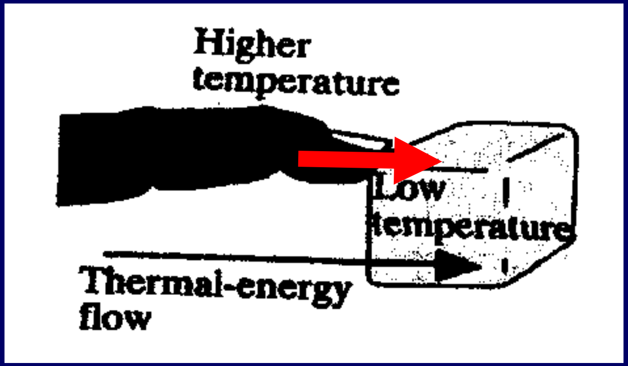
<u>More detail:</u>

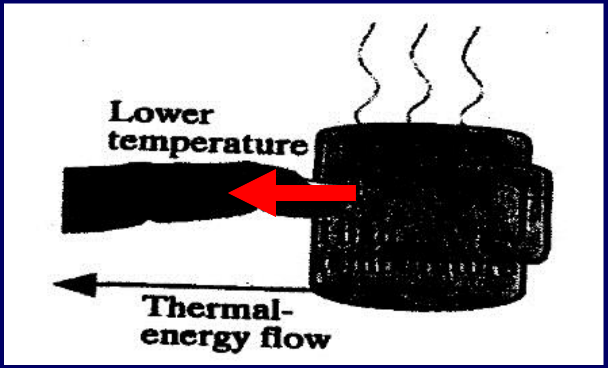
It flows from a <u>higher</u> temperature object
to a <u>lower</u>-temperature object and
it will not spontaneously
flow the other way!

What to remember about this version of Law #2:

HEAT flows from hot to cold; <u>COLD</u> doesn't flow!

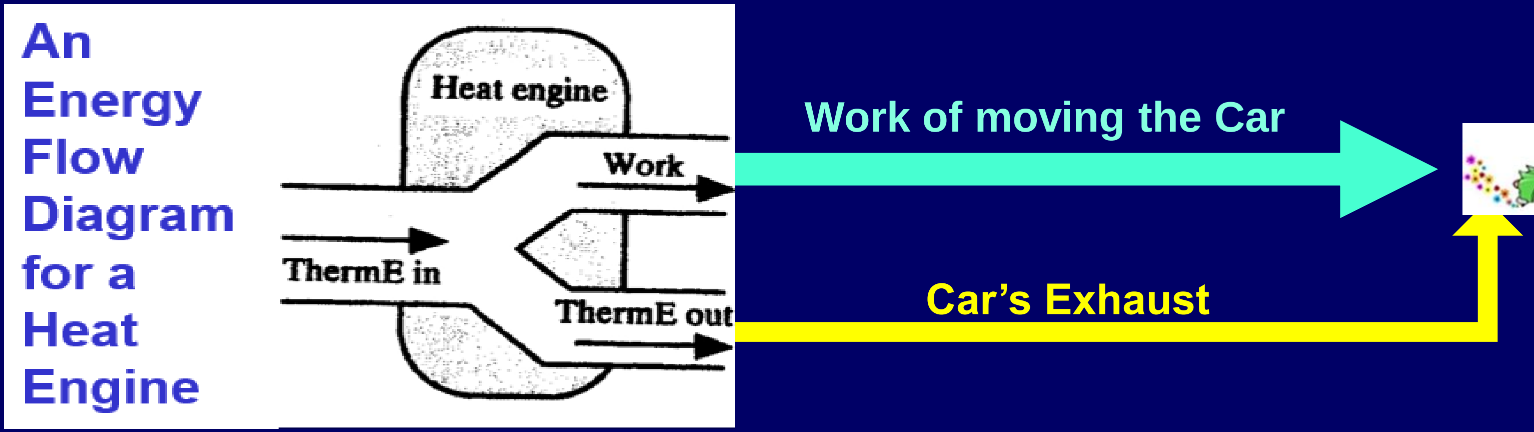
Example from p 40 ➔





2nd way to state it: **as the "Law of Heat Engines"**

Any process that uses THERMAL ENERGY AS **INPUT** to do the **WORK** must also have THERMAL ENERGY OUTPUT . . . or **exhaust!**



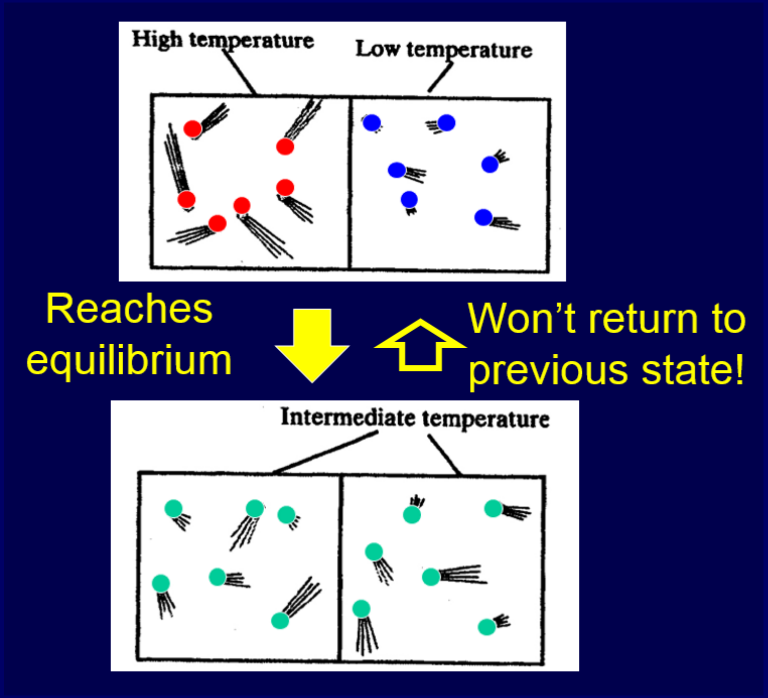
What to remember about this version of Law #2:

heat engines are always <u>less than 100 % efficient</u>!

➔ **IMPROVED ENERGY EFFICIENCY IS A KEY ASPECT OF GREEN TECHNOLOGIES!**

3rd way to state it: **as the "Law of Increasing Entropy"**

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



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

What to remember about this version of Law #2

"IRREVERSIBILITY"

There is an irreversibility about any process that creates thermal energy.

Once a system <u>creates</u> thermal energy, that system will <u>never</u> "by itself" be able to <u>return</u> to its previous condition . . .

. . . and eventually can end up as

WASTED ENERGY!

Got all that Homer?

Clicker Q0.

Which of the LAWS is MOST CLOSELY **related to this statement about energy resources ➔**

"When the Earth's energy resources are used, energy is degraded from highly useful forms, (such as oil) to less useful forms such as thermal energy."

1. The Law of Conservation of Energy *(one way of stating it):*
   "energy cannot be destroyed but it can be conserved."

2. The 1st Law of Thermodynamics *(one way of stating it):*
   "energy cannot be created, but it can be destroyed and disappear from the system."

3. The 2nd Law of Thermodynamics *(one way of stating it):*
   "heat engines are always less than 100% efficient at using thermal energy to do work."

Clicker Q0.

Which of the LAWS is MOST CLOSELY **related to this statement about energy resources ➔**

> ***"When the Earth's energy resources are used, energy is degraded from highly useful forms, (such as oil) to less useful forms such as thermal energy."***

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3. The 2nd Law of Thermodynamics *(one way of stating it):*
   "heat engines are always less than 100% efficient at using thermal energy to do work."

TOPIC # 7 (cont.)

PART D – The Laws Of Thermodynamics

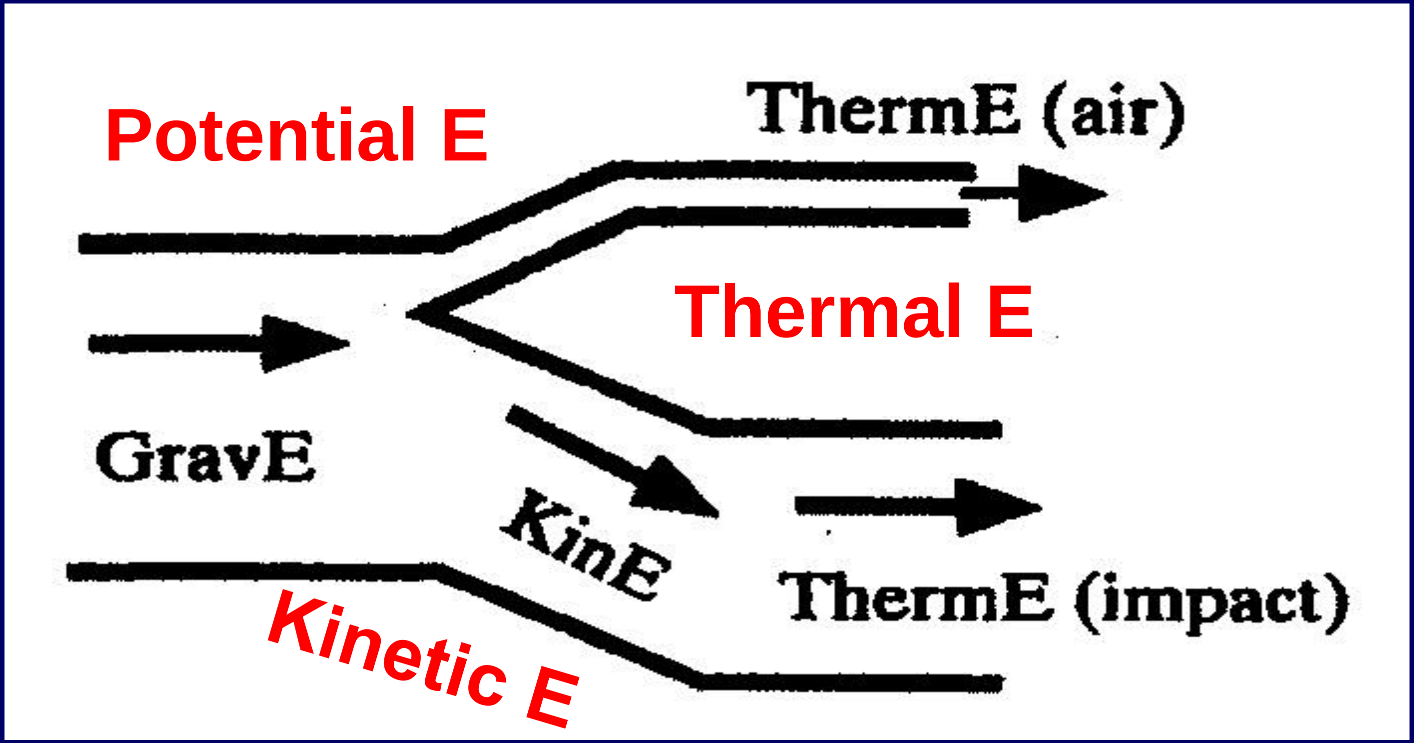
SUMMARY

The 1st Law of Thermodynamics
• Energy is conserved (knows as The Law of Conservation of Energy) • The amount of energy in the universe is constant. • Energy can be neither created nor destroyed. • It is impossible to build a machine that produces <u>more</u> energy than it uses

The 2nd Law of Thermodynamics
• Heat cannot flow from a cold object to a hot object on its own. • With each energy conversion from one form to another, some of the energy becomes unavailable for further use. • It is impossible to convert heat energy into work with 100 percent efficiency. • It is impossible to build a machine that produces <u>as much</u> energy as it uses. • The entropy of the universe tends to a maximum.

