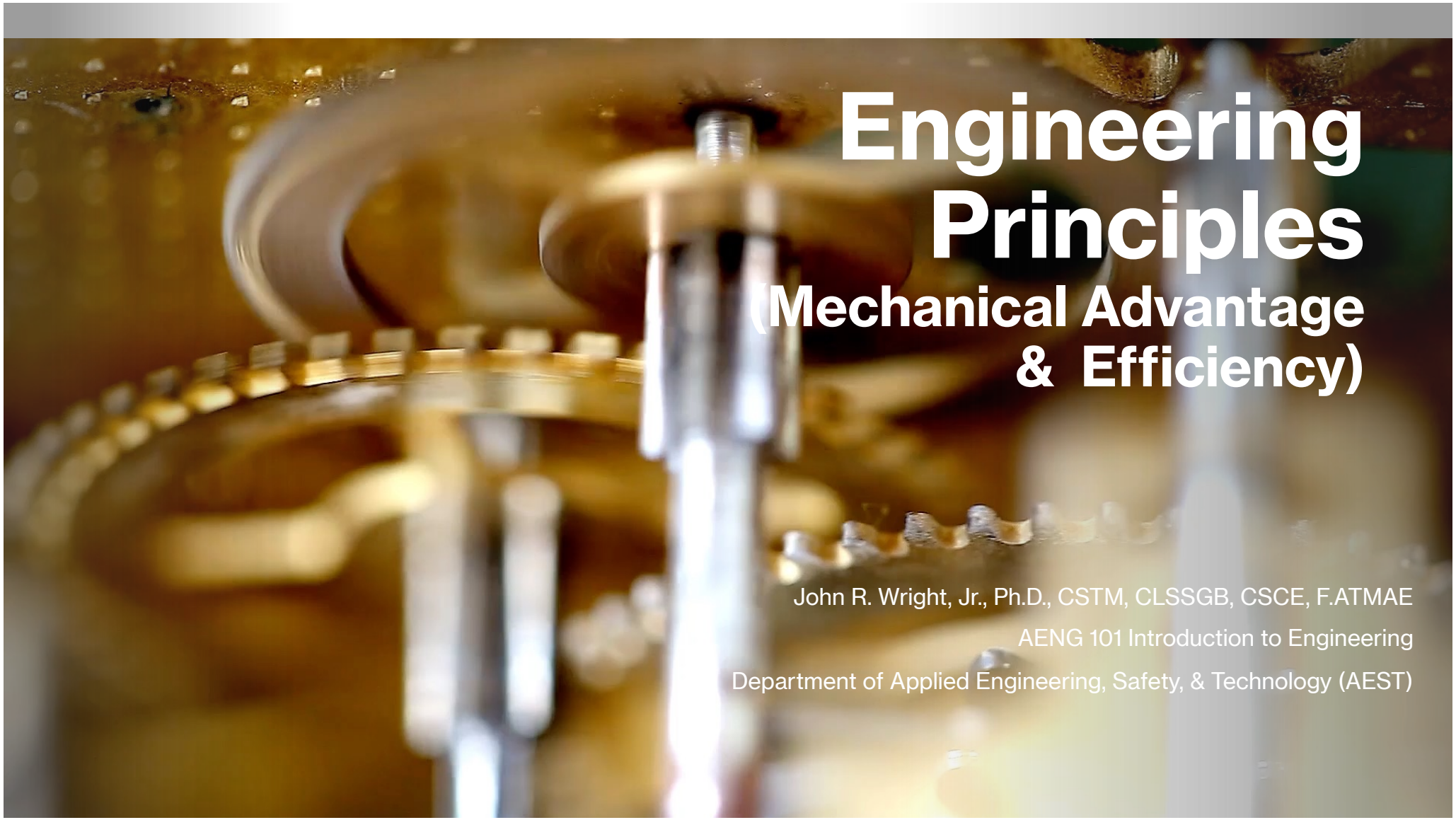


Engineering Principles
(Mechanical Advantage & Efficiency)

