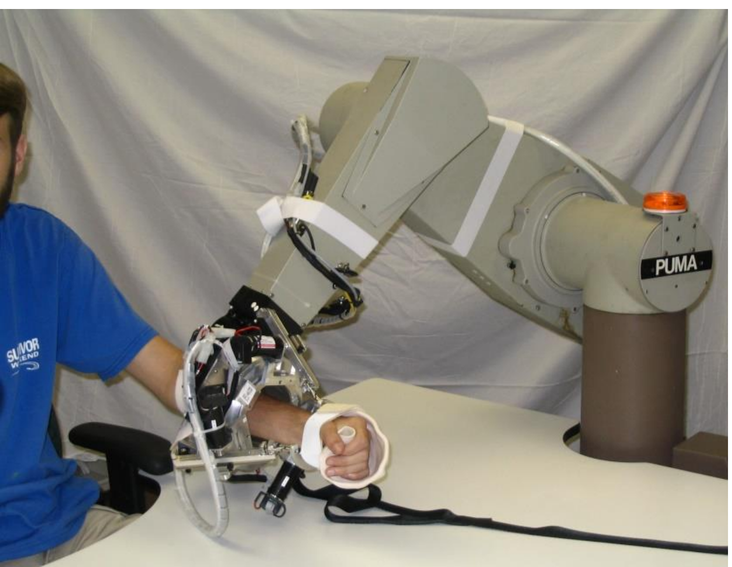
ENGI 128

INTRODUCTION TO ENGINEERING SYSTEMS

Lec 11:
Thermodynamics I –
Energy Storage and Conversion

“Understand Your Technical World”


4641


PUMA

PS06 Q&A

?

Having problem with your droid?

Thermodynamics

The Four Laws of Thermodynamics

0. If $Sys_1 \rightleftharpoons Sys_2$, and $Sys_2 \rightleftharpoons Sys_3$ then $Sys_1 \rightleftharpoons Sys_3$

1. Energy can neither be created nor destroyed, it can only change forms

2. $\text{Entropy}(Sys_1) + \text{Entropy}(Sys_2) \leq \text{Entropy}(Sys_1 \rightleftharpoons Sys_2)$

3. As $t \to 0$, $\text{Entropy}(Sys) \to \text{const}$

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Energy Storage

Energy Storage

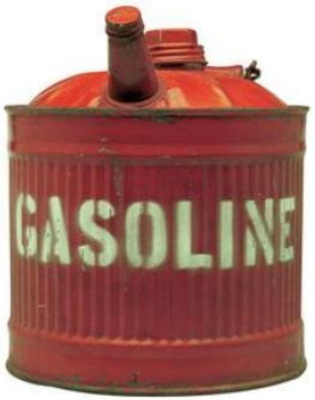
Potential energy can be stored

- The unit is Joules
- How much work can I do if I discharge, burn, or metabolize this thing?

Power is rate of energy use

- Units are Joules/sec

You can store energy in lots and lots of ways…



Types of Energy Storage Elements

Chemical Energy

- Bonds (chemical potential energy)

Mechanical Energy

- Springs/Gravity (potential energy)
- Moving mass (kinetic energy)

Electrical Energy

- Capacitors
- Inductors

Acoustic/Fluid Energy

- Moving air
- Compressing air

Thermal Energy

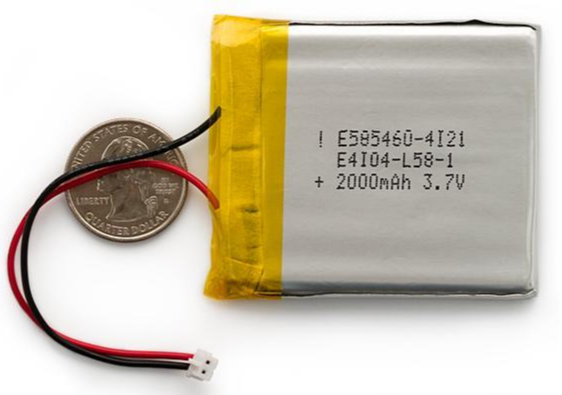
- Mass (all masses can store heat)