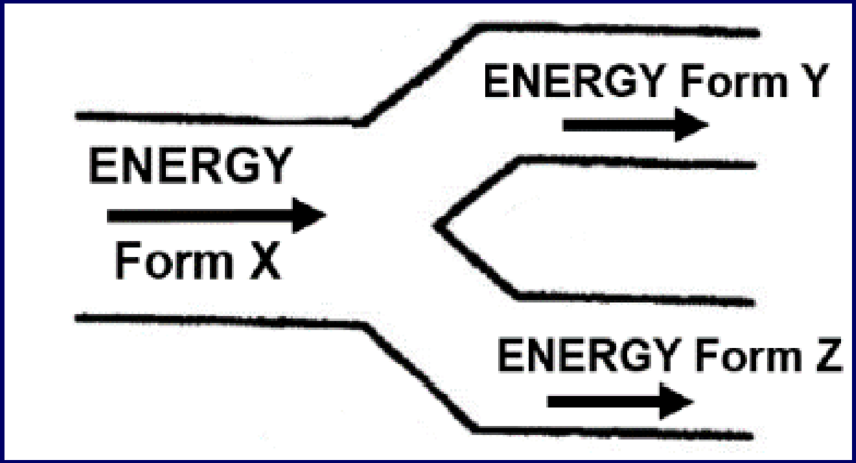
MORE ABOUT ENERGY FLOW DIAGRAMS like this one:

Energy flow for a falling book, with air resistance.



1st Law of Thermodynamics

The WIDTH of the “pipes” is proportional to AMOUNT of energy in each Energy From



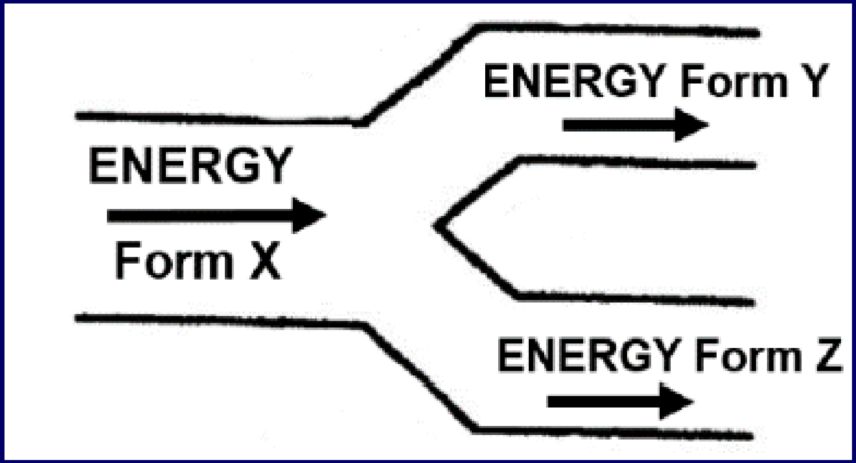
$X = Y + Z$

CLICKER Q1: In the energy flow diagram above, which Law of Thermodynamics tells us that:

The amount of energy in Pipe **X** MUST BE EQUAL to the amount of energy in Pipe **Y + Pipe Z**?

(a) LAW #1 or (b) LAW #2

The WIDTH of the “pipes” is proportional to AMOUNT of energy in each Energy From

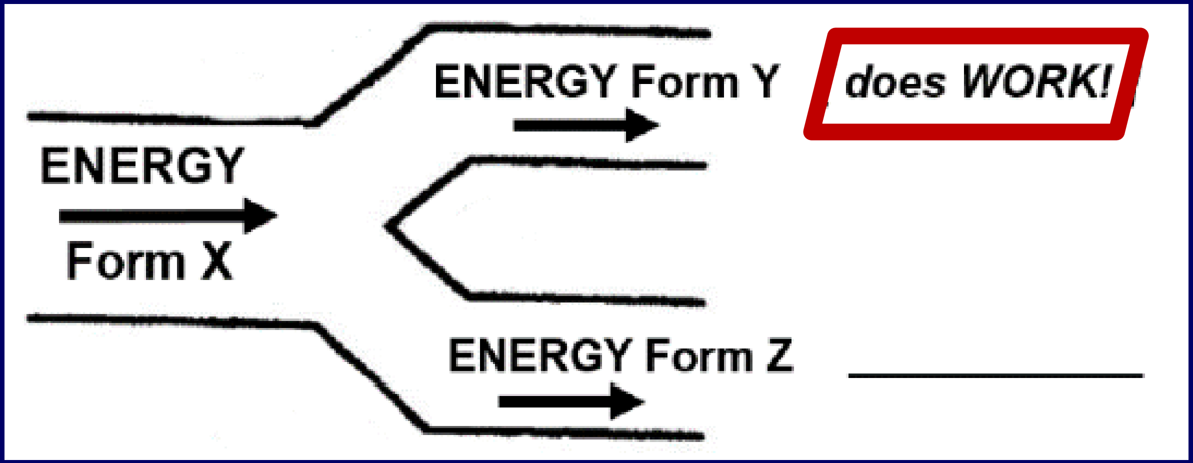


$X = Y + Z$

CLICKER Q1: In the energy flow diagram above, <u>which</u> Law of Thermodynamics tells us that:

The amount of energy in Pipe **X** <u>MUST BE EQUAL</u> to the amount of energy in Pipe **Y + Pipe Z**?

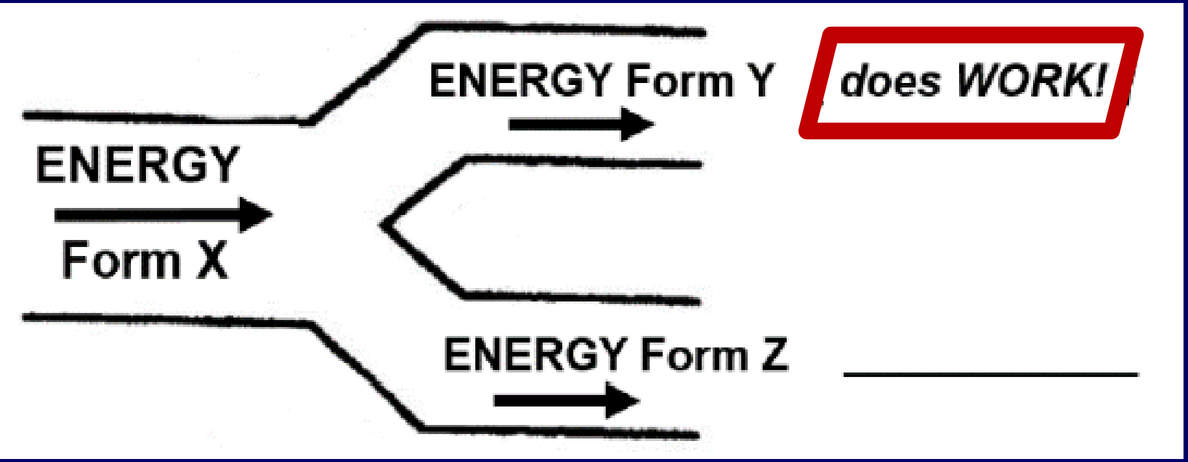
(a) $\boxed{\text{LAW \#1}}$ or (b) LAW #2



Clicker Q2. In the energy flow diagram above, which Law of Thermodynamics tells us that:

It would be IMPOSSIBLE for **Energy Form Z** to do as much work as **Energy Form Y** ?

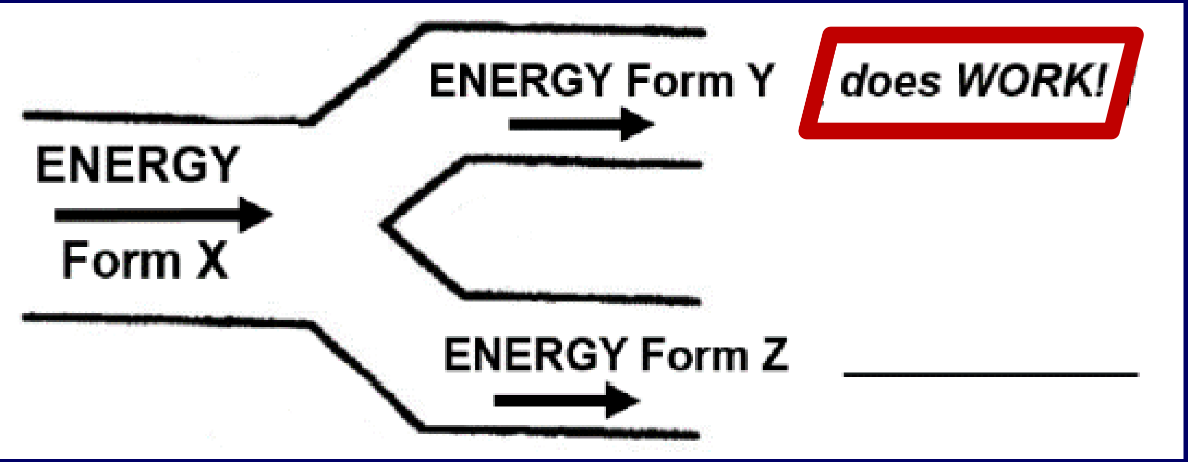
(a) LAW #1 or (b) LAW #2



Clicker Q2. In the energy flow diagram above, which Law of Thermodynamics tells us that:

It would be IMPOSSIBLE for **Energy Form Z** to do as much work as **Energy Form Y** ?

