Micro-Scale Energy & Machines

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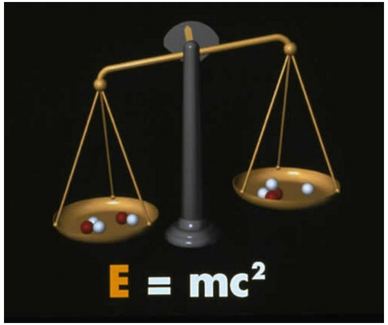
Mass Energy

- A hydrogen atom has less mass than the combined masses of the proton & electron that make it up
- Two objects of the same parts will not, in general, have the same mass
- Instead the mass depends on
  - How those parts are arranged
  - How those parts move within the bigger object
- $E = mc^2$ (where $c = 3 \times 10^8$ m/s) ⟶ energy equals mass times the speed of light squared)
- OR $m = E/c^2$ (how Einstein originally wrote it)
- m $\neq$ amount of matter

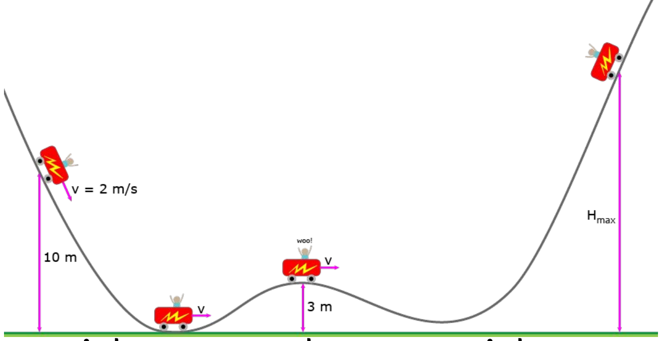


Mass is…

1. An indicator of how hard an object is to accelerate
2. How much gravitational force that object will feel

- Anytime you weigh something on a scale, you're actually measuring the total energy of that object ⟶ MASS IS ENERGY

Potential & Kinetic Energy



- Potential energy can be negative
- If left to their own devices, all objects move from high potential energy to low potential energy
- The electron also has kinetic energy (always positive) as it orbits the proton ⟶ m_{extra} = KE+PE / $c^2 < 0$
- All atoms have less mass than the combined masses of the protons, neutrons, & electrons that make them up ⟶ (same is true for molecules)
  - The masses of protons & neutrons are made of quarks
  - Mass from quark potential energy
  - Electrons & quarks aren't made of smaller things
  - Even this mass is a reflection of various kinds of potential energies

In conclusion...

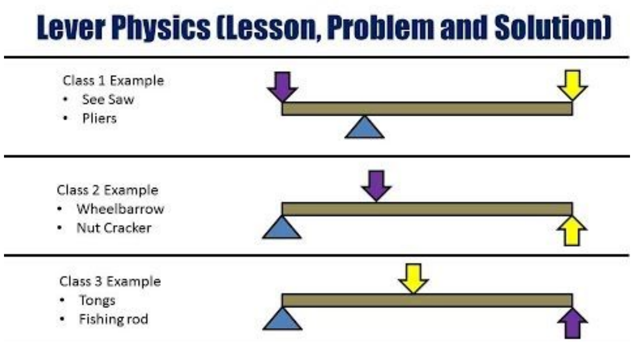
- Mass is a property - a property that all energy exhibits
- $m \neq$ amount of stuff
- $m =$ amount of energy

Machines

- Machine = a device used to multiply forces or simply to change the direction of forces
- The concept that underlies every machine is the conservation of energy
    - Energy cannot be created nor destroyed (it can be transformed from one form into another, but the total amount of energy never changes) ⟶ work input = work output
    - Since work equals force times distance, we can say : $(\text{force x distance})_{input} = (\text{force x distance})_{output}$
- Mechanical advantage = the ratio of output force to input force for a machine

Lever

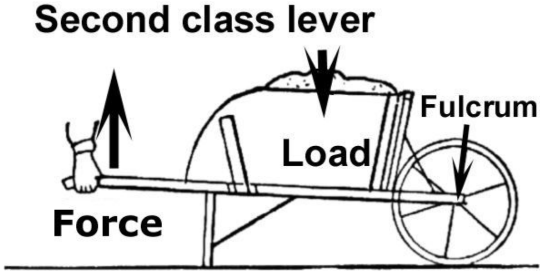
- Includes a stiff structure that rotates around a fixed point called a fulcrum
- At the same time we do work on one end of the lever, the other end does work on the load & we can see that the direction of force is changed
  - If we push down, the load is lifted up
- If the heat from friction is small enough to neglect, the work input will be equal to the work output
- $MA_{lever} = L_{in}/L_{out}$