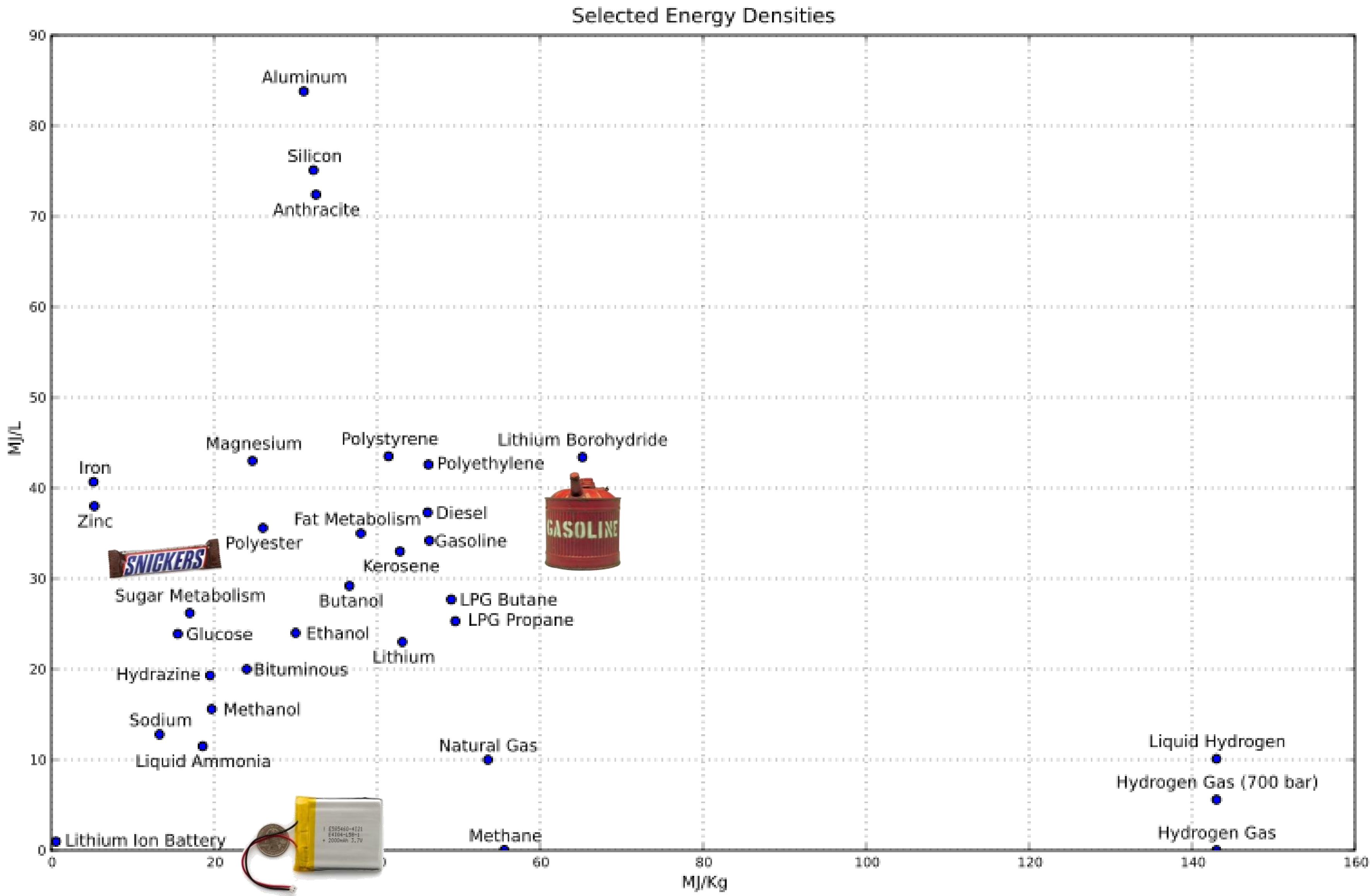
Energy Density

How much energy can I store in a given volume

- Units are joules/liter

There is a <u>lot</u> of variation…





Selected Energy Densities
MJ/L
MJ/Kg
0
10
20
30
40
50
60
70
80
90
0
20
60
80
100
120
140
160
Aluminum
Silicon
Anthracite
Magnesium
Polystyrene
Lithium Borohydride
Polyethylene
Iron
Zinc
Diesel
Fat Metabolism
Polyester
Gasoline
Kerosene
SNICKERS
GASOLINE
Sugar Metabolism
Butanol
LPG Butane
LPG Propane
Glucose
Ethanol
Lithium
Hydrazine
Bituminous
Methanol
Sodium
Liquid Ammonia
Natural Gas
Liquid Hydrogen
Hydrogen Gas (700 bar)
Lithium Ion Battery
Methane
Hydrogen Gas