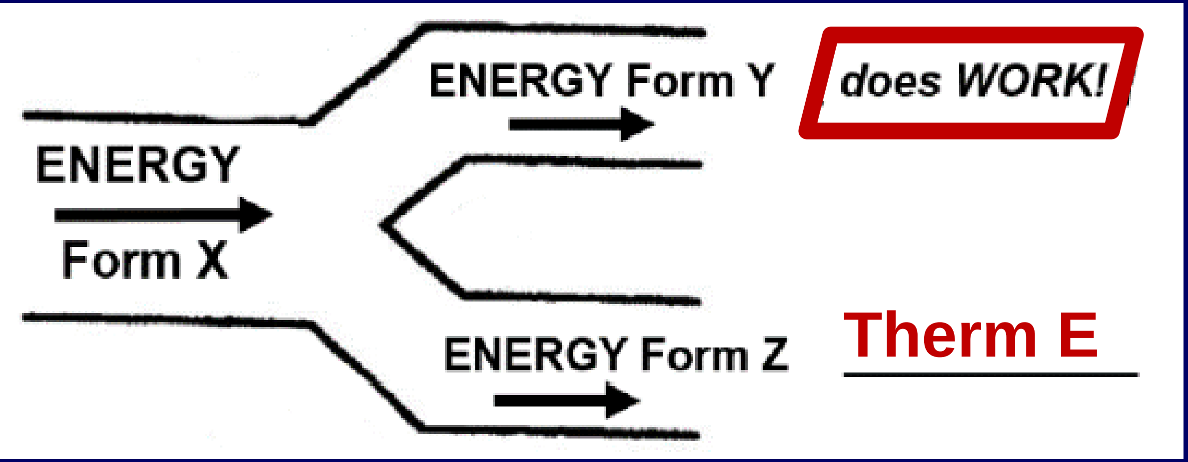
(a) LAW #1 or (b) LAW #2



Thought Q3: What form of energy do you think Z is?

Is it doing work?

Is it useable energy, or not?



Thought Q3. What form of energy do you think Z is?

Is it doing work?

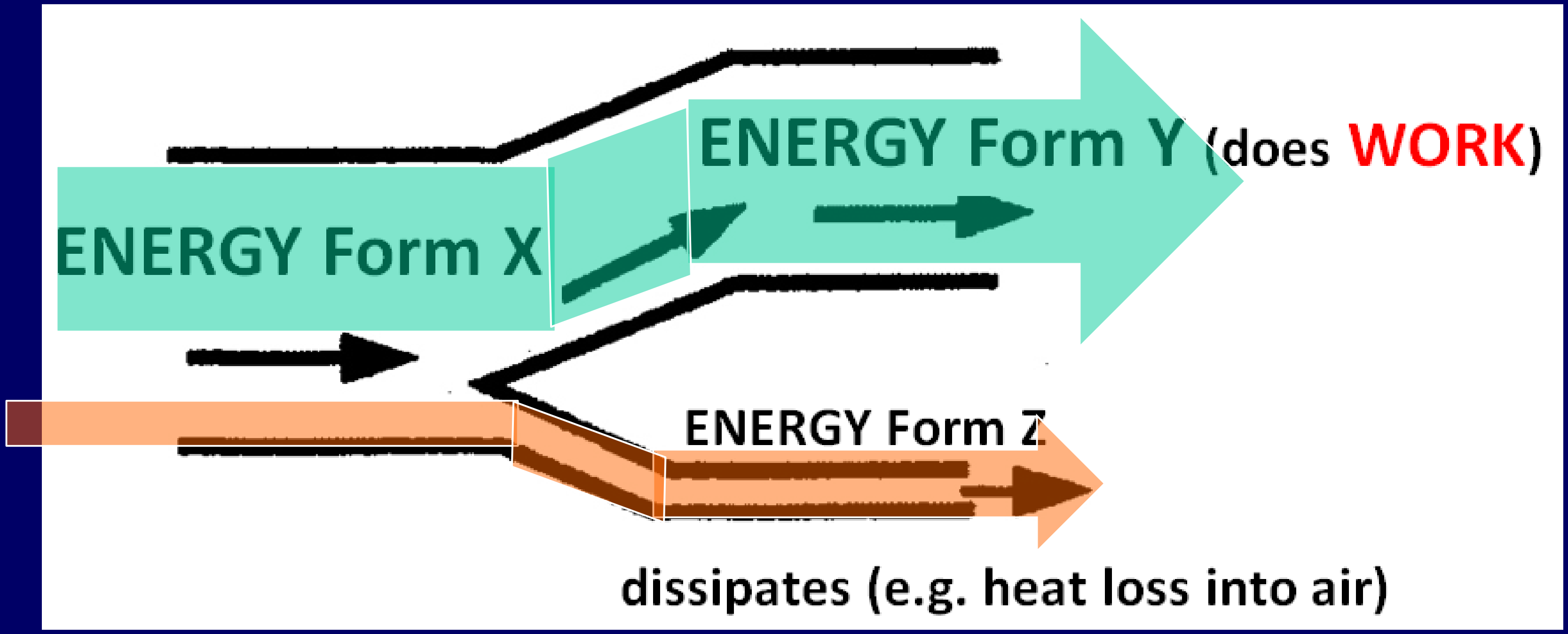
No

Is it useable energy, or not?

Not usable; heat loss or exhaust

SIMPLE SUMMARY:
IN EVERY ENERGY CONVERSION . . .

- Some of it goes where you want it:



- Some goes elsewhere:
  (usually as heat loss or "exhaust")

Applying
The Laws of Thermodynamics
to Energy Efficiency . . .

Although ENERGY may not be destroyed,
it <u>can</u> become INEFFICIENT
(not easily used or available to do work!)

Efficiency = work done / energy used

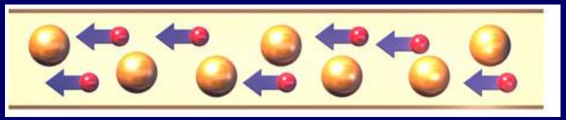
Review

This concept is critically important for designing successful GREEN TECHNOLOGIES & for mapping out SOLUTIONS for addressing climate change

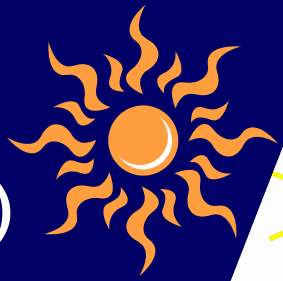
LINKING TO LIFE:
Efficiencies encountered in everyday processes & products:

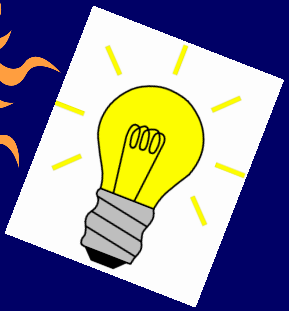
ENERGY IN OUR EVERYDAY LIVES . . .

- **ELECTRICITY** (PE)
(electrons flowing though a wire)

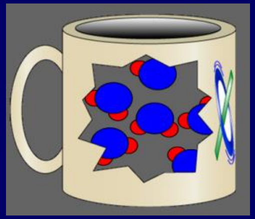


- **LIGHT /**
  ELECTROMAGNETIC ENERGY (PE)
  (solar radiation or light from a bulb)





- **HEAT / THERMAL ENERGY** (PE)
  (energetic jiggling molecules
  in a hot substance)

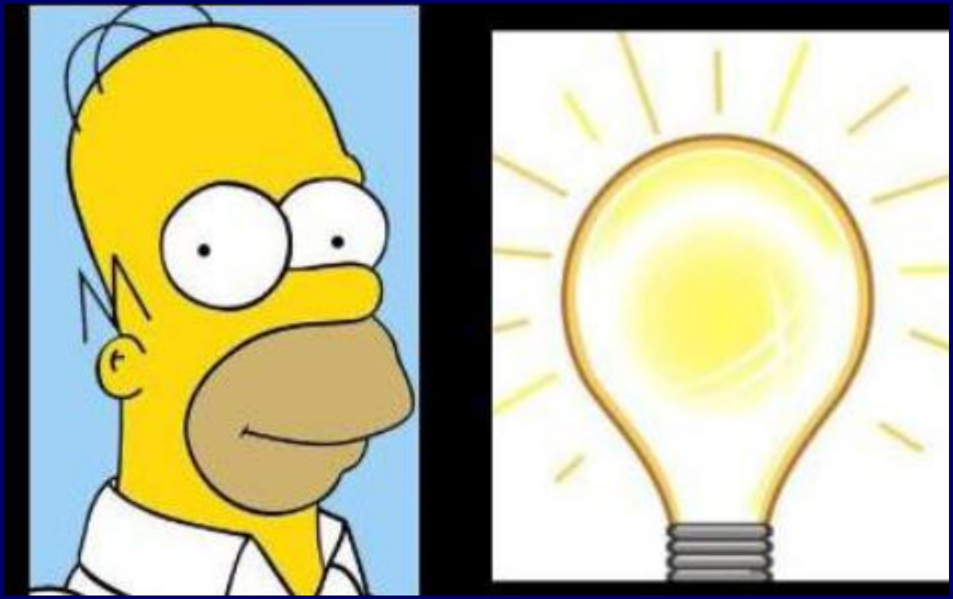


- **A MOVING MASS** (KE)
  (a large truck going 80 mph)

☺

ENERGY EFFICIENCY & LIGHT BULBS

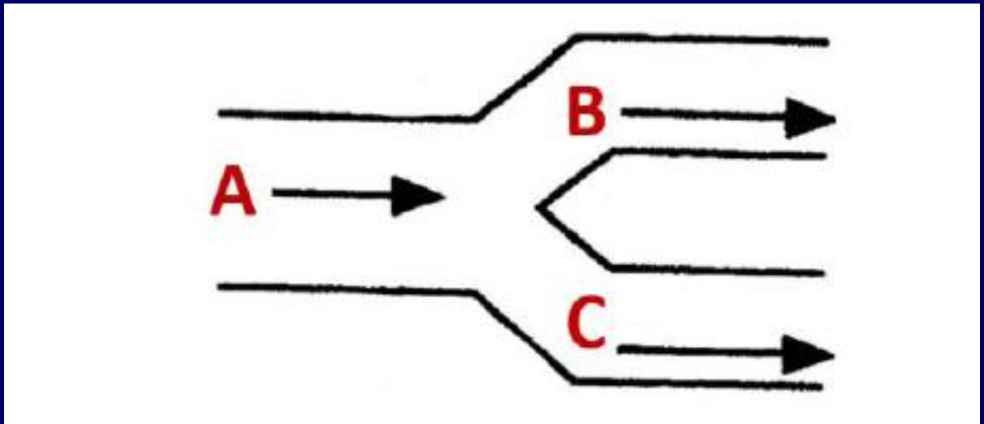
Which type of light bulb should Homer buy???




whiteboard

TEACHING TEAM . . . .
TO YOUR GROUPS!

Here is a simple and unlabeled ENERGY FLOW DIAGRAM.



Imagine it is for a **LIGHT BULB**

What 3 forms of energy are involved in the function of a light bulb?

Draw AND LABEL an energy flow diagram for a LIGHT BULB !

