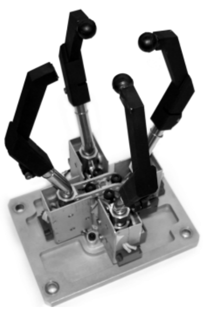
CISC 1003 - EXPLORING ROBOTICS

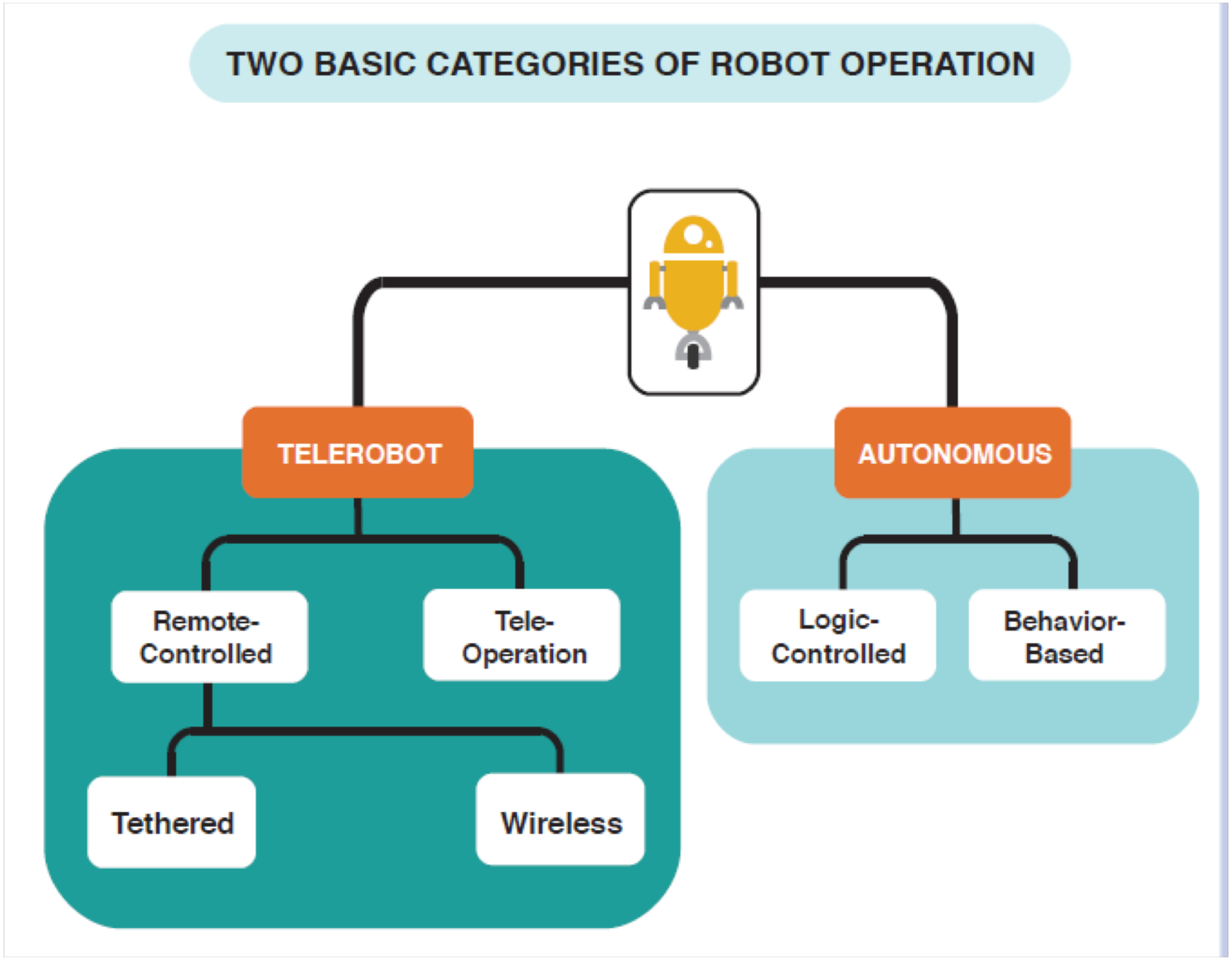
ROBOT CONSTRUCTION: REVIEW



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

What is a robot? (Cont.)