John R. Wright, Jr., Ph.D., CSTM, CLSSGB, CSCE, F.ATMAE

AENG 101 Introduction to Engineering

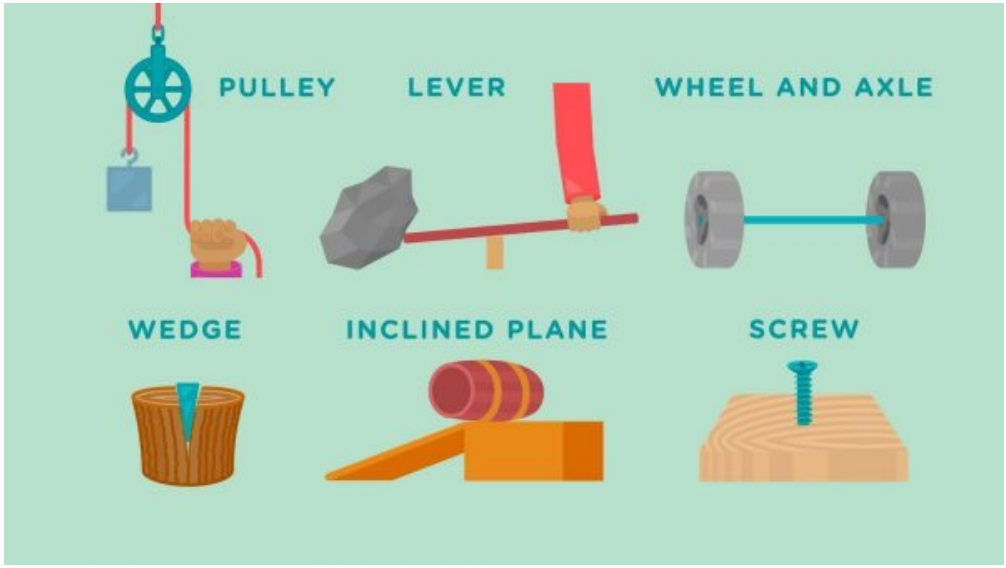
Department of Applied Engineering, Safety, & Technology (AEST)

Outline

- Simple Machines
- Friction
- Entropy
- Efficiency
- System Efficiency

Six Simple Machines

- Mechanical Advantage
  - Inclined Plane
  - Wedge
  - Pulley
  - Screw
  - Lever
  - Wheel and Axle
- IMA – Ideal Mechanical Advantage
  - Example: 3:1 IMA
- AMA – Actual Mechanical Advantage
  - Example: 2.79:1 AMA
- Distance may also be desired, but it is not typically used to determine the Mechanical Advantage.
- Increasing Mechanical Advantage comes at the price of adding distance (added movement)

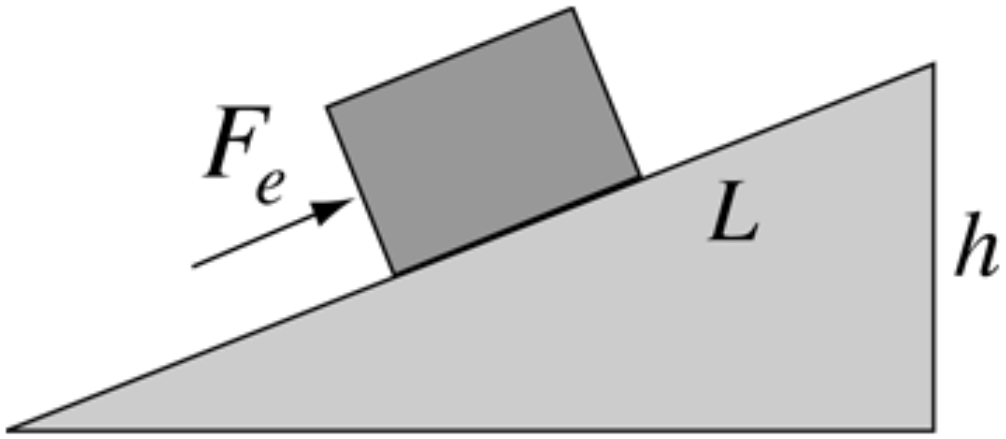


https://www.generationgenius.com/simple-machines-reading-material/

Simple Machine (Inclined Plane)

- IMA = Length (ramp travel) / Height (ramp height)

- Related Math (Trigonometry)
  - Soh Cah Toa
  - F_e = Effort Force

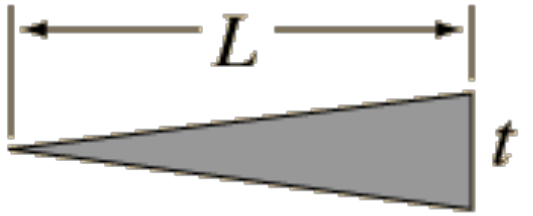


Incline $IMA = \frac{L}{h}$

http://hyperphysics.phy-astr.gsu.edu/hbase/Mechanics/incline.html

Simple Machines (Wedge)