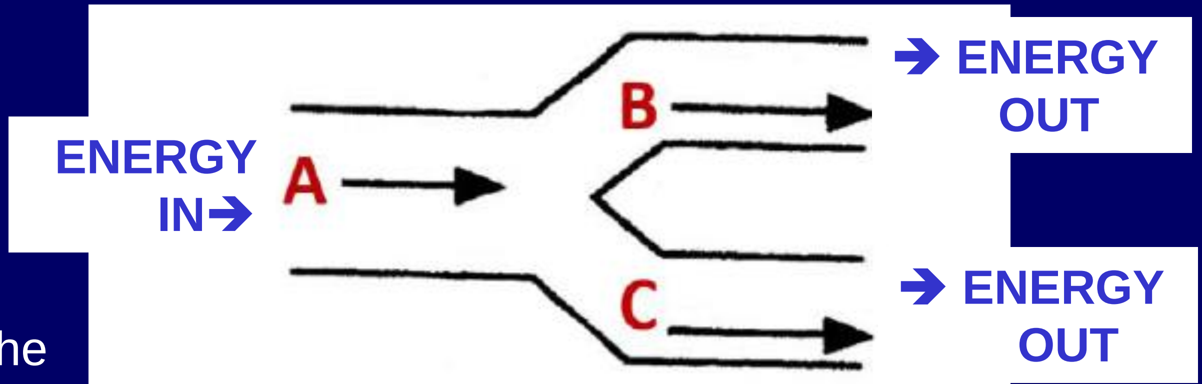
Match **Pipes A, B and C** with the **FORMS OF ENERGY** flowing through the different parts of the Diagram

FORMS OF ENERGY:

<u>LIGHT</u> *(electromagnetic energy)*

<u>ELECTRICITY</u> *(electrical energy)*

<u>HEAT</u> *(thermal energy)*



A = ______________________

B = ______________________

C = ______________________

NOTE: the width of the arrows has <u>not</u> been adjusted to show the <u>relative amounts</u> of energy in each type of energy flow.)

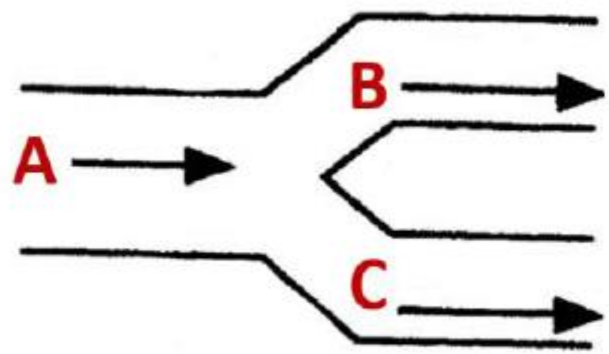
Match Pipes A, B and C with the FORMS OF ENERGY flowing through the different parts of the Diagram

FORMS OF ENERGY:

LIGHT *(electromagnetic energy)*

ELECTRICITY *(electrical energy)*

HEAT *(thermal energy)*



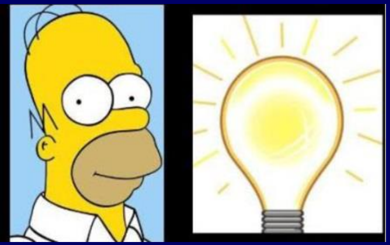
A = ELECTRICITY

B = LIGHT HEAT

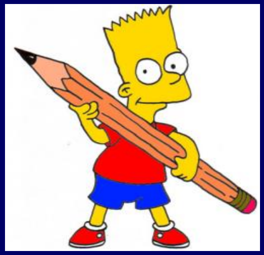
C = HEAT LIGHT

This arrangement is OK too

NOTE: the width of the arrows has not been adjusted to show the relative amounts of energy in each type of energy flow.)



Homer doesn’t want to give up his incandescent light bulbs but they are very inefficient and lose 90% or their energy as heat!



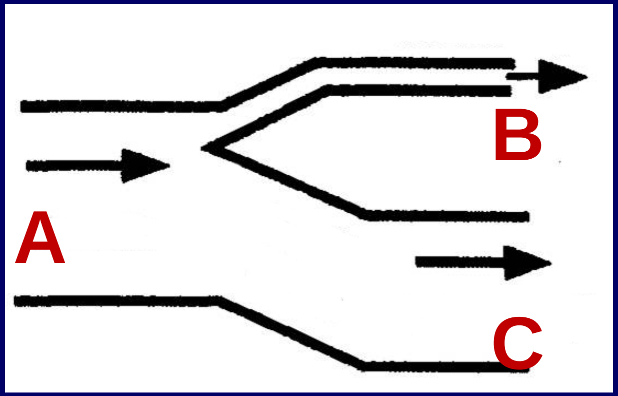
So help Bart draw an energy flow diagram for Homer’s old bulb that will show him how inefficient it is.

Show the different Energy Flow pipe widths involved!


Homer doesn't want to give up his incandescent light bulbs but they are very inefficient and lose 90% or their energy as heat!

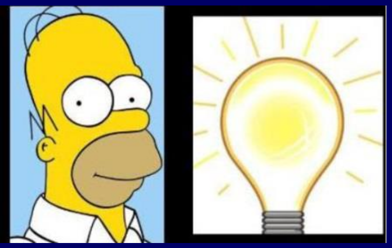
Bart's diagram ➔

(yours might look a bit different)

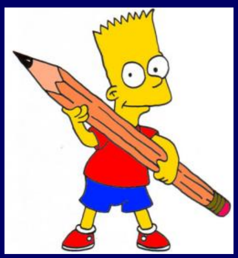


Clicker Q4. Select the # with the correct labels for Bart's diagram:

1. A = Electrical E B = Thermal E C = Light E
2. A = Light E B = Thermal E C = Electrical E
3. A = Electrical B = Light E C = Thermal E
4. A = Thermal E B = Electrical E C = Light E

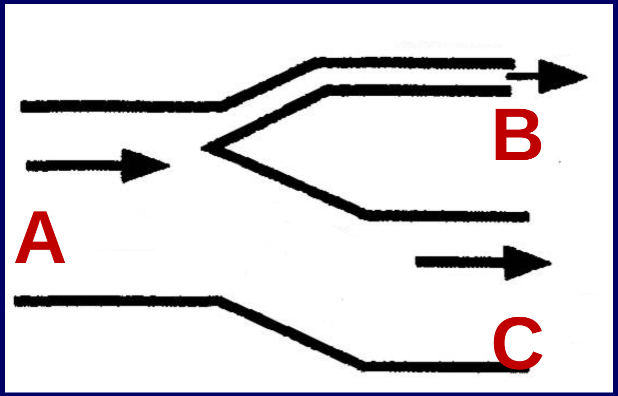


Homer doesn't want to give up his incandescent light bulbs but they are very inefficient and lose 90% or their energy as heat!



Bart's diagram ➔

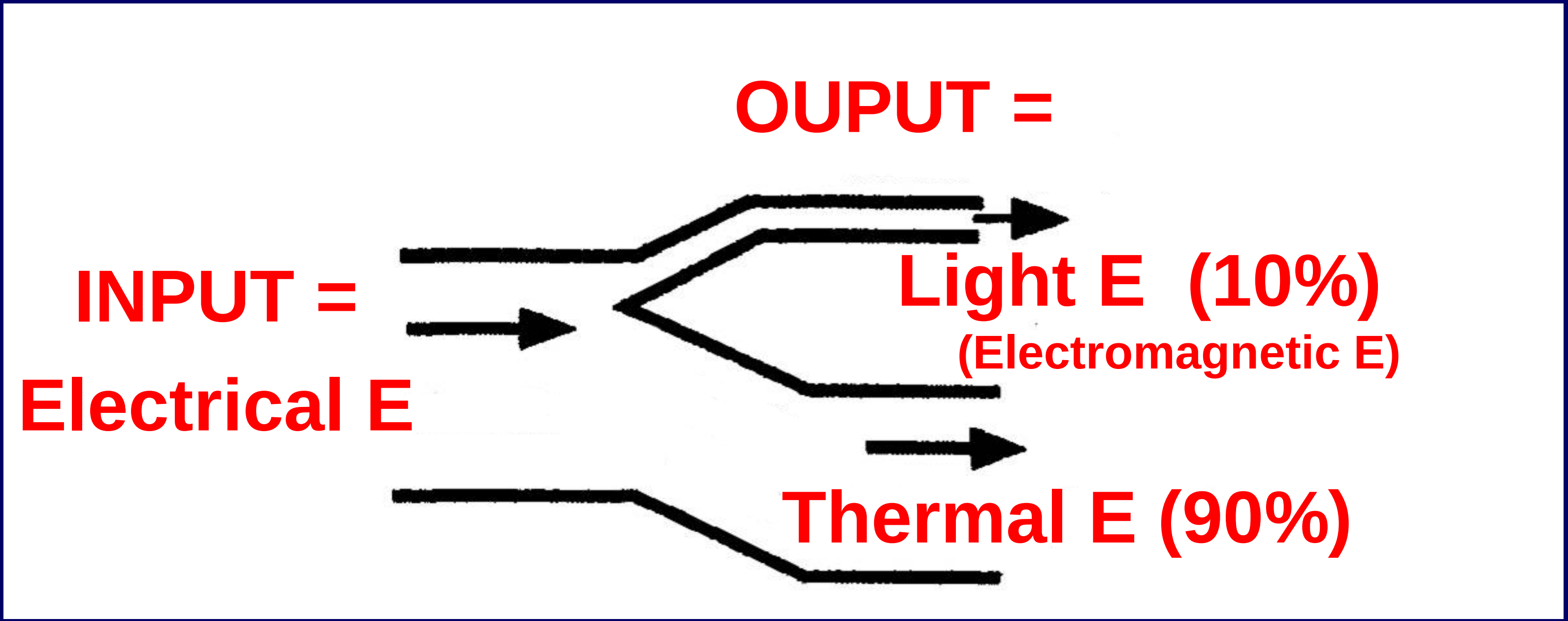
(yours might look a bit different)



Clicker Q4. Select the # with the correct labels for Bart's diagram:

1. A = Electrical E B = Thermal E C = Light E
2. A = Light E B = Thermal E C = Electrical E
3. A = Electrical B = Light E C = Thermal E
4. A = Thermal E B = Electrical E C = Light E

Here it is labeled:

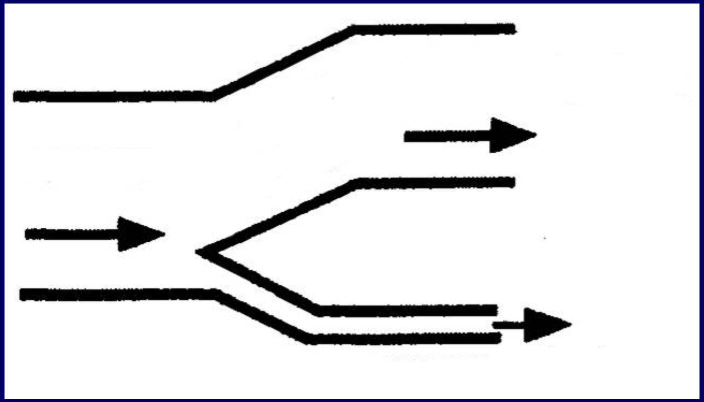


NOTE:

