Thermodynamics
1 – Transforming Energy

Energy: *CANNOT* (*forget Einstein for now* ☺) be created or destroyed but *CAN* be converted from one form to another.

$$\Delta E = \Delta E_K + \Delta E_P + \Delta E_H \dots = W$$

We often convert one from to another in order to utilize the energy.

- Chemical **Energy** of gasoline is converted to Thermal **Energy** in a car, which in turn is converted to Mechanical **Energy** to move the car.
- Potential **Energy** of water in a dam is converted to Mechanical **Energy** as it falls, which is then converted to Electrical **Energy** by a turbine.

During these processes we often say Energy is lost… but this can't be true. ***Energy can neither be created or destroyed***.

In fact energy is not lost, but instead converted to an undesired form. (Often Thermal **Energy**)

We use the term efficency to describe the effectiveness of an energy conversion.

$$e = \frac{\text{what you get out}}{\text{what you put in}} \times 100\%$$

(what you get out → W_{out}/P_{out}; what you put in → W_{in}/P_{in})

Example:
A 75 W incandescent light bulb produces 2.8 W of visible light. **Calculate of the efficiency of the bulb**.

$$e = \frac{P_{out}}{P_{in}} \times 100\% = \frac{2.8W}{75W} \times 100\% = 3.7\%$$

A 15 W light CFB (Compact Fluorescent Bulb) produces the same visible light. **Calculate the efficiency of the bulb**.

$$e = \frac{P_{out}}{P_{in}} \times 100\% = \frac{2.8W}{15W} \times 100\% = 19\%$$

How many times more efficient is a CFB than an incandescent light bulb?

$$\frac{18.7\%}{3.7\%} \sim 5x$$

Example:
Cranes are often used to increase an objects potential energy. Crane 1 used 25 kJ of energy to lift a 200 kg box to the top of a building. Crane 2 uses 10 kJ to lift a 120 kg box to the same roof. Which crane is more efficient?

Crane 1 → $e = \frac{mgh}{25{,}000J} \times 100\% = 7.84h\,\%$

Crane 2 → $e = \frac{m_2gh}{10{,}000J} \times 100\% = 11.8h\,\%$

Energy in the Body: Bio again…. ☹

In the cells of our body __glucose__ is converted into energy.

cellular respiration → $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$

The energy is then stored in a molecule called adenosine triphosphate (__ATP__). This energy is released to do the work of life!

__1g__ of glucose releases ~ __17 kJ__ of Energy

Eating Calories		
Food	**E content in Cal**	**E content in kJ**
Fried Egg	100	418
Apple	125	523
Beer (can)	150	628
Latte	260	1088
Slice of Pizza	300	1255
Apple Pie Slice	400	1674

Burning Calories (70 kg person)	
Activity	**Rate at which we consume E (W)**
Typing	125
Walking @ 5 km/h	380
Cycling @ 15 km/h	480
Swimming (Fast Front Crawl)	800
Running @ 15 km/hr	1150

1 Cal = __4.184__ kJ

Example:
A 12 oz can of beer contains 150 cal of beer. If all that energy is stored in the simple carbohydrate Glucose how many g's of sugar are in the beer?

$$150 \text{ cal} \times \frac{4.184 \text{ kJ}}{1 \text{ cal}} \times \frac{1 \text{ g}}{17 \text{ kJ}} = 37 \text{ g sugar}$$

Example:
A cyclist racing in the Gran Fondo pedals for 5.0 hrs (→ 180,000 s) at a speed of 15 km/hr. How much metabolic energy (in kJ's) is required? How much energy goes to forward propulsion is the process is only 25% efficient.

$$\Delta E = W = \Delta P \cdot t = (480 \text{ J/s})(180{,}000 \text{ s})$$

$\Delta E =$ ~~3.24×10^7~~ kJ 8.64×10^6 kJ

$E_{out} =$ ~~3.24×10^7 kJ~~ $\times 0.25$

$E_{out} =$ ~~8.1×10^6 kJ~~ 2.16×10^3 kJ

Example:
How many flights of stairs could you climb on the energy contained in a 12 oz can of beer? Assume that your mass is 70 kg and that each flight of stairs has a vertical displacement of 3.0 m. Again assume 25% efficiency.

$$E_{in} = 628 \text{ kJ} \times 0.25 = 157 \text{ kJ}$$

$$E_{in} = mgh$$

$$h = \frac{E_{in}}{mg} = \frac{157{,}000 \text{ J}}{(70 \text{ kg})(9.8 \text{ m/s}^2)} = 229 \text{ m}$$

$$\text{flights} = \frac{229 \text{ m}}{3.0 \text{ m}} = 76.3 \text{ flights}$$

76 flights