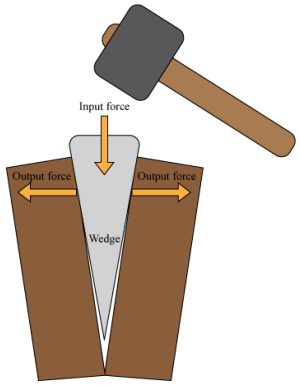
- Adaptation of the Inclined Plane
- IMA = L / t



Wedge $IMA = \frac{L}{t}$

L = depth of penetration

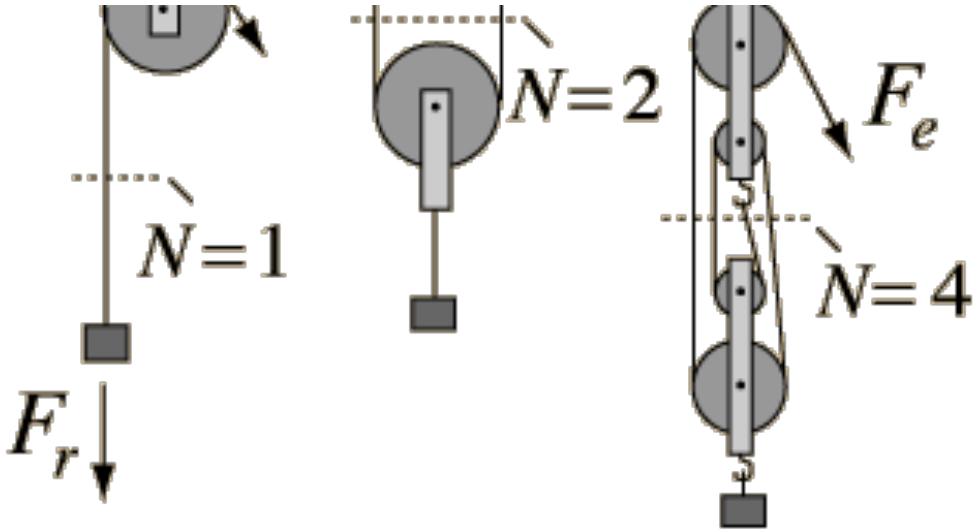
t = separation of wedged surfaces



https://flexbooks.ck12.org/cbook/ck-12-middle-school-physical-science-flexbook-2.0/section/13.8/primary/lesson/wedge-ms-ps

https://inventorsoftomorrow.com/2016/10/12/wedges-2/

Simple Machines (Pulley)