You can draw it this way too ➔

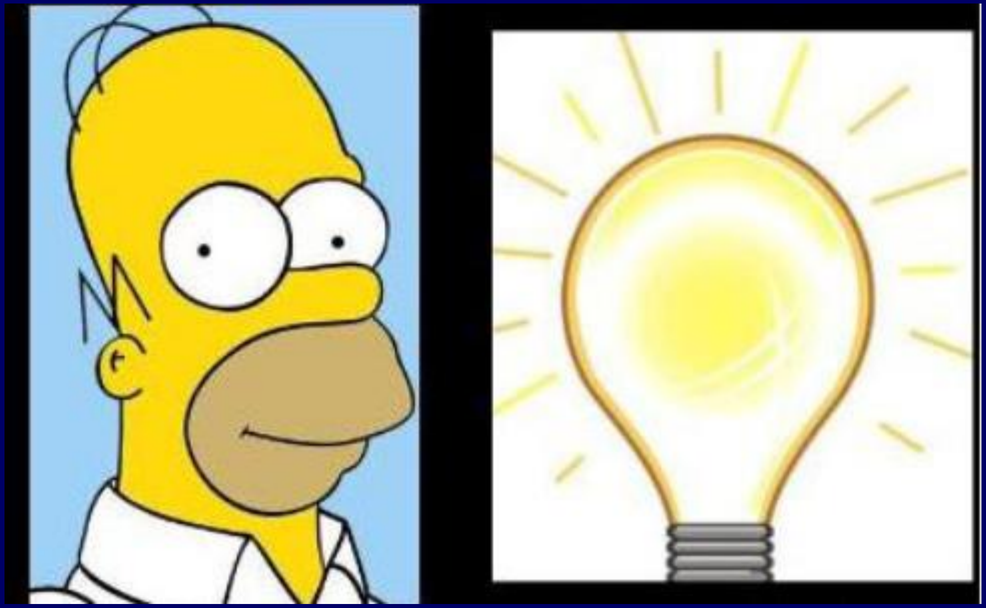
as long as you LABEL

the pipes CORRECTLY!



G-2 ENERGY EFFICIENCY GROUP ASSIGNMENT

Which type of light bulb should Homer buy???



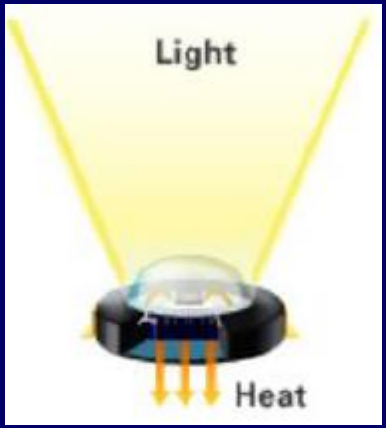
Flip to the Class Notes Appendix: p 99

INCANDESCENT BULBS: electricity passes through a metal filament until it becomes so hot that it glows.

Release 90% of their energy as heat.

COMPACT FLUORESCENT BULBS (**CFL**): electric current is driven through a tube containing gases. Reaction produces ultraviolet light → visible light aided by the fluorescent coating on the inside of the tube.

Release about 80% of energy as heat.



LED bulbs use **LIGHT EMITTING DIODES** to produce light. The movement of electrons through a semiconductor material illuminates the tiny LED light sources.

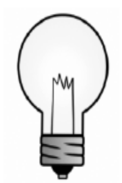
LEDs can approach 80% efficiency

(i.e., 80% of the electrical energy is converted to light energy.)

Draw a **proper ENERGY FLOW DIAGRAM** for each type of light bulb:

Width of the arrows should properly represent (**electrical energy**) converted into *light* (**electromagnetic energy**) and *heat* (**thermal energy**).

THE ARROW WIDTHS WILL BE DIFFERENT FOR EACH TYPE OF LIGHT BULB!

		RANK
	Diagram for Incandescent bulb:	
	Diagram for CFL bulb:	
	Diagram for LED w/ 80% efficiency:	

Then . . .
based on your Energy Flow Diagrams, RANK the amount of thermal energy being emitted by each bulb type based on the bulb's expected temperature -- from coolest (#1) to hottest (#3)

Fill in on G-2 Form and p 99 of your own Class Notes

OK

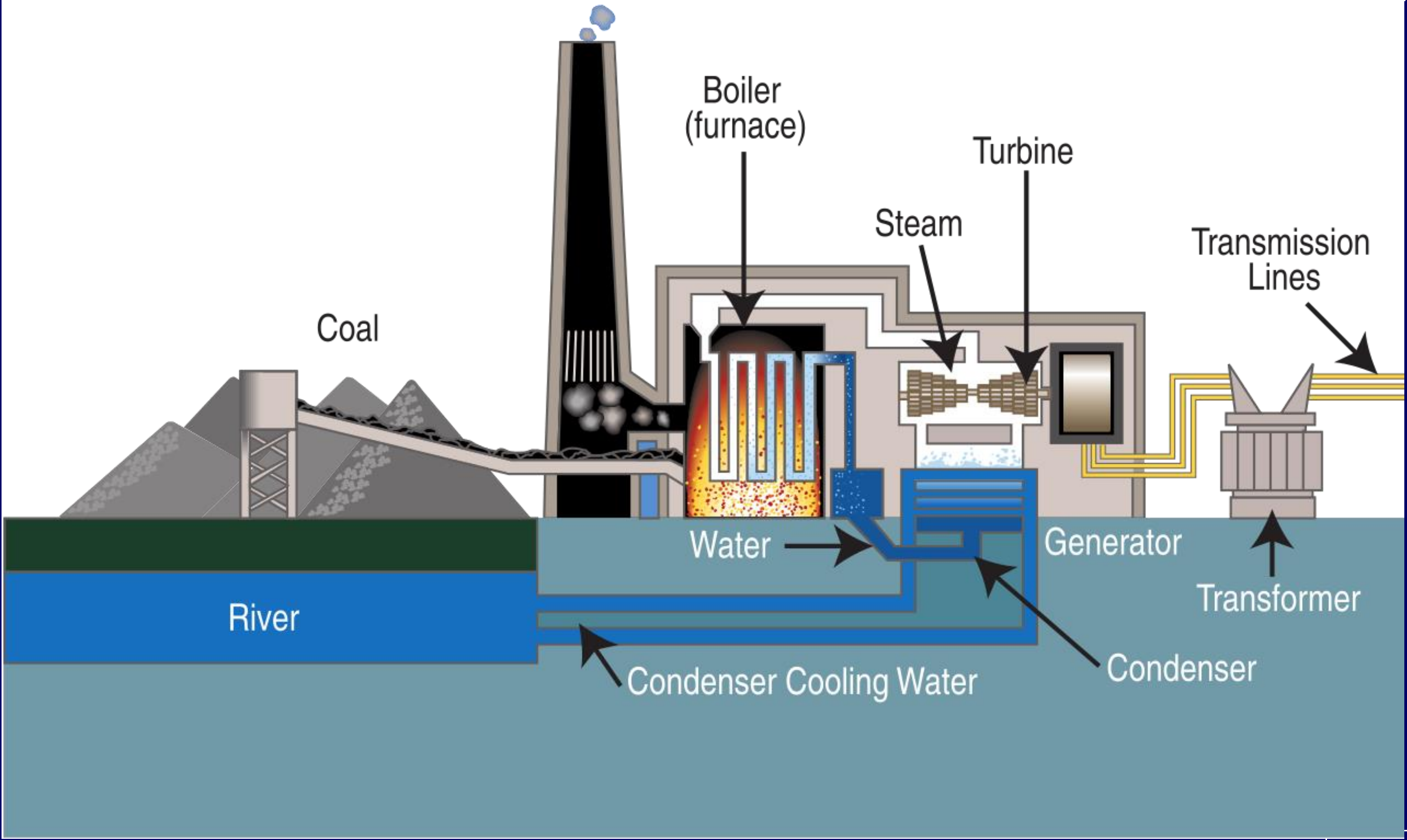
GET TO WORK ON

Page 1 of G-2

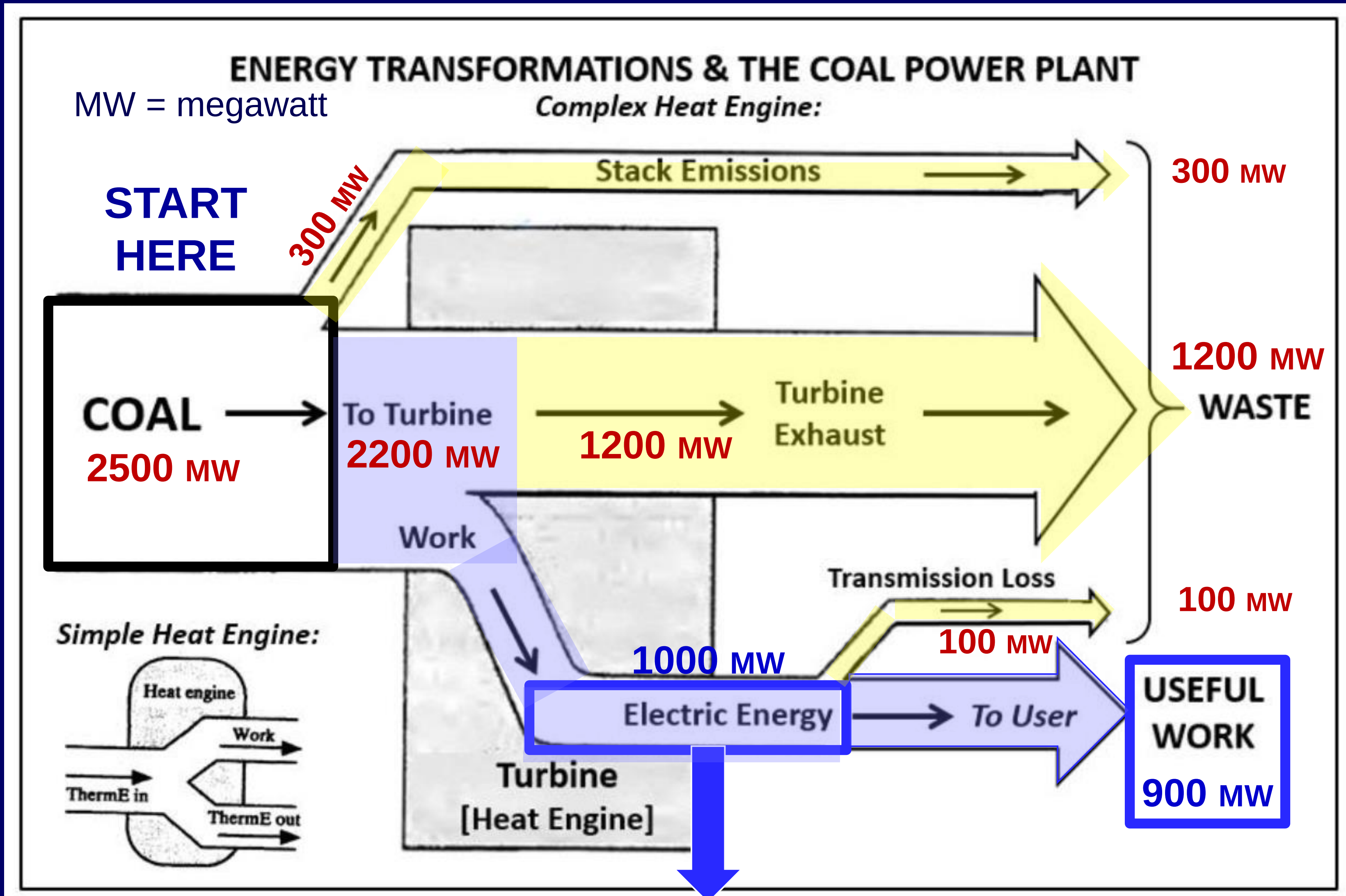
Now let's switch to
ELECTRICITY GENERATION
BY DIFFERENT METHODS . . .

