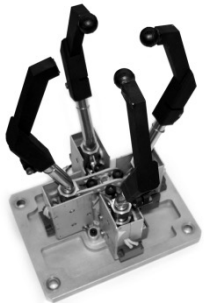
CISC 1003 – EXPLORING ROBOTICS

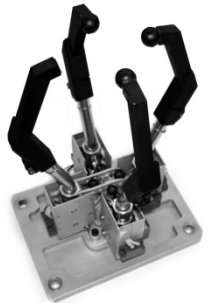
ROBOT CONSTRUCTION: EFFECTORS AND ACTUATORS

Arms, Legs, Wheels, Tracks and What Really Drives Them



https://www.robotshop.com/blog/en/how-do-i-choose-appropriate-actuators-6903

Effectors



- Effector: any device on a robot that has an effect (impact or influence) on the environment
  - Wheels on a mobile robot
    - Or legs, wings, fins…
  - Whole body might push objects
  - Grippers on an assembly robot
    - Or welding gun, paint sprayer
  - Speaker, light, tracing-pen
- The controller sends commands to the effectors
  - To perform a desired task

http://www.wikiwand.com/en/Robot_end_effector

Replicating fossil paths with toilet roll [Prescott & Ibbotson (1997)]

- A spiral 'foraging' trail generated by the robot trace-maker.
  - Control combines thigmotaxis (stay near previous tracks) & phobotaxis (avoid crossing previous tracks)
    - Thigmotaxis: motion in response to a touch stimulus
    - Phobotaxis: change in the direction of locomotion in response to a given stimulus

Replicating fossil paths with toilet roll [Prescott & Ibbotson (1997)]

Actuators

- Actuator: the mechanism that enables the effector to execute an action or movement.
  - In animals and humans:
    - muscles and tendons are the actuators
    - make the arms and legs and the backs do their jobs.
  - In robots:
    - actuators include electric motors and various other technologies.
    - Connected via transmission:
      - System gears, brakes, valves, locks, springs…

Actuators

- Actuators

Effectors and Actuators

- terms are often used interchangeably to mean: “whatever makes the robot take an action”
  - but they aren’t the same thing

Effectors and Actuators

- most simple actuators control one degree of freedom
  - i.e., a single motion
  - e.g., up-down; left-right; in-out

Effectors and Actuators

- how many degrees of freedom a robot has determines how it can affect its world
  - therefor how well, if at all, it can accomplish its task
- More on D.O.F. later…

Passive vs. Active Actuation

- The action of actuators and effectors requires some form of energy to provide power.
- Some actuators use *passive actuation*

http://www.mdpi.com/1424-8220/15/11/28287/htm

Passive Actuation

- Utilizing potential energy (usually gravity) of the effector and its interaction with the environment
  - Instead of active power consumption.
- A glider is an example of this

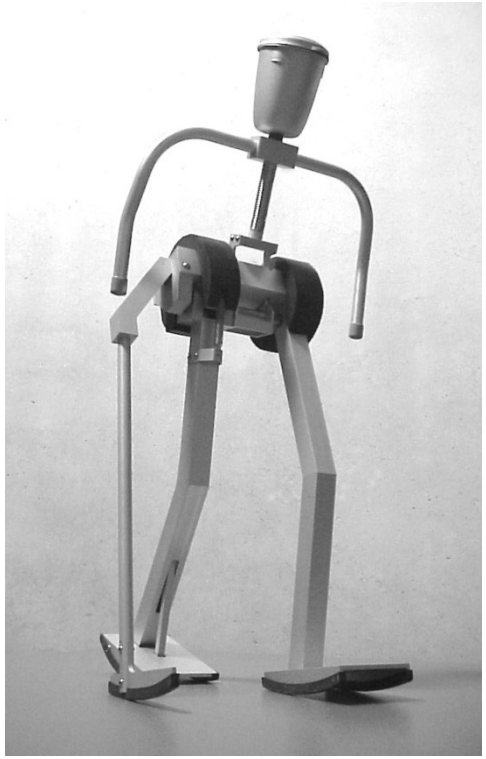
http://www.mdpi.com/1424-8220/15/11/28287/htm

Passive Actuation

- Utilizing potential energy (usually gravity) of the effector and its interaction with the environment
  - Instead of active power consumption.
- Advantage:
  - No need for extra weight required by energy source (battery, gasoline, etc) and complicated actuators.
- Disadvantage:
  - Dependence on a motivating source that may be transient.
    - For example, weather may affect glider movement

http://www.mdpi.com/1424-8220/15/11/28287/htm

Movement



A passive walker: a robot that uses gravity and clever mechanics to balance and walk without any motors.*