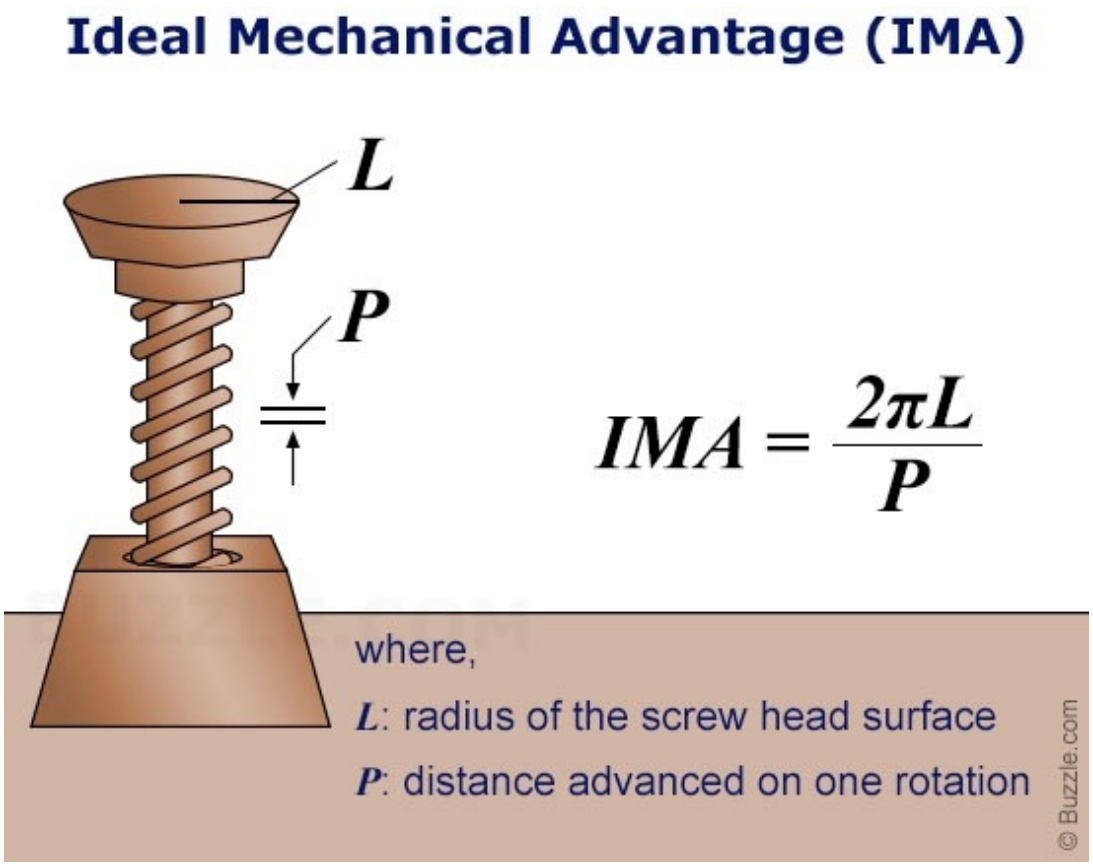


http://www2.phy.ilstu.edu/pte/489.01content/simple_machines/simple_machines.html

- IMA = N
  N = number of supporting strings
- Related Knowledge
  - Three types of Pulley Systems
    - Fixed
    - Movable
    - Complex (Block & Tackle)
  - F_e = Effort Force
  - F_r = Resistance Force

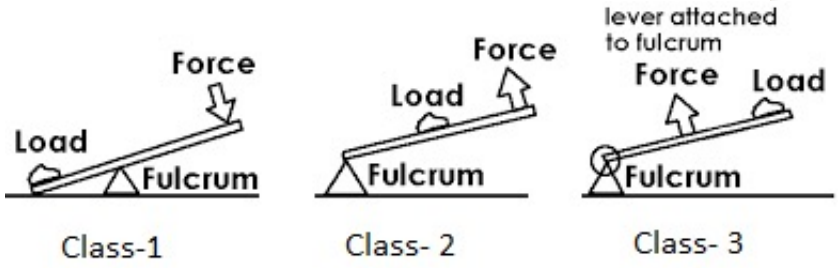
Simple Machines (Screw)

- A screw is actually an inclined plane wrapped around a shaft
- IMA = Circumference / Pitch
  - C = 2 * 3.14 * r
  - L = radius (r)
  - P = Pitch (distance between the threads)



https://sciencestruck.com/simple-machine-screws

Simple Machines (Lever)



https://www.toppr.com/ask/content/concept/kinds-of-levers-208470/

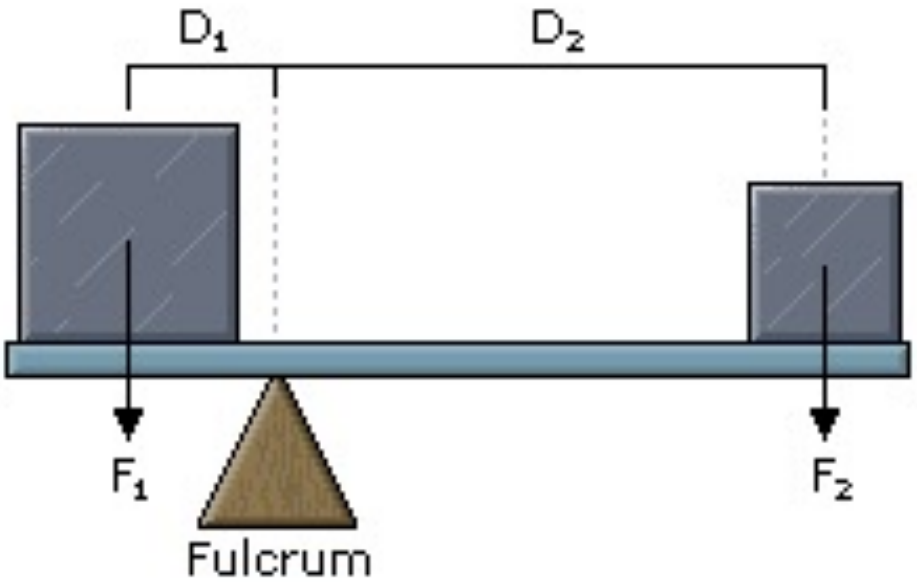
- A lever is a device that changes the force and distance of mechanical motion
  - input, fulcrum, and an output
- Classes of levers
  - Class 1, fulcrum in the middle (teeter-totter)
  - Class 2, fulcrum on one end and output in the middle (wheel-barrel)
  - Class 3, fulcrum on one end and input in the middle (car jack)