A COAL POWER PLANT:

Coal burned ➔ Boiler heats water ➔ Steam ➔Spins Turbine ➔ Electricity

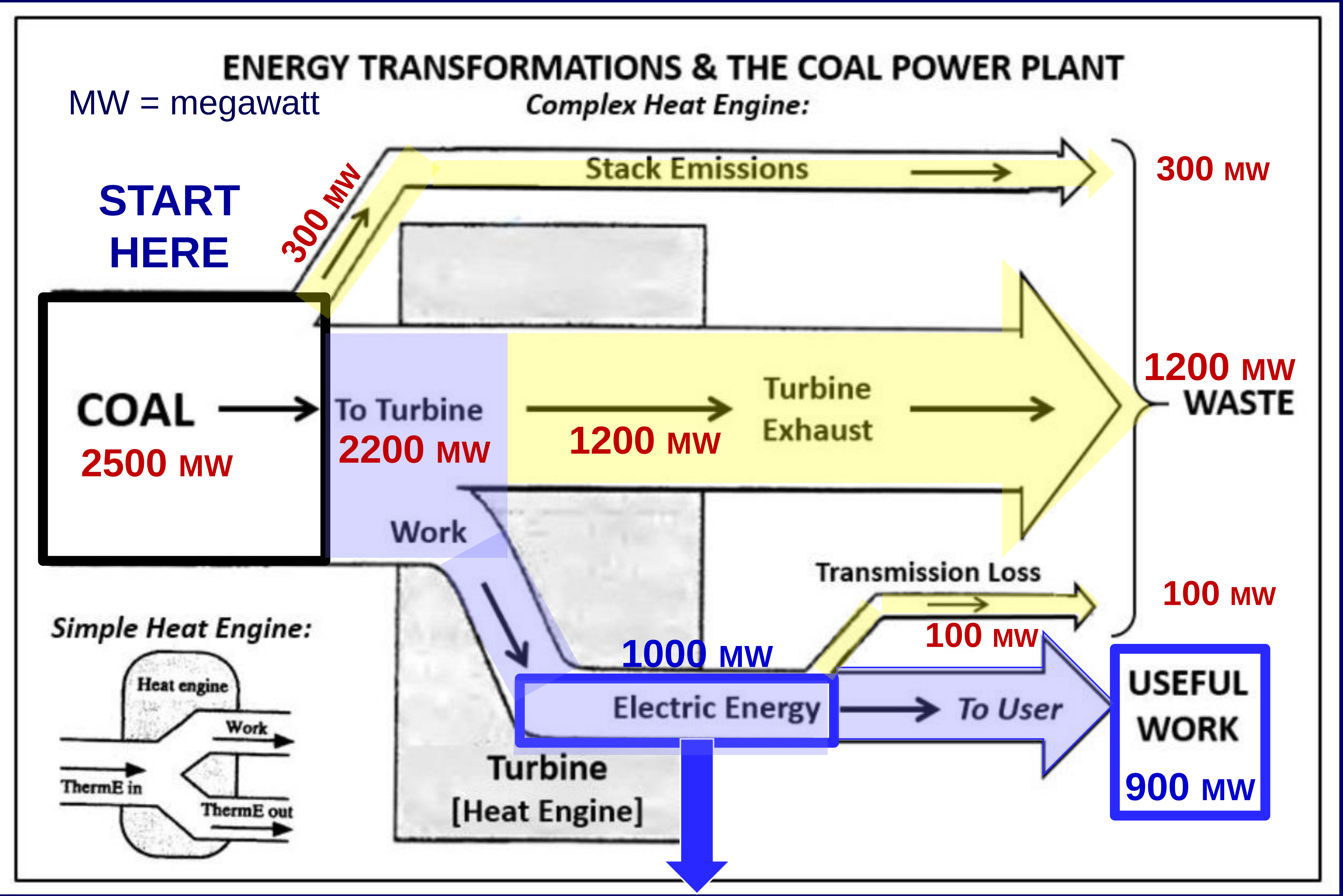


Source: Tennessee Valley Authority



Energy Efficiency of ELECTRICITY GENERATION = ______

(1000 MW electrical energy produced ÷ 2500 MW in coal fuel = 0.4 = 40%)



Energy Efficiency of ELECTRICITY GENERATION = 40%

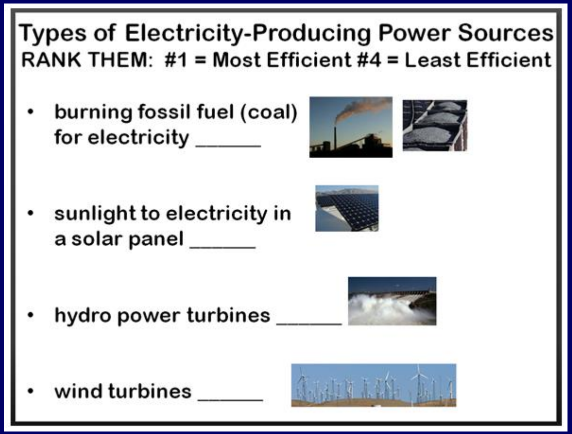
Energy Efficiency of PRODUCING USEFUL ELECTRICITY = ___%:

(900 MW electrical energy produced ÷ 2500 MW in coal fuel = 0.36 = 36%)

TEAM COMPETITION !

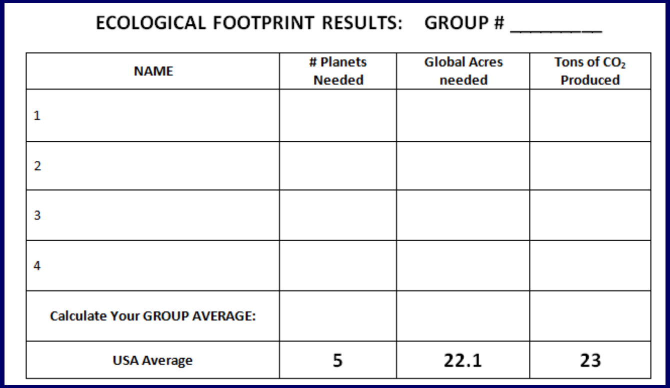
WITHIN EACH GROUP . . .

(1) DISCUSS & RANK the Energy Generating Sources & fill in your rankings on the short form:


Types of Electricity-Producing Power Sources
RANK THEM: #1 = Most Efficient #4 = Least Efficient

- burning fossil fuel (coal) for electricity ______
- sunlight to electricity in a solar panel ______
- hydro power turbines ______
- wind turbines ______

(2) Then enter YOUR GROUP'S FOOTPRINT RESULTS on the back of the form:


ECOLOGICAL FOOTPRINT RESULTS: GROUP # _________

NAME	# Planets Needed	Global Acres needed	Tons of CO_2 Produced
1			
2			
3			
4			
Calculate Your GROUP AVERAGE:			
USA Average	5	22.1	23

We'll re-visit (1) and (2) after TEST #2 on Wednesday

Rank the Efficiency of Each Type of Electricity-Producing Power Source:

Rank from 1 to 4 Rank #1 = Most Efficient

- **burning fossil fuel (coal) for electricity ______**

Coal-fired electric power plant

- **sunlight to electricity in a solar panel ______**

Photovoltaic (PV) panel

- **hydro power turbines ______**

Hydroelectric plant

- **wind turbines ______**

Wind farm

☺

NEXT:
TRANSPORTATION
&
ENERGY
EFFICIENCY

PART E – ENERGY TRANSFORMATIONS & ENERGY EFFICIENCY

Applying The Laws of Thermodynamics & The Laws of Motion to TRANSPORTATION

Here I am with my HUMMER!

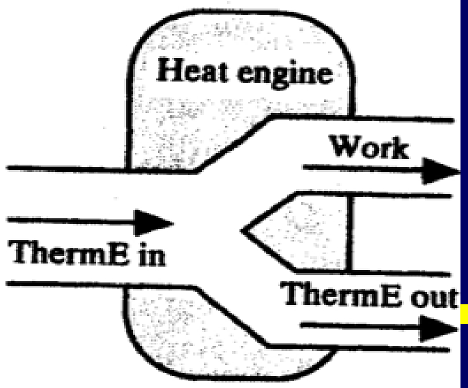
vs.

Here I am with my LEAF!

Efficiency = work done / energy used

ENERGY TRANSFORMATIONS & NEWTONS LAWS OF MOTION

An Energy Flow Diagram for a Heat Engine



Car's Exhaust

review

1st Law of Motion
(Law of Inertia)

A moving object will continue moving in a straight line at a constant speed . . .

. . . and a stationary object will remain at rest . . . unless acted on by an unbalanced force.

p 43

Newton's Laws in everyday life:

1st LAW =

The LAW of INERTIA!

☺

2nd Law of Motion
(Newton's Law of Motion)

The acceleration (a) produced on a body by a force (F)

is proportional to:
the magnitude of the force (F)

and inversely proportional to:
the mass (m) of the object.