*The robotics primer, Mataric

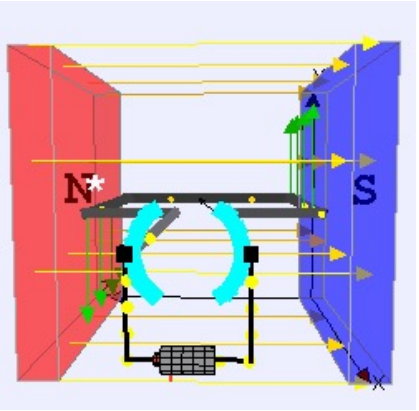
Types of Actuators

- Electric motors
  - speed proportional to voltage
    - voltage varied (by pulse width modulation)
- Hydraulics
  - Pressurized liquid
- Pneumatics
  - Pressurized air

Types of Actuators

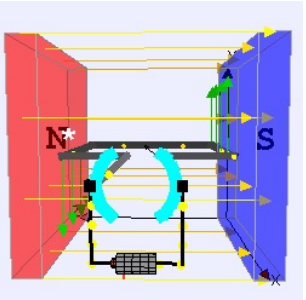
- Others, including:
  - Photo-reactive materials
  - Chemically reactive materials
    - For example, include chemicals that only affect certain ph levels in materials
  - Thermally reactive materials
    - Have materials that only react at certain temperatures
  - Piezoelectric materials
    - Crystals create a charge when pushed or pressed.
      - Piezoelectricity

DC Motors



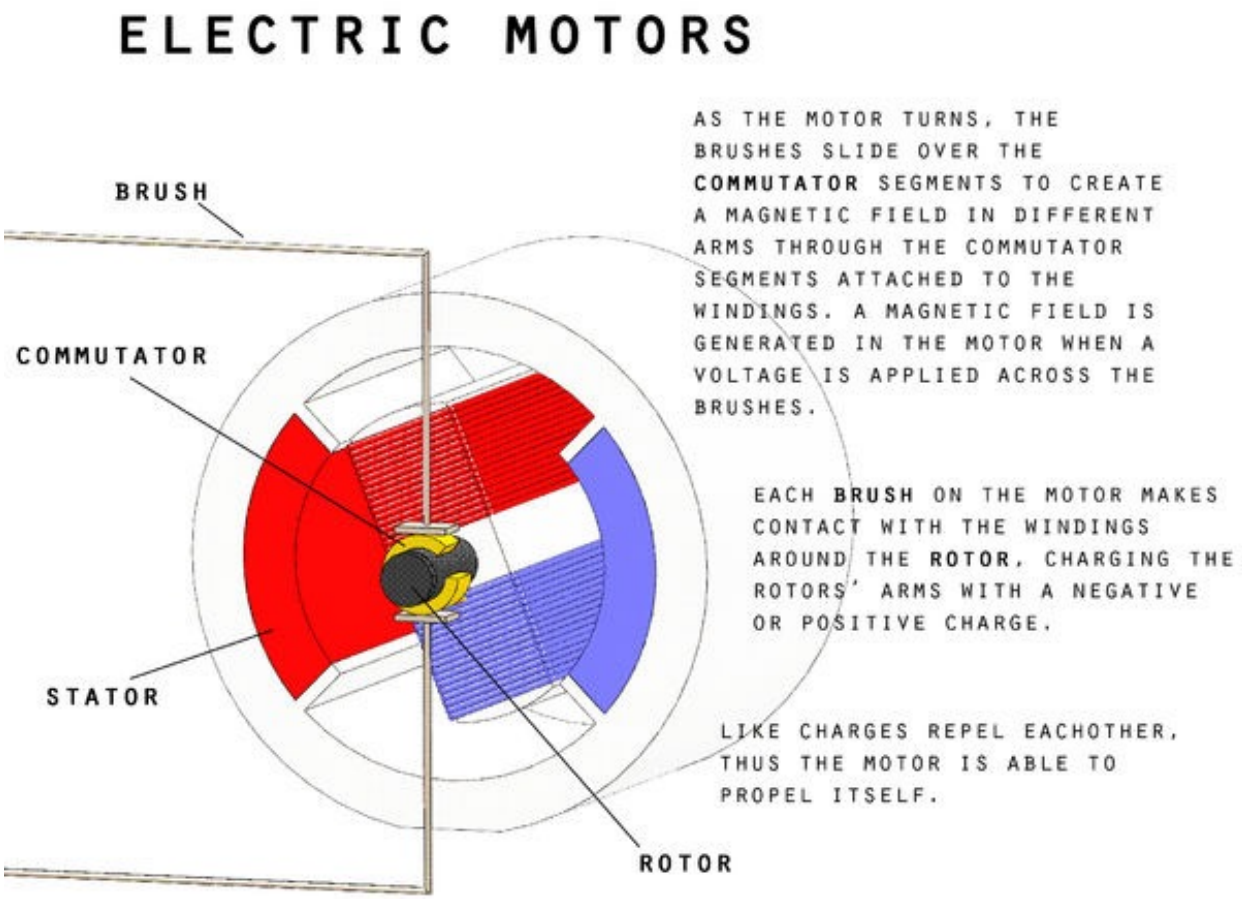
- Compared with all other types of actuators, ***direct current (DC) motors*** are simple, inexpensive, easy to use, and easy to find.
- Motors have a copper wire wound in a way that creates magnetic fields
  - These “push" the rotor inside of the motor around in a circle.