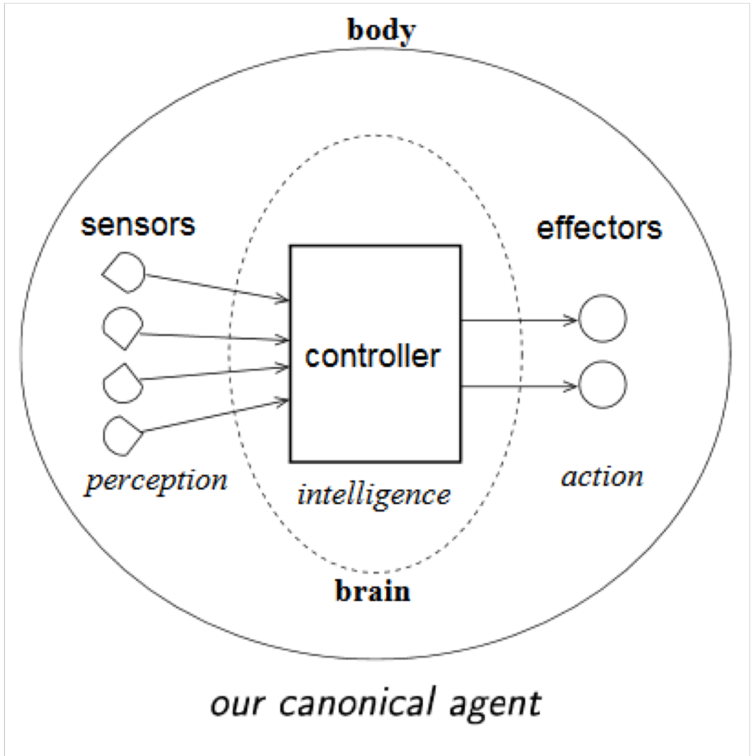
- Our definition of robot (for our purposes):
  - An autonomous agent, acting independently. Our environment is the real world.
  - The robot can sense its environment (including its own internal state) and act on it to achieve pre-defined goals.
- Robotics: The study of robots – their design, construction, capabilities and purpose.



* Robot Programming: A Guide to Controlling Autonomous Robots, Cameron Hughes and Tracy Hughes

Our definition of a robot

- Robot = autonomous embodied agent
- Has a *body* and a *brain*
- Exists in the physical world (rather than the virtual or simulated world).
- Is a mechanical device



Robot definition (cont.)

- Contains *sensors* to perceive its own state
- Contains *sensors* to perceive surrounding environment
- Has *effectors* that perform actions
- Has a *controller* that takes input from the sensors, makes *intelligent* decisions about actions to take, and performs these actions by sending commands to motor

Robot State

- Refers to the description of the system at any point in time
- Internal state refers to the state of the robot
  - E.g., its battery is low
- External state refers to the state of the world
  - As the robot perceives it
    - E.g., it is wet on the ground

Robot components

- All have five common components:
  - Control:
    - Human: Brain, central nervous system
    - Function: the brain makes decisions based on sensory input , nervous system sends signals to muscles
    - What is the equivalent in Robots?
      - Usually the brain is a computer of some kind, wires send signals
  - Effectors (body/structure):
    - Human: Bones and muscles - legs, arms, wrists, neck, etc.
    - Function: Allows movement
    - What is the equivalent in Robots?
      - Motors allow movement, wheels

Robot components

- All have five common components (cont.):
  - Perception (sensors):
    - Humans: 5 senses detected by our body (what are they?)
      - Touch, Smell, Sight, Hearing, Taste
    - Robots: Touch sensor notifies robot of contact with another object, sound sensor allows robot to perceive audio.
  - Power source:
    - Humans: food and digestive system
    - Function: provide energy
    - Robots: usually batteries of some kind