You are what you eat…

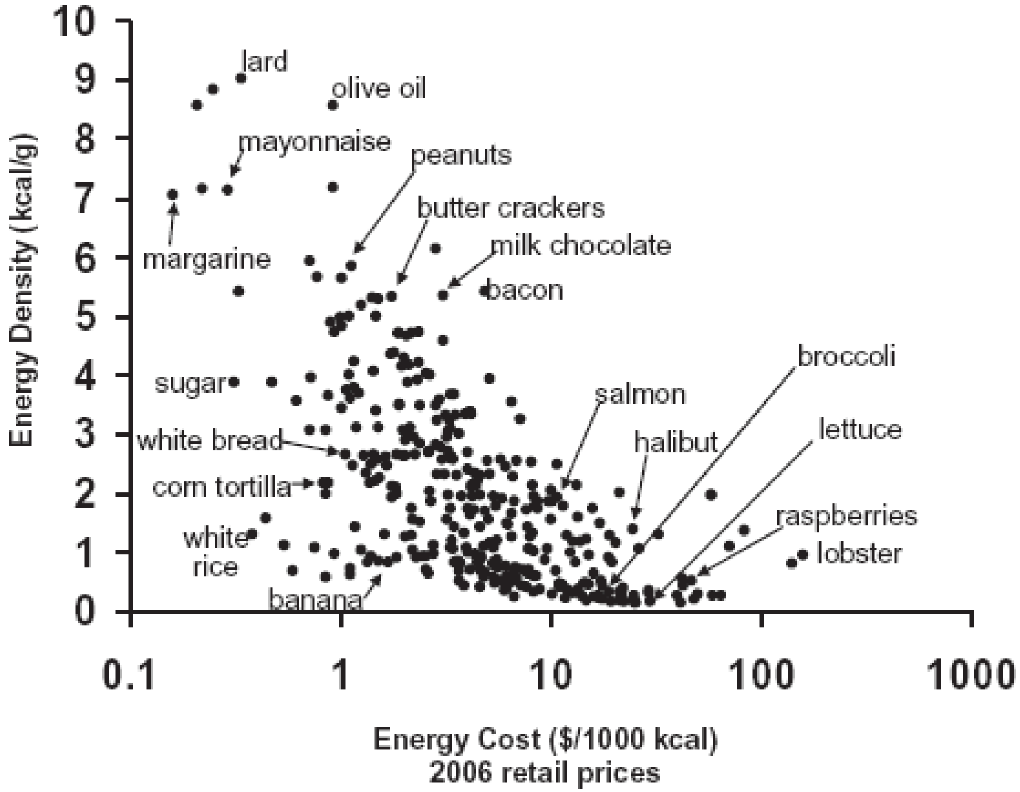


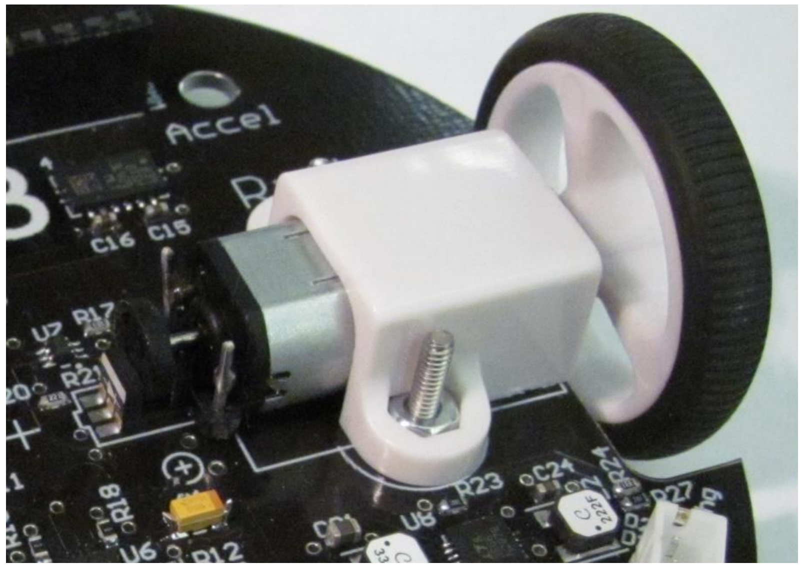
Figure 1 **Relationship between energy density of selected foods (kcal/g) and energy costs (US$/ 1,000 kcal).** Food prices from Seattle supermarkets, 2006. Note that the energy cost differential between added sugars and fats and fresh vegetables and fruit can be several thousand percent, as indicated by the logarithmic scale.