DC Motors



- To make a motor run, you need to provide it with electrical power in the right voltage range.
  - Low voltage, slower movement.
  - Higher voltage, faster movement
    - but more wear on the motor and can burn out if run fast for too long.
    - Like a lightbulb on a battery. More voltage means a brighter light.

DC Motors



http://makezilla.com/2016/01/21/how-to-motors/

Types of Actuators

- Electric Actuator

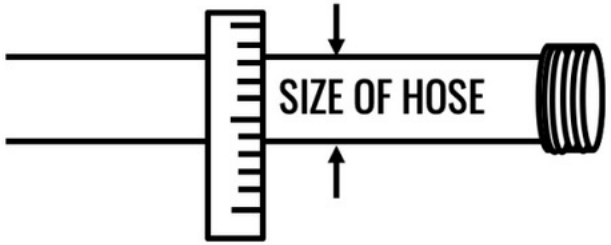
Basics of Electricity

- The three most basic components of electricity are voltage, current, and resistance.
  - VOLTAGE is like the pressure that pushes water through the hose.
    - It is measured in volts (V).
  - CURRENT is like the diameter of the hose. The wider it is, the more water will flow through.
    - It is measured in amps (I or A).
  - RESISTANCE is like sand in the hose that slows down the water flow.
    - It is measured in ohms (R or Ω).

Electricity is like a water hose

Voltage — Volts (V)

Current — Amps (A or I)



Resistance — Ohms (R or Ω)

https://www.freeingenergy.com/understanding-the-basics-of-electricity-by-thinking-of-it-as-water/

Electricity is like a water hose

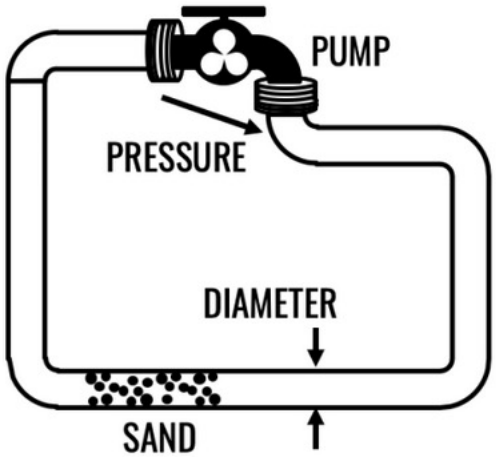
- Voltage, current, and resistance are all related
  - If you change one of them in a circuit, the others will change, too
  - Specifically, voltage is equal to current multiplied by resistance (V = I x R).
  - Electricity is like a water hose
  - Thinking about water:
    - if you add sand into the hose and keep the pressure the same, it's like reducing the diameter of the hose
      - => less water will flow.