$a = F / m$ or $F = ma$

p 43

3rd Law of Motion
(Law of Force Pairs)

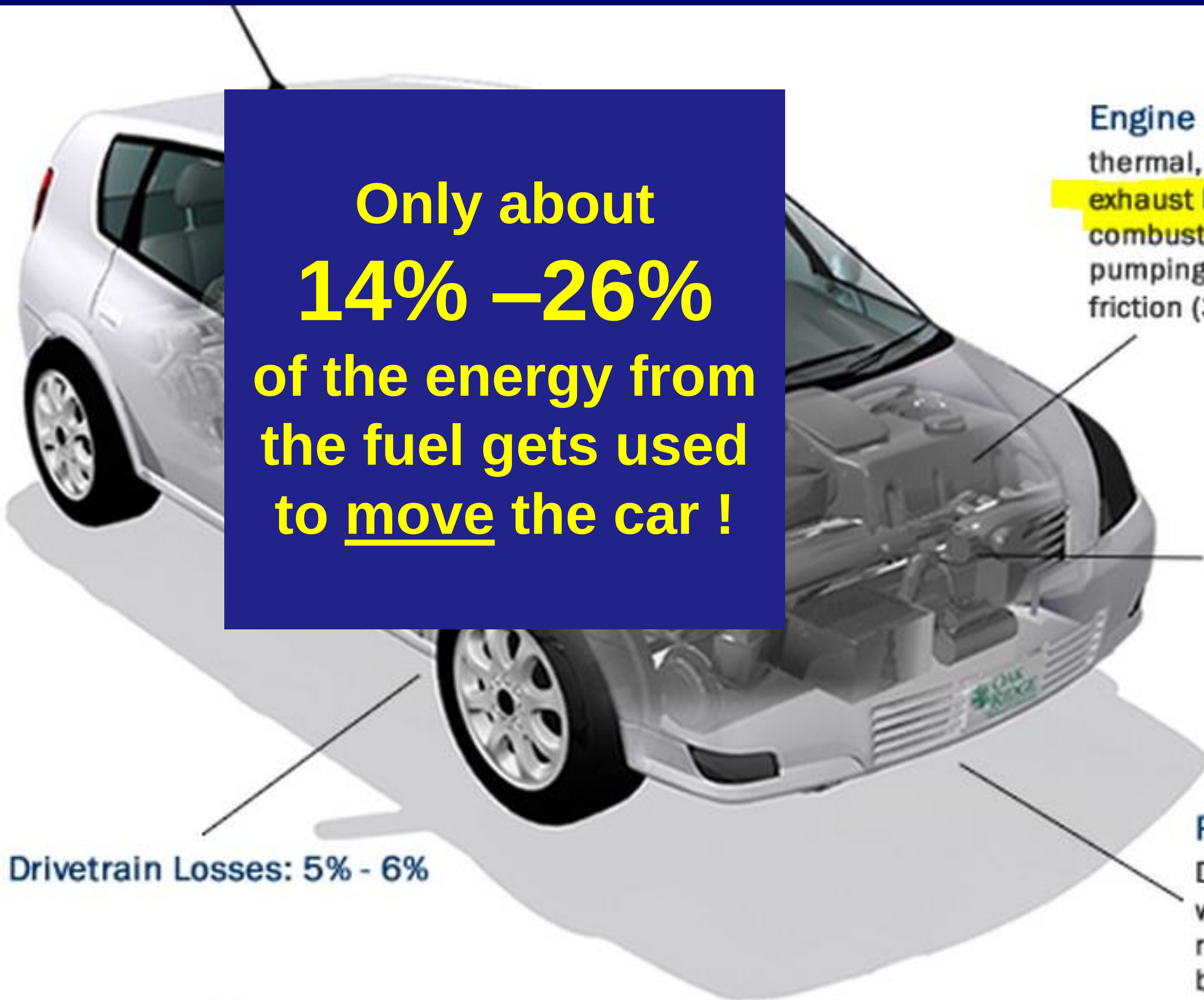
For every action there is an equal and opposite reaction.

3rd Law = "Law of Force Pairs"

- **Forces always occur in pairs**; an **action** and a **reaction**. To every action force there is an equal and opposite reaction force;

- whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first body.

Fuel Economy: Where the Energy Goes

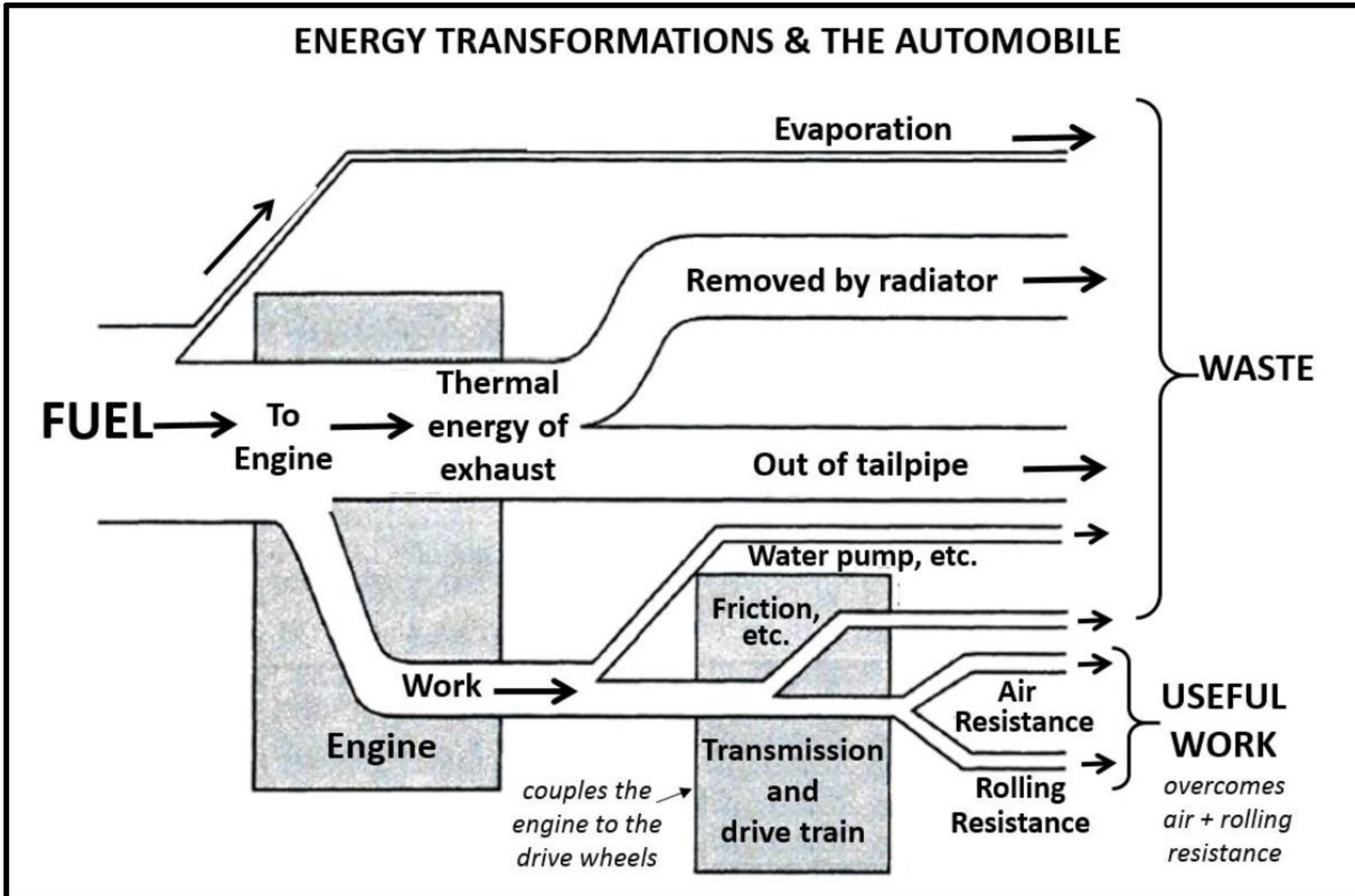


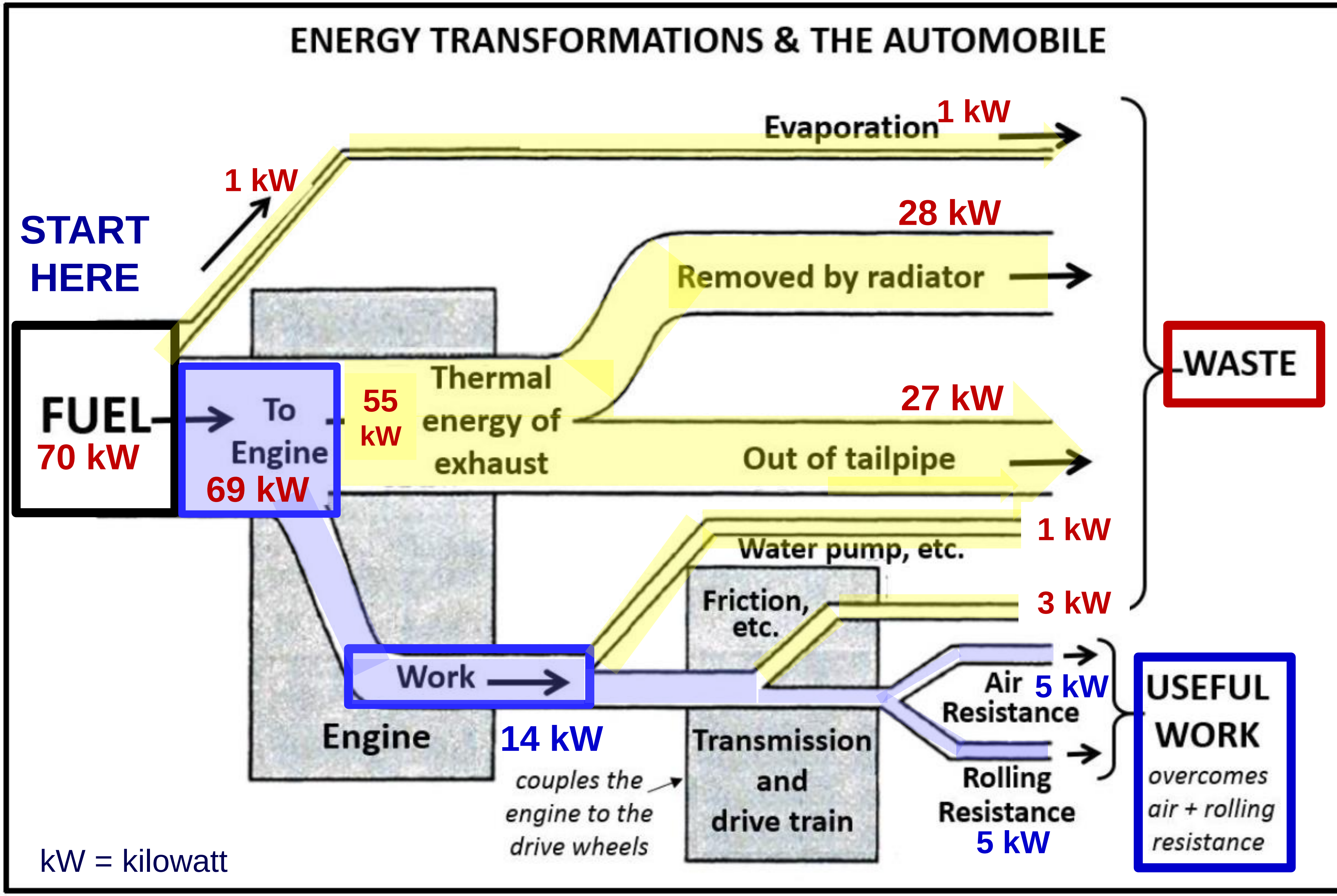
Only about

14% –26%

of the energy from the fuel gets used to <u>move</u> the car !