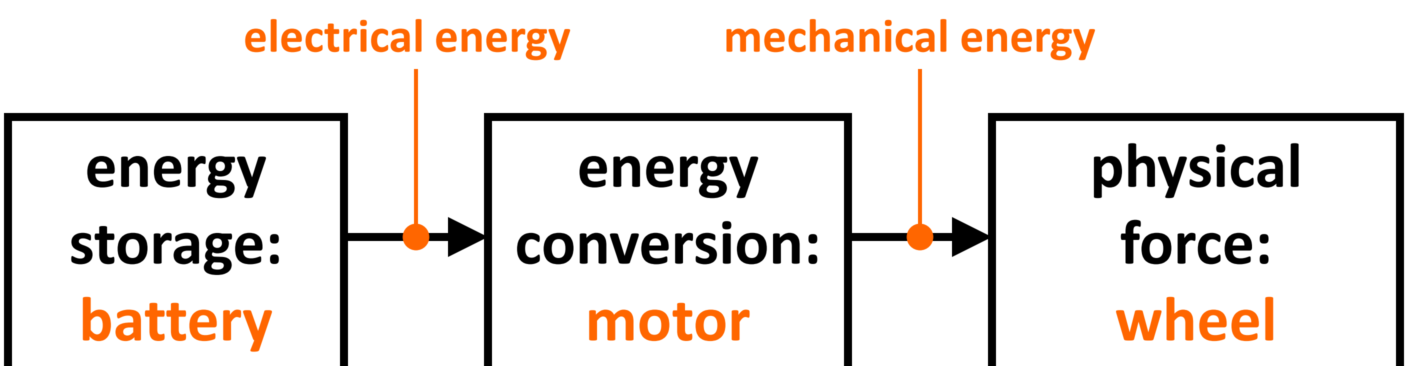
Energy Conversion

Electric Motor

Converts electrical energy into mechanical energy

Can also work in reverse, and convert mechanical energy into electrical energy

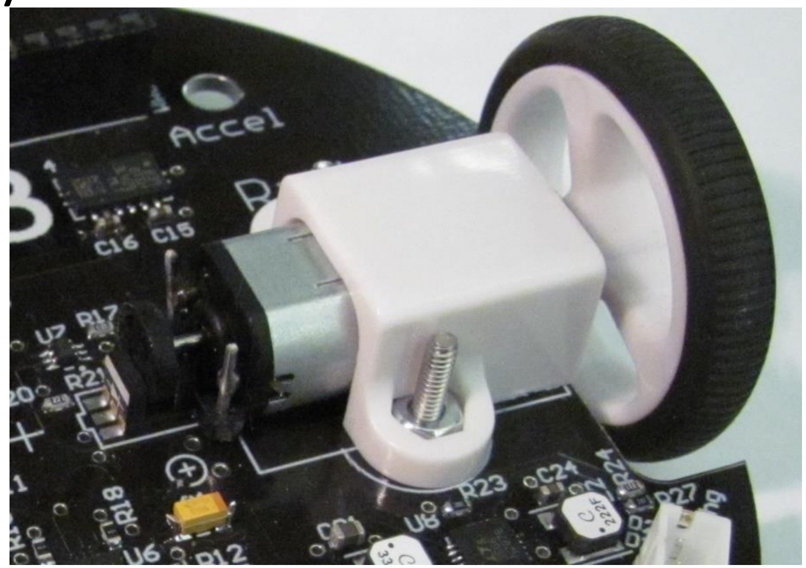


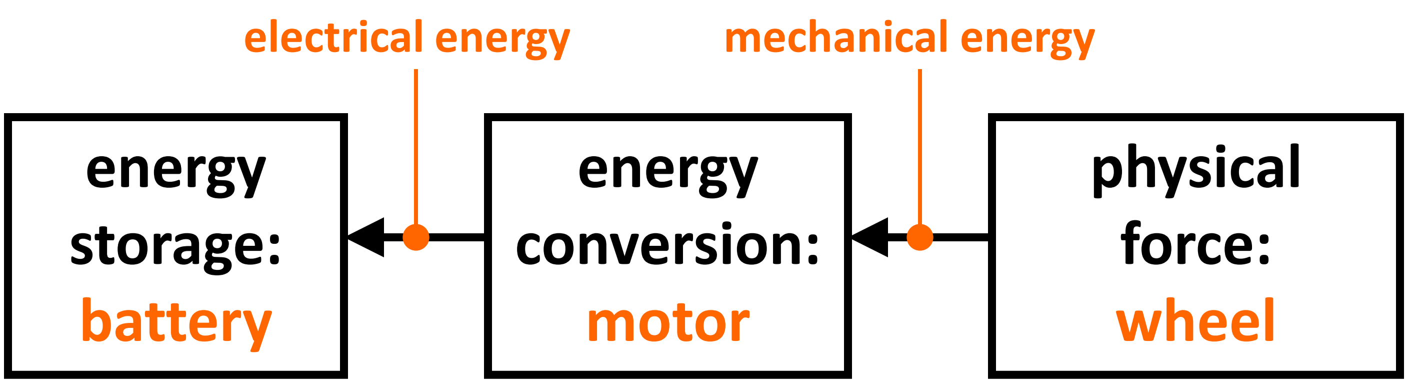


Electric Generator

Converts mechanical energy into electrical energy

Can also work in reverse, and convert electrical energy into mechanical energy





In General: Transducers

Convert energy from one form to another

There are lots of them on your robot:

- LEDs
- Light Sensors
- IR receivers
- Speakers
- Motors

Some energy conversions are bidirectional

- Are they all bidirectional?
- How else can you convert energy to produce motion?

Thermal Energy

Hot things have more thermal energy than cold things (duh…)

Thermal energy is called *heat*

In fact, this is how thermodynamics gat started, trying to understand how to get the heat out of hot things and convert it to mechanical energy

But why start with hot things?

Hot Stuff

Because its easy to get things hot!

More Heat = More energy

You want your system to be as hot as possible*

- Because things that are hot have more energy (duh…)

Ok, say you have some hot stuff

- How can you get *mechanical* energy out of it?

Use the hot stuff to heat something else:

How about we use heat to boil water,

then use the boiled water (steam) to push a *piston*,

then use the piston to push a *connecting rod*

then use the connecting rod to turn a *wheel*,

then use the wheel to drive a *train*!

Voilà: Thermal energy → Mechanical energy

(Obvious, right?)