1st Class Lever

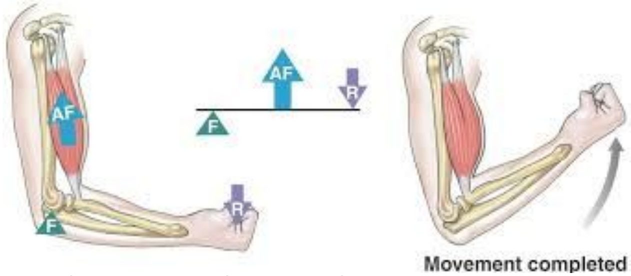
- A lever where the fulcrum is between the force and the load
    - When you push down on one end and you lift a load at the other
    - You can increase force at the expense of distance
    - Directions of input and output are opposite
        - Example: seesaw in a playground

2nd Class Lever



- A lever where the load is between the fulcrum and the input force
  - To lift a load, you lift the end of the lever
  - Force on the load is increased at the expense of distance
  - Since the input & output forces are on the same side of the fulcrum, the forces have the same direction
    - Example: placing one end of a long steel bar under an automobile frame and lifting on the free end to raise the automobile; wheelbarrow

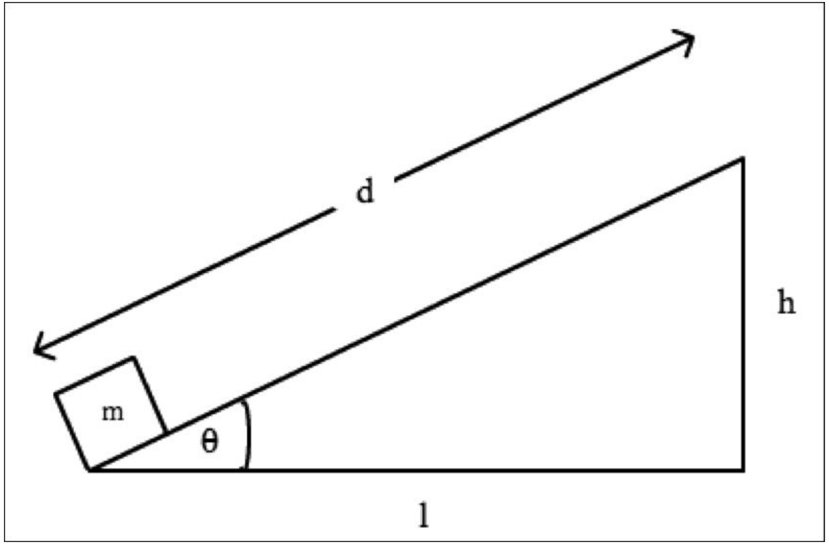
3rd Class Lever



- A lever where the fulcrum is at one end and the load is at the other
    - The input force is applied between them
    - Increases distance at the expense of force
    - The input and output forces are on the same side of the fulcrum and therefore they have the same direction
    - Example: Moving your bicep muscles where the fulcrum is your elbow and the load is in your hand

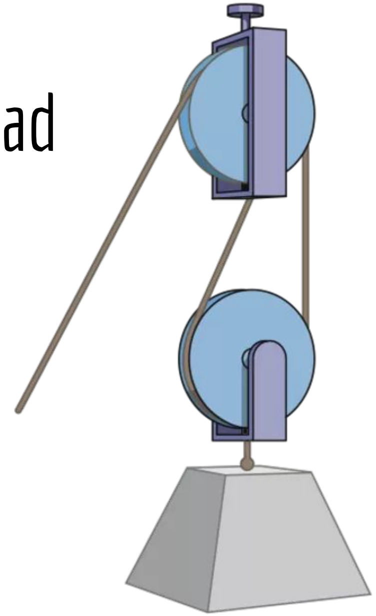
Ramp

- A slope or inclined plane for joining two different levels
- $MA_{ramp} = L/h$



Pulley

- Like levers & ramps, pulleys sacrifice displacement to achieve greater force
- MA is shown by how many ropes are supporting the load
- MA_{pulley} = # of pulley blocks



Efficiency

- Efficiency = in a machine, the ratio of useful energy output to total energy input, or the percentage of the work input that is converted to work output
    - (efficiency = output work/input work)