Electricity Basics

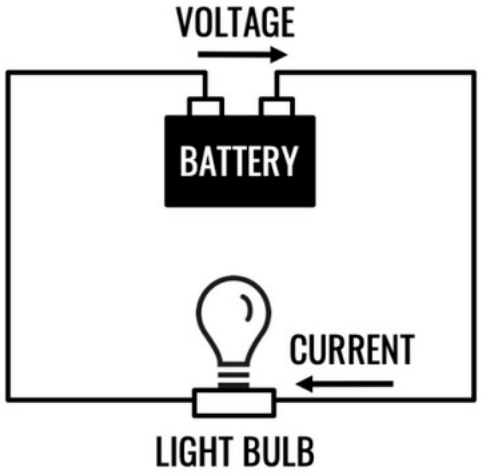
Voltage = Current x Resistance

(V = I x R)

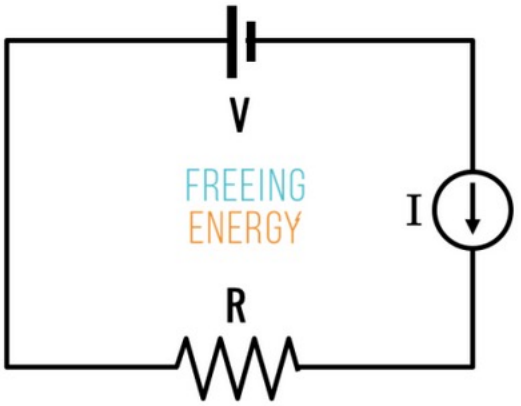
Water



Electricity



Circuit Diagram



https://www.freeingenergy.com/understanding-the-basics-of-electricity-by-thinking-of-it-as-water/

Ohm's Law

- Discovered in 1825
- Relates 3 key quantities in electrical circuits
  - Voltage (V)
  - Current (I)
  - Resistance (R)

$$V = I \times R$$

Voltage = Current x Resistance

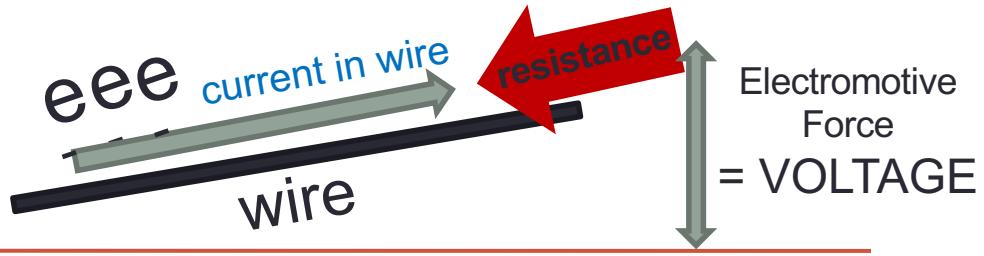
In scientific units: Volts = Amperes x Ohms

- Voltage can be considered the FORCE which is DRIVING the total electrical flow rate (current)
  - *against* the resistance encountered in a portion of an electrical circuit.

Georg Simon Ohm

Voltage = (electrical) Current x (electrical) Resistance

Compare to pushing or cycling a bike up a hill



1) **Voltage in a circuit :** like your capacity for work to push or cycle the bike (or to 'drive' it);

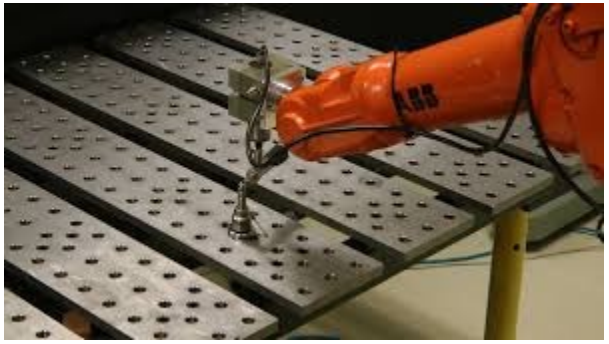
2) The **resistance** is like the friction force on the tyres, the stiffness of the bike components, and the steepness of the hill;
all these factors together determine the rate of progress for a given force.

3) **The rate of progress (up the hill) – is similar to the "current" in a circuit**, which measures the total passage of electricity in a given time through a particular point.