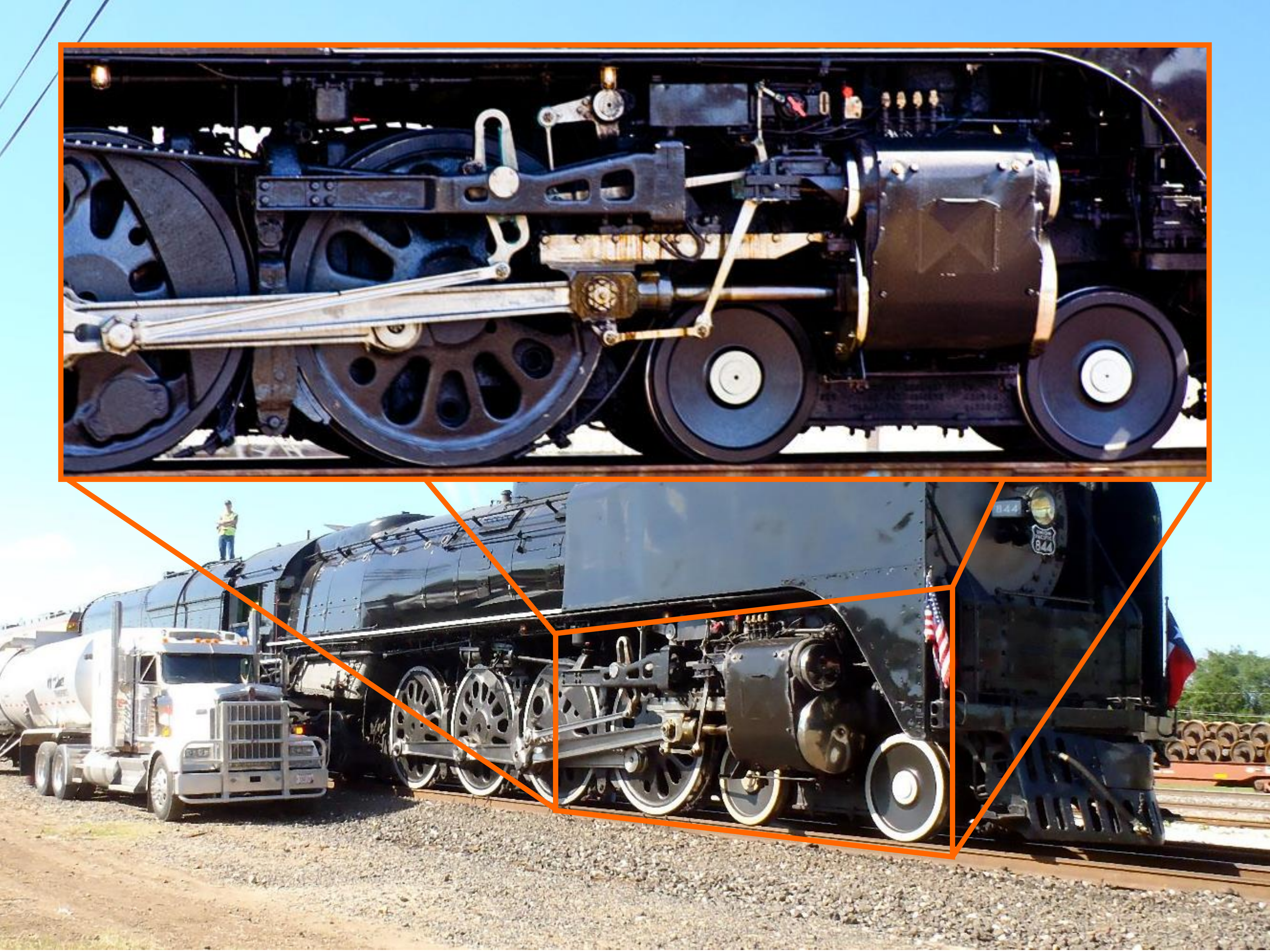
Generating Mechanical Energy

Union Pacific 844


Union Pacific 844 - Lionell Collectors Club Express - July 26, 2010 ©Skip Weythman

[UP844 at Speed]