Robot components

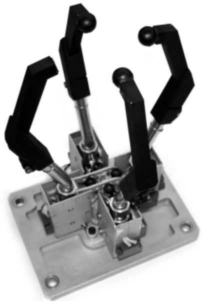
- Communications:
  - Humans: voice, gesture, hearing
  - Function: communication with outside world
  - Robots: input/output functionality, expressions, wireless signals

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

- Any device that affects the environment
  - Either through direct impact or influence
  - Examples:
    - 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



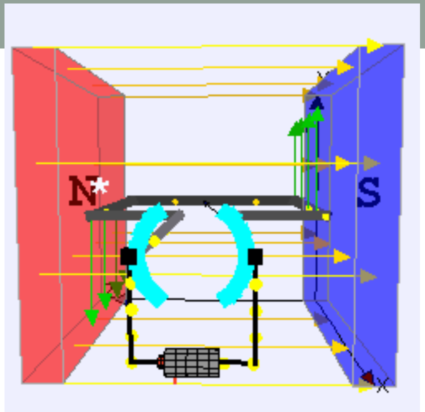
Effectors

- Specific categories:
  - Manipulators: Industrial robot arms, capable of picking and placing objects, mimicking human
  - Mobile/humanoid robots: effectors enables moving around

Actuators

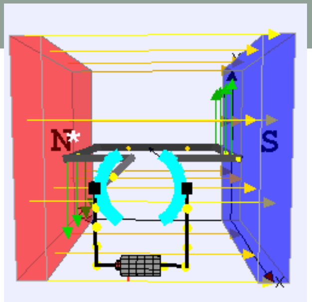
- The mechanisms that enables the effector to execute an action or movement.
  - In animals and humans:
    - muscles and tendons are the actuators
    - make the arms and legs and the backs do their jobs.
  - In robots:
    - Converts software commands into physical movements
      - Through electronic or hydraulic signals
    - Actuators include electric motors and various other technologies.
    - Connected via transmission:
      - System gears, brakes, valves, locks, springs…

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.

Motors



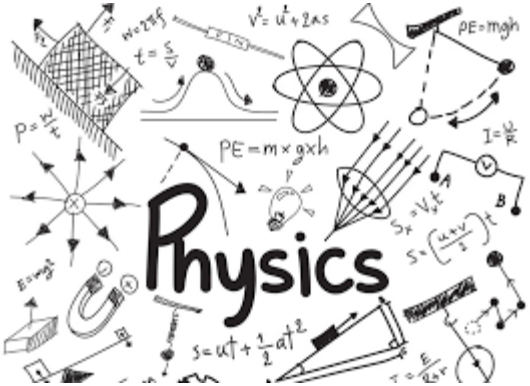
- To make a motor run, you need to provide it with electrical power in the right voltage range.
  - Low voltage, slower movement.
  - Higher voltage, faster movement
    - but more wear on the motor and can burn out if run fast for too long.
    - Like a lightbulb on a battery. More voltage means a brighter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

Gearing of motors

- Combining different *gears* is used to change the speed and torque (turning force) of motors.

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

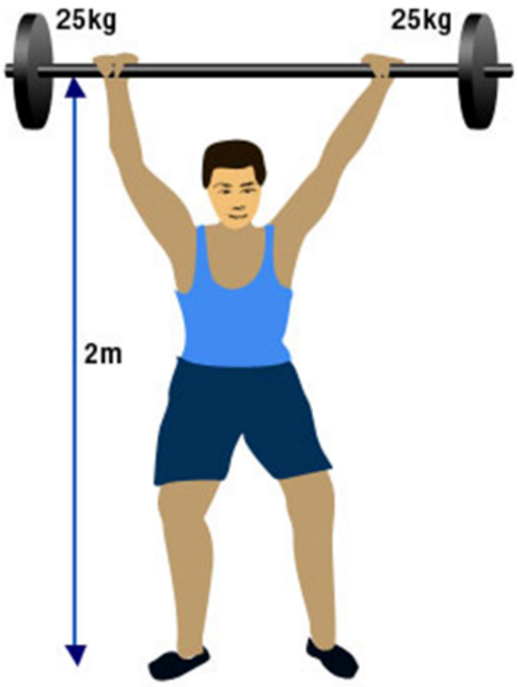
SOME PHYSICS



http://theconversation.com/physics-is-taught-badly-because-teachers-struggle-with-basic-concepts-86083