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjjy8CamY7zAhWkneAKHQqOBY8QFnoECAIQAQ&url=https%3A%2F%2Fcdn.website-editor.net%2Fd484d117f2334e5a8c5c55596caa9193%2Ffiles%2Fuploaded%2FPP_ohms%252520law.pptx&usg=AOvVaw1yCePDMbC8GBSCJ1kqNhec

Variables Affecting Actuators Choice

- Load (e.g. torque to overcome own inertia)
- Speed (fast enough but not too fast)
- Accuracy (will it move to where you want?)
- Resolution (can you specify exactly where?)



http://www.payper.com/palletizer-robots, https://www.dreamstime.com/stock-illustration-robot-running-high-speed-clipping-path-included-image49547946, , https://www.youtube.com/watch?v=niKo_-EgdJ0

Variables Affecting Actuators Choice

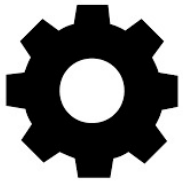
- Repeatability (will it do this every time?)
- Reliability (mean time between failures)
- Power consumption (how to feed it)
- Energy supply & its weight

www.photonics.com/a42575/Robotic_Automation_for_Solar_Cell_Manufacturing, https://www.dreamstime.com/stock-images-robot energy-charge-image22373104

Questions?

GEARS

Gears



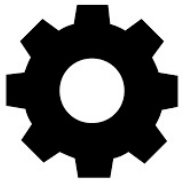
- Gears are wheels with teeth. Gears mesh together and make things turn.
- Gears are used to transfer motion or power from one moving part to another.

Gearing of motors

- Combining different ***gears*** is used to change the **speed** of motors.

http://www.jsumo.com/steel-gear-bundle-08-module-6421-reduction

Gears



- Both the input gear (driver gear) and the output gear each have a set number of teeth
- The ratio between these two gears can be used to find the speed of the output gear
  - if the input speed to the driven gear is known.

Gears

- **Output Speed** = (*Input gear* / *Output gear*) * *Input Speed*

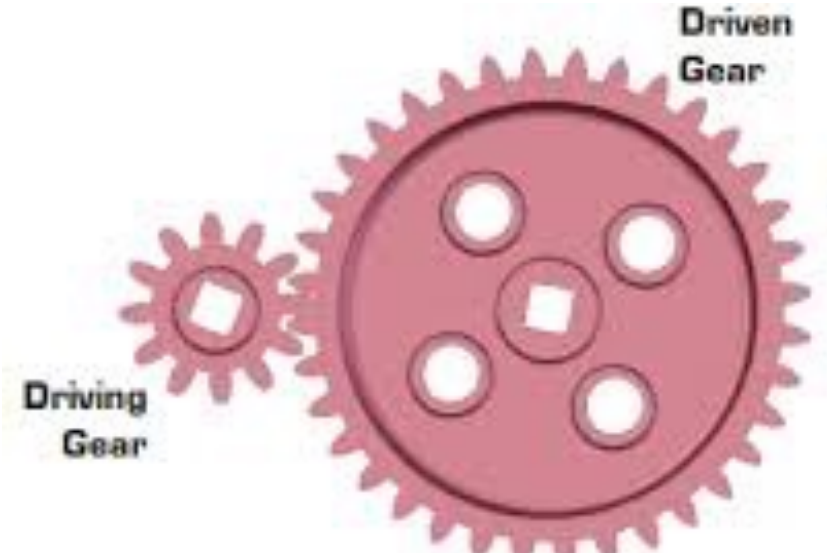
Gears - example

- A motor is attached to a 10 tooth spur gear
  - Gear spins at 100 rpm (rotations per minute)
  - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What is the output speed?

Gears - example

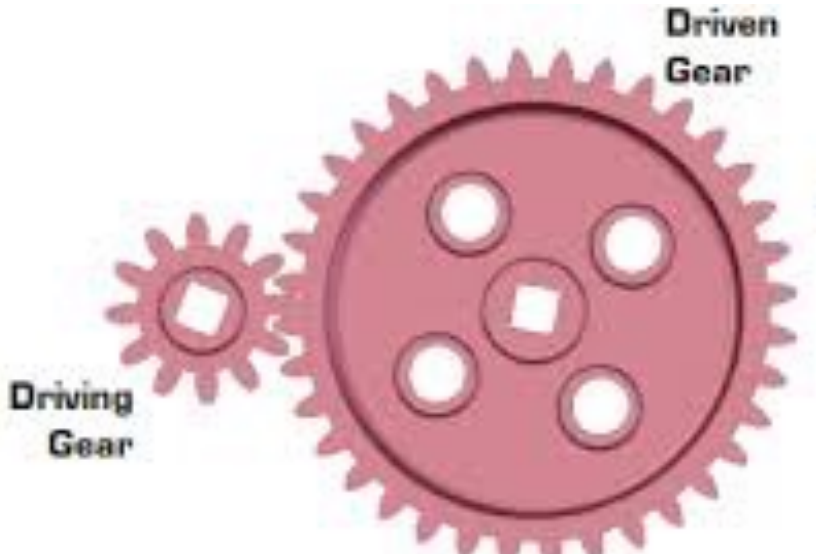
- A motor is attached to a 10 tooth spur gear
  - Gear spins at 100 rpm (rotations per minute)
  - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What is the output speed?
  - Output speed = (10 /20) * 100 = 50 rpm

Combining Gears



Combining Gears

- What happens to the speed?