844
UNION
PACIFIC
844
UNION PACIFIC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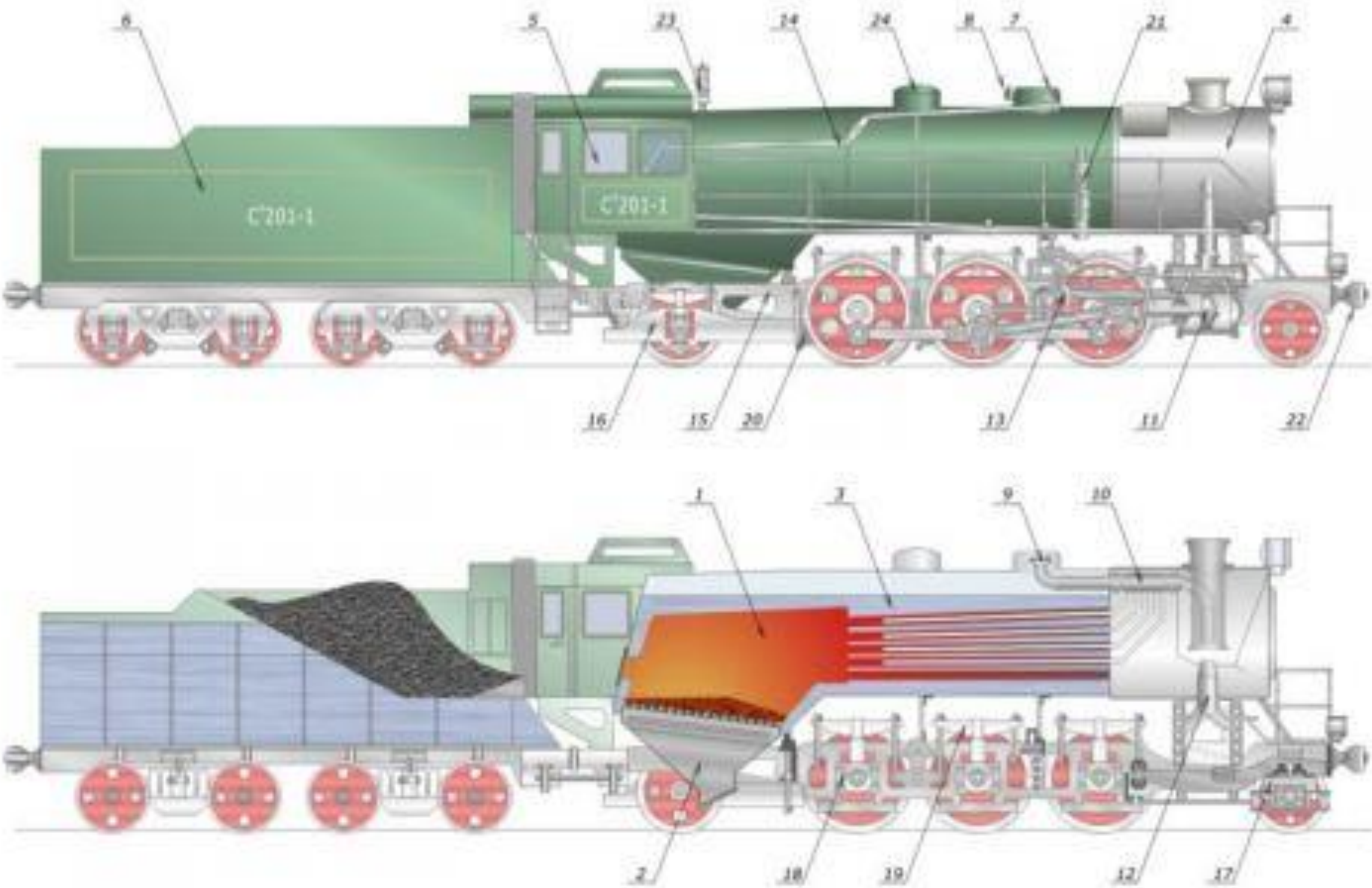
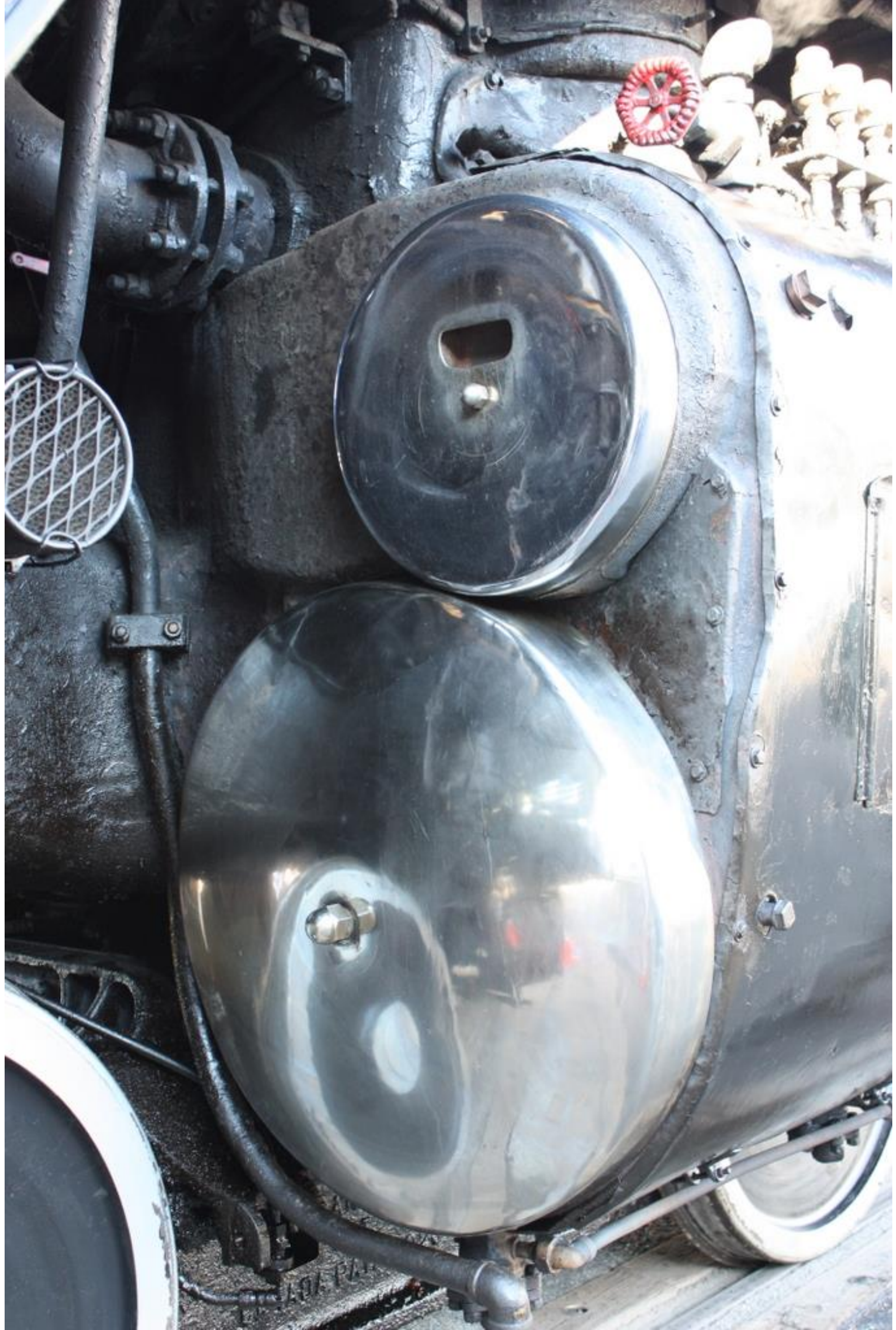
Steam Locomotive Internals