http://www.fueleconomy.gov/feg/atv.shtml


ENERGY TRANSFORMATIONS & THE AUTOMOBILE
Evaporation
Removed by radiator
FUEL
To Engine
Thermal energy of exhaust
Out of tailpipe
WASTE
Water pump, etc.
Friction, etc.
Work
Air Resistance
USEFUL WORK
overcomes air + rolling resistance
Engine
Transmission and drive train
Rolling Resistance
couples the engine to the drive wheels

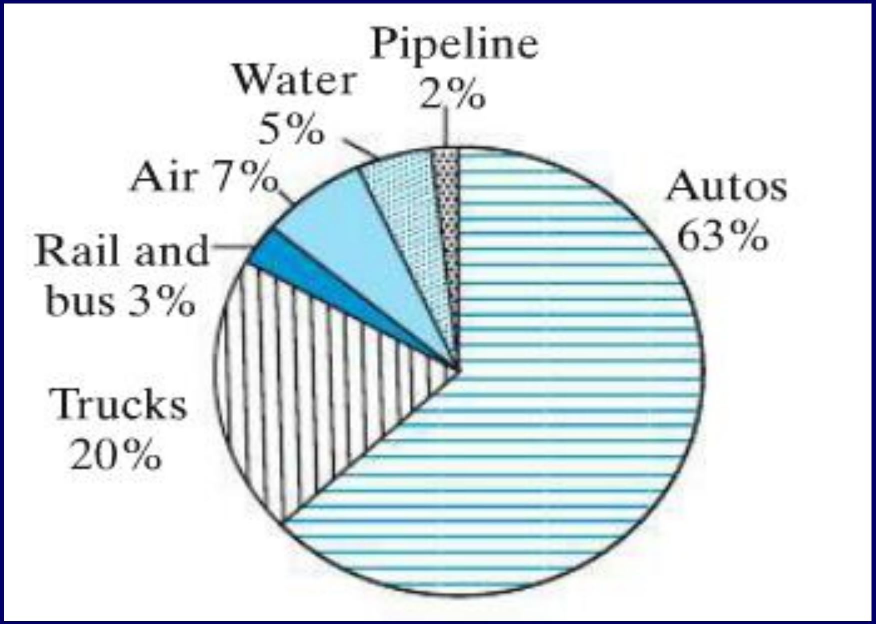

ENERGY TRANSFORMATIONS & THE AUTOMOBILE
START HERE
FUEL
70 kW
1 kW
Evaporation
1 kW
To Engine
69 kW
55 kW
Thermal energy of exhaust
28 kW
Removed by radiator
27 kW
Out of tailpipe
WASTE
1 kW
Water pump, etc.
Friction, etc.
3 kW
Work
Engine
14 kW
couples the engine to the drive wheels
Transmission and drive train
Air Resistance
5 kW
Rolling Resistance
5 kW
USEFUL WORK
overcomes air + rolling resistance
kW = kilowatt

Q 3. What % of the energy from the fuel going into the engine actually does work running the engine?

_______ = Engine's Energy Efficiency

Q 4. What is the % of all the energy in the fuel eventually does "work" that moves the car (by overcoming air resistance and rolling resistance)?

_________ = Overall Energy Efficiency of the Automobile (not just the Engine)



Freight-moving efficiencies of three transportation modes

	kg-km per MJ	tonne-km per liter
Rail (freight train)	2900	100
Truck (heavy)	720	25
Air (freight)	145	5

Q 5. Why do you think trains are so <u>much more</u> efficient for moving freight?

Q 6. Why do you think air freight is the <u>least</u> efficient mode of moving freight?

Table 7.4

U.S. passenger-moving efficiencies of several human transportation modes

	passenger-km per liter	passenger-mi per gal	passenger-km per MJ
Human on bicycle	642*	1530*	18.0
Human walking	178*	425*	5.0
Intercity rail	60	144	1.7
Carpool auto (occupancy = 4)	36	88	1.0
Urban bus	33	80	0.9
Commercial airline	21	50	0.6
Commuting auto (occupancy = 1.15)	11	25	0.3

*For walking and bicycling, the table uses the "gasoline equivalent" of the required number of food calories.

Q 7. Why do you think bicycling is almost 4 times more efficient than simply walking?

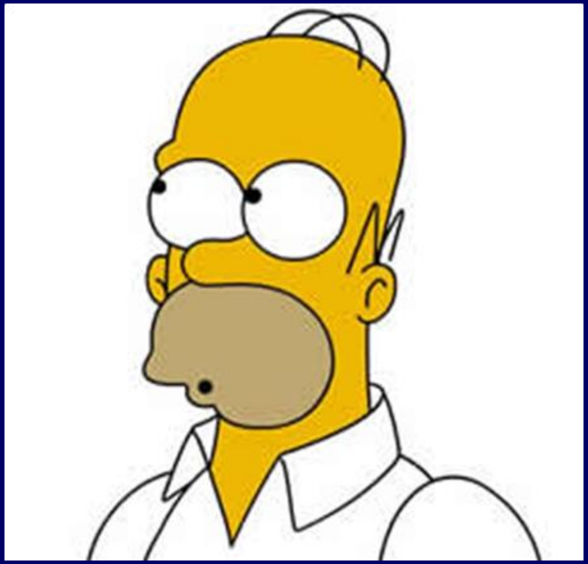
On back page:

Q 8. Suggest as many ways as your group can think of to promote transportation energy efficiency

OK
GET TO WORK ON
Page 2-4 of G-2

How about a few practice questions for

TEST #2, Homer?



Clicker Q5 -The **"Goldilocks Problem"** refers to the question: "Why is Venus too hot, Mars too cold, and Earth's temperature just right!" Your textbook explains that . . .

1. Earth's temperature is "just right" because Earth has a **greenhouse effect** and Venus and Mars do not.

2. Earth's temperature is "just right" due to: (a) **the inverse-square law** (the Earth being just the right distance from the Sun), (b) the **greenhouse effect,** and (c) **the Earth's reflectivity** – all working together

3. Earth's temperature is "just right" because the Earth radiates like a black body and is just the right distance from the Sun – Mars is too close & Venus too far.

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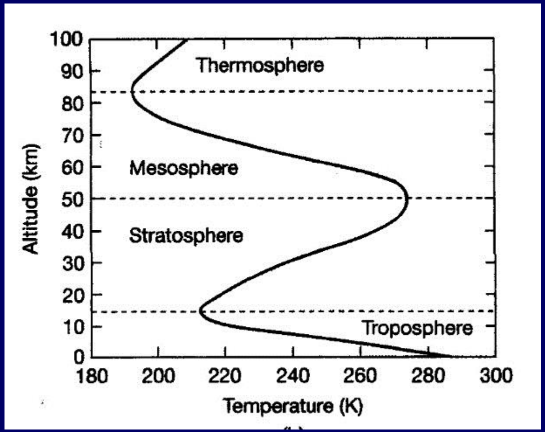
Clicker Q6 The atmospheric layer of **the troposphere** is important to global climate change because:



1. it is the layer that is heated up **primarily** by gases that can absorb high-energy **shortwave radiation** coming in directly from the Sun

2. it is the layer in which **temperature INCREASES with altitude** in the atmosphere

3. it is the layer with a high concentration of **ozone** that absorbs harmful **ultraviolet radiation**.

4. it is the layer in which most of the absorption by **greenhouse gases** occurs in the atmosphere

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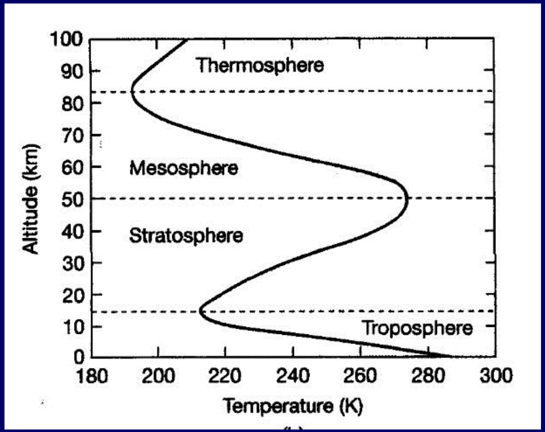

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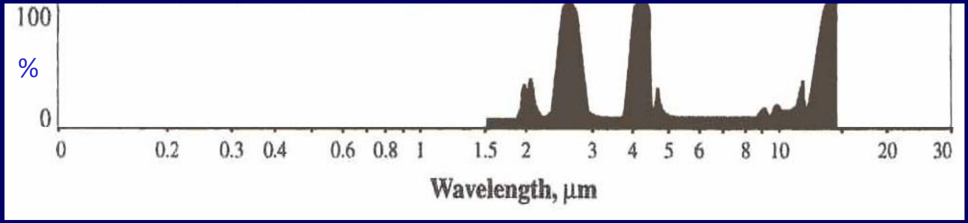
Clicker Q7 - Which of the following is a correct statement about this absorption curve:



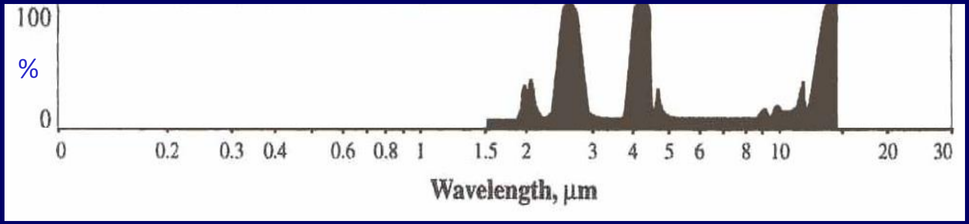
1. the curve represents absorption by a gas that can absorb both **visible light** and **infrared radiation**

2. **t**he curve represent absorption by a gas that is likely to be a **Greenhouse Gas.**

3. **t**he curve represents absorption by a gas that protects the Earth from **ultraviolet (UV) radiation**

4. **t**he curve represents absorption by a gas that can absorb **ultraviolet, infrared,** & **visible** light wavelengths of radiation.

Clicker Q7 - Which of the following is a correct statement about this absorption curve:



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Study hard for

TEST #2

Homer!