https://www.walmart.com/ip/Gener8-Teeter-Totter/577755996

https://www.amazon.com/Radio-Flyer-40Z-Kids-Wheelbarrow/dp/B01GJSKYAW

https://garagedreams.net/products/best-portable-lightweight-car-jacks

Simple Machines (Lever)

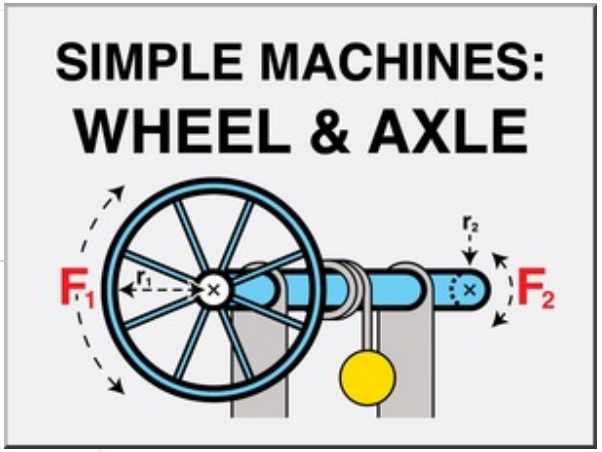


- IMA = Force Output / Force Input
- Related Math (Algebra)
  - $F_1D_1 = F_2D_2$
  - (Work in = Work out)

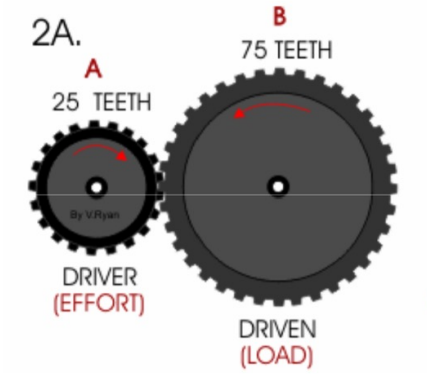
Simple Machines (Wheel & Axle)

- A Wheel & Axle is just a modified lever
- IMA = Force Output / Force Input

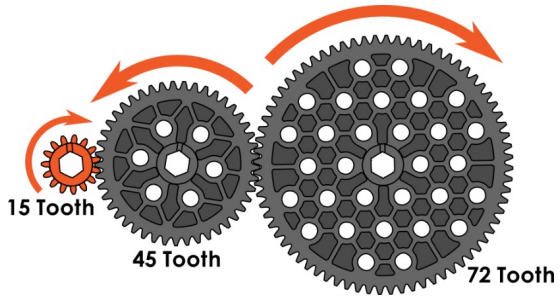
- Related Knowledge:
  - Gearing
    - IMA = Driven Gear # teeth / Drive Gear # teeth
    - IMA = Driven Gear Diameter / Drive Gear Diameter
    - IMA = Driven Gear Radius / Drive Gear Radius
    - IMA – Driven Gear Circumference / Drive Gear Circumference
  - Idler Gears used to change direction or make up distance
    - Not used in IMA Calc



https://www.abcteach.com/documents/clip-art-simple-machines-wheel-and-axle-color-i-abcteachcom-47934