[UP844 tractive force math]

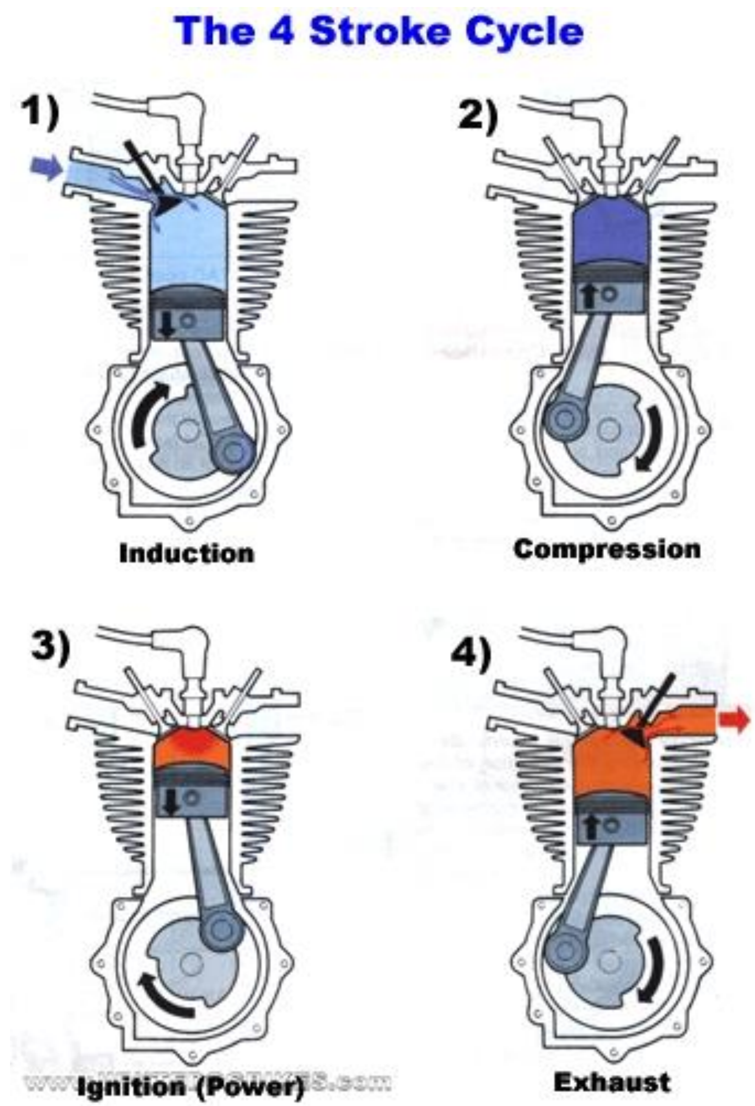
Gasoline Engine

Gasoline Engine

Converts chemical energy to mechanical energy through *heat*

Four Steps (Strokes):

1. Intake:
   - Suck air/fuel in
2. Compression
   - Compress the air/fuel mixture
3. Combustion
   - Burn the Fuel →Heat the air →Expand the air→Move the piston
4. Exhaust
   - Push hot air/burnt fuel out