Combining Gears

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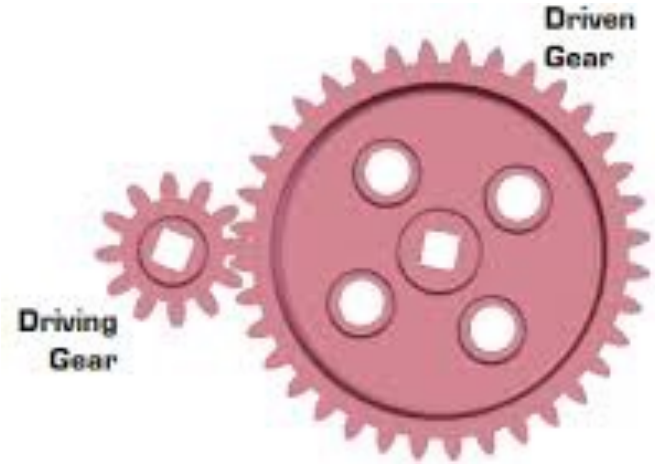
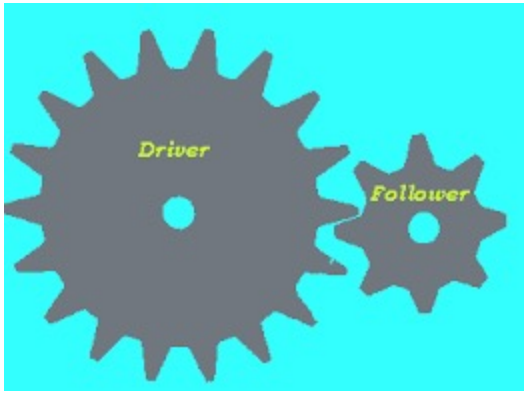
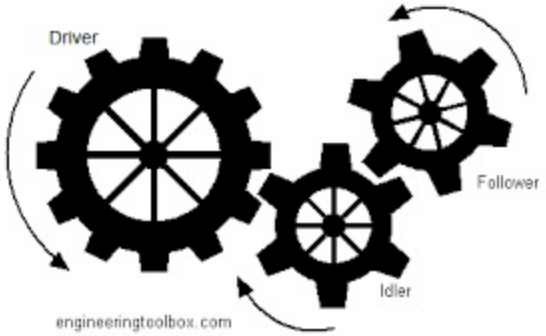


http://klinikrobot.com/product/gear-sets/plastic-gear-fs5-0508-000-gear-14-32t.html

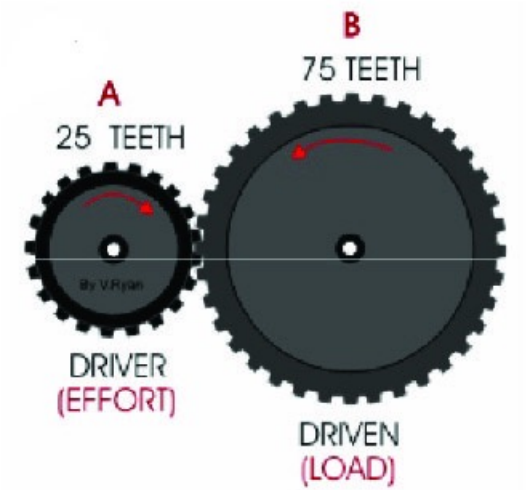
Gear System



- Compound Gears



Gear Ratio



$$\frac{\text{Driven}}{\text{Driving}} = \frac{75}{25} = \frac{3}{1} \rightarrow 3{:}1$$

Gears – The Purpose

Gears are generally used for one of four different reasons:

- To reverse the direction of rotation
- To increase or decrease the speed of rotation
- To move rotational motion to a different axis
- To keep the rotation of two axis synchronized

Questions?

Lab time!

- Let’s work with our virtual robots!