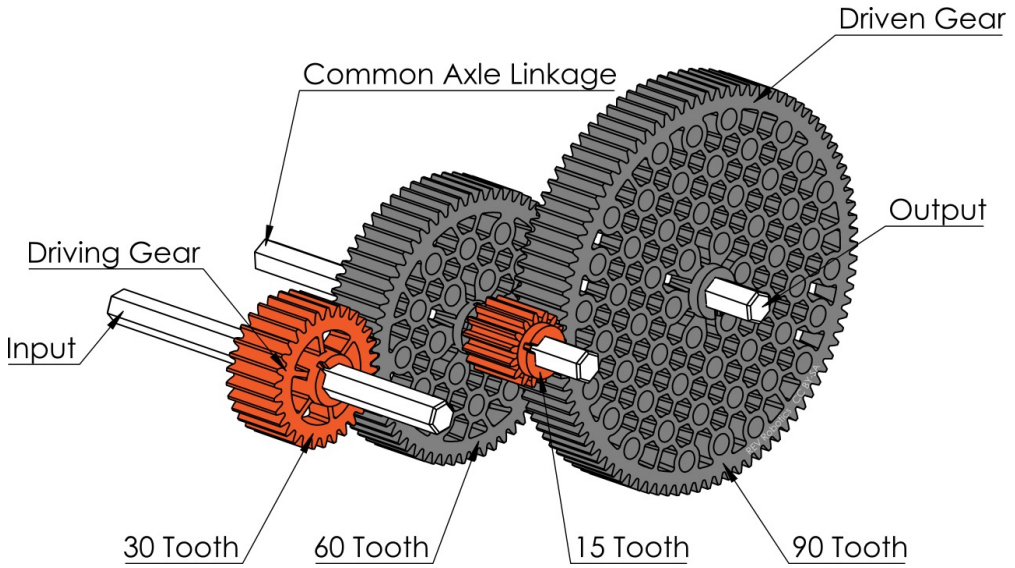


https://www.quora.com/How-do-I-calculate-the-gear-ratio



https://docs.revrobotics.com/15mm/transmitting-and-transforming-motion/gears/gears-advanced

Related Wheel & Axle (Compound Gears)



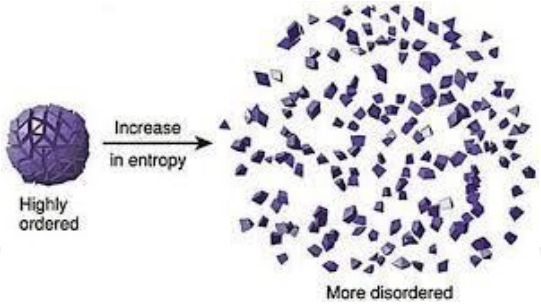
https://docs.revrobotics.com/15mm/transmitting-and-transforming-motion/gears/gears-advanced

Friction

- *Friction* is defined as a resistance to motion between two objects
- From an energy viewpoint, when there is friction - kinetic energy is converted into thermal energy
- The > power or work, the > the friction between two objects
  - The > friction produced, the > the heat produced

Schwaller, A. E. (1989). Transportation, energy and power technology. Albany, NY: Delmar.

Entropy



- “Entropy arises from the laws of thermodynamics. Let us state all three laws:
  - First law is known as the Law of Conservation of Energy which states that energy can neither be created nor destroyed: energy can only be transferred from one form to another. Thus, if there is work in terms of energy transformation in a system, there is equivalent loss of energy transformation around the system. This fact balances the first law of thermodynamics.
  - Second law of thermodynamics states that the entropy of any isolated system always increases. Entropy always increases, and rarely ever decreases. If a locker room is not tidied, entropy dictates that it will become messier and more disorderly over time. In other words, all systems that are stagnant will inviolably run against entropy which would lead to its undoing over time. Over time the state of disorganization increases. While energy cannot be created or destroyed, as per the First Law, it certainly can change from useful energy to less useful energy.
  - Third law establishes that the entropy of a system approaches a constant value as the temperature approaches absolute zero. Thus, the entropy of a pure crystalline substance at absolute zero temperature is zero. However, if there is any imperfection that resides in the crystalline structure, there will be some entropy that will act upon it.” https://linkedstarsblog.com/2019/03/25/chaos-and-the-tide-of-entropy/

Efficiency

- AMA / IMA * 100
  - AMA is the Actual Mechanical Efficiency (Measured)
  - IMA is the Ideal Mechanical Efficiency (Calculated)

  - AMA will always be less than IMA due to friction and entropy.