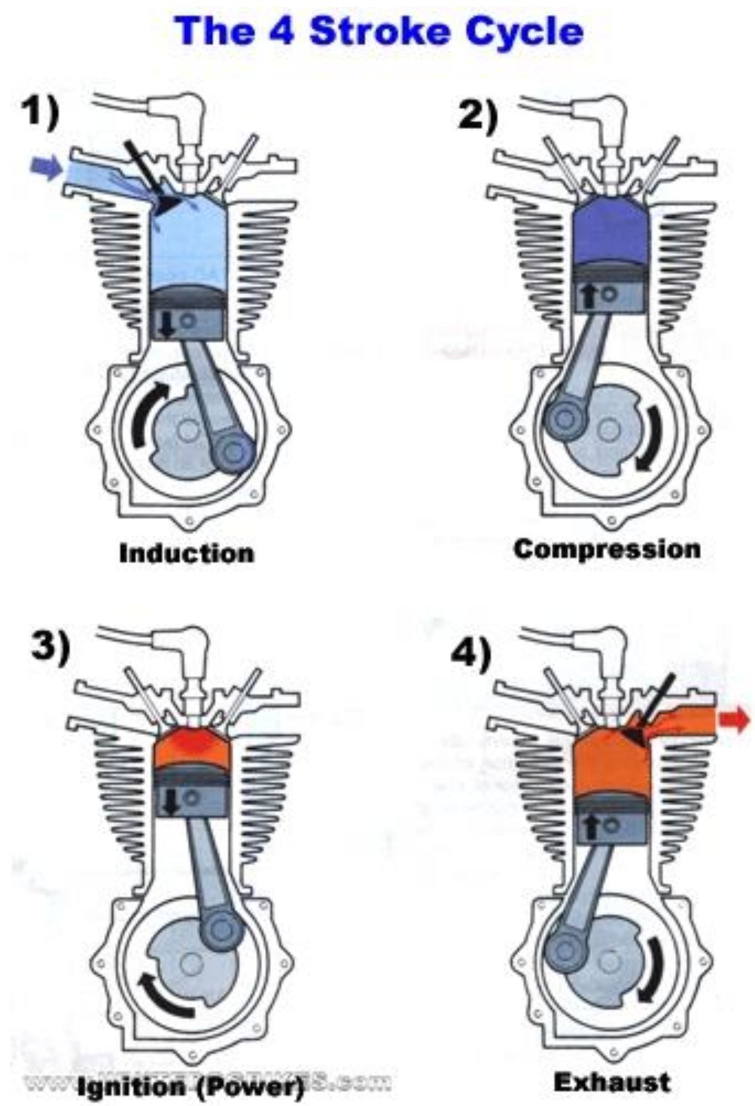


Gasoline Engine

Converts chemical energy to mechanical energy through *heat*

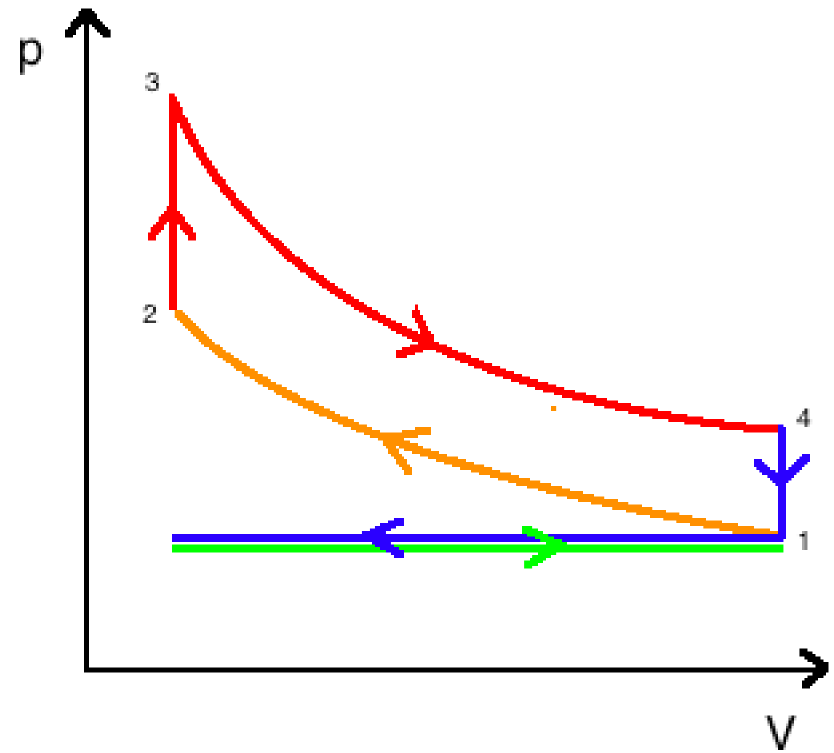
Four Steps (Strokes):

1. Intake:
    - Suck air/fuel in
2. Compression
    - Compress the air/fuel mixture
    - **Decrease V/increase P**
3. Combustion
    - Burn the Fuel →Heat the air →Expand the air→Move the Piston
    - **Increase T/Increase P**
    - **(Expansion) Increase V/Decrease P**
4. Exhaust
    - Push hot air/burnt fuel out
    - **Decrease T/Decrease P**



Thermodynamics: The Otto Cycle

A common way to analyze thermodynamic systems is with a graph of pressure vs. volume: a *P-V Diagram:*



The Otto Cycle

[otto cycle model demo]

Next Week:

Thermodynamics and Vehicles

(Car Talk)

Bring your car-related questions!