System Efficiency

- “The symbol used to define efficiency is the Greek letter eta (η):

$$\eta = Pout / Pin$$

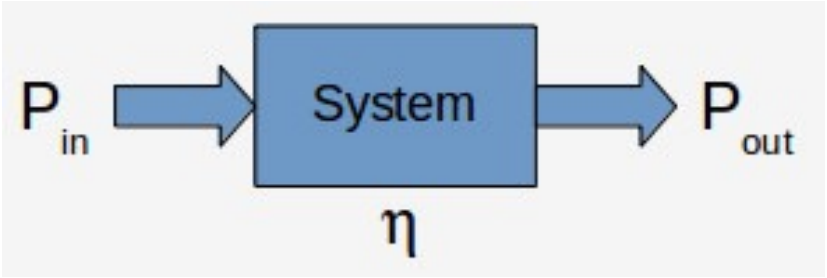
- If we want to express the efficiency as percentage the mathematical expression becomes:

$$\eta\ [\%] = Pout / Pin\ *100$$

- For example if we take an electric motor which receives a 1000 W power from a battery and outputs 900 W at the rotor, what is the efficiency of the motor?

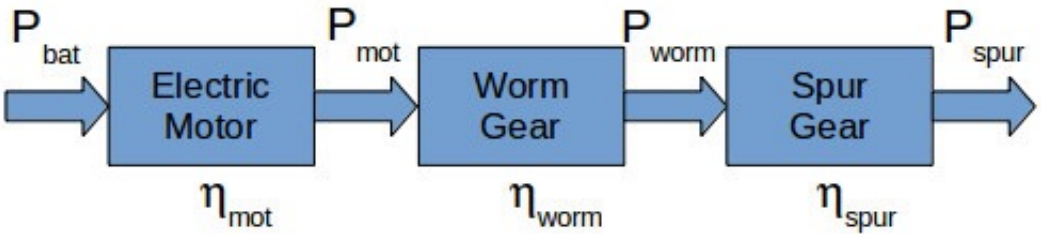
$$\eta mot = 900 / 1000\ *100 = 90\%”$$

https://x-engineer.org/graduate-engineering/mechatronics/mechanisms/what-is-efficiency/

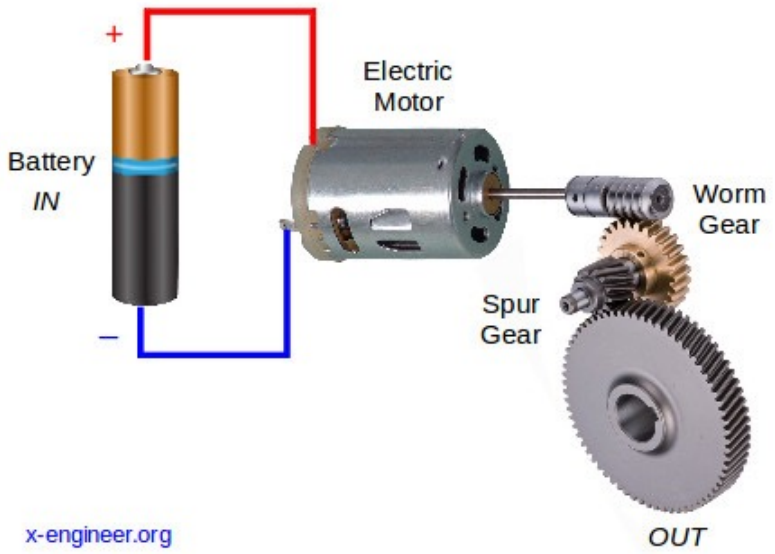


https://x-engineer.org/graduate-engineering/mechatronics/mechanisms/what-is-efficiency/

System Efficiency



- “Suppose we have an electro-mechanical actuation system composed by:
  - a battery (Source)
  - an electric motor (95%)
  - a worm gear (70%)
  - a spur gear (98%)”
- .95 * .70 * .98 = .6517
- ~65% System Efficiency



https://x-engineer.org/graduate-engineering/mechatronics/mechanisms/what-is-efficiency/

Rube Goldberg Design Challenge

- Review Handout for Our Class Design Challenge Rules & Objective
- Create Teams
  - Be sure you have a remote location to be able to work from (out-of-class)
  - For fall 2021 (19 students as of today)
    - five teams of three
    - one team of four
  - Keep track of who developed/designed the elements (lack of participation may influence your grade).
  - Not being able to meet with your group may force you to work alone or impact your evaluation.
  - Elect a team captain. Email Progress Reports are due on 10/6 and 10/13.
- Inspiration:
  - https://www.youtube.com/watch?v=qybUFnY7Y8w&t=1s