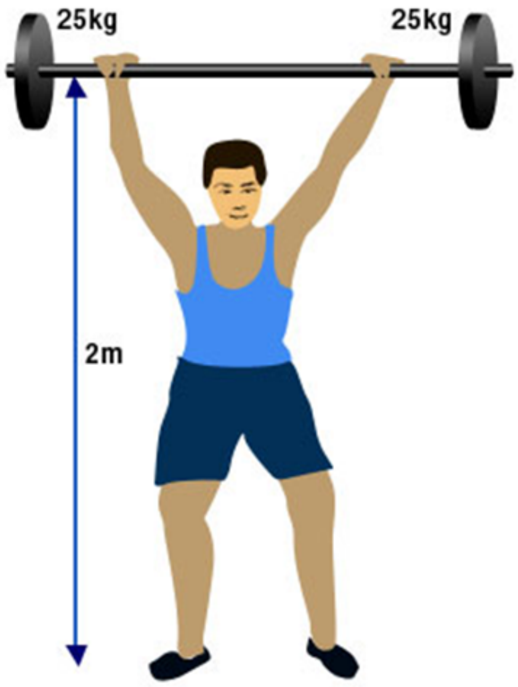
Work, Force and Distance

- Energy is the ability to do work
- Measured in Joules
- Work: The action of a *force* to cause *displacement* of an object
  - Work(J) = Force (N) x distance (m)
    - 1 joule = 1 Newton * 1 meter



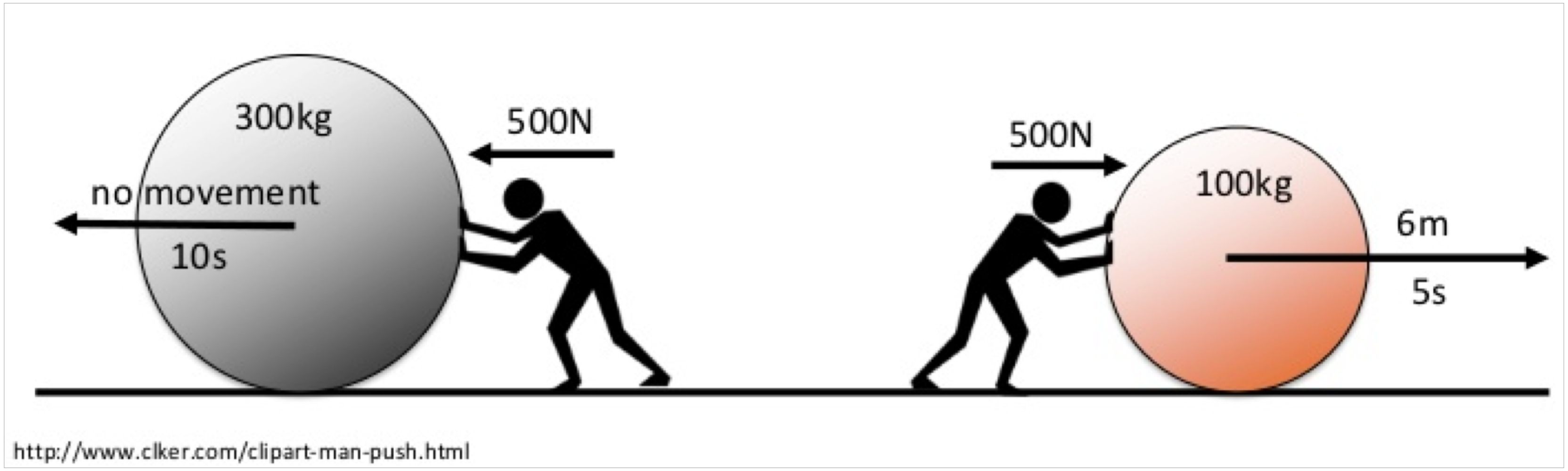
Work, Force and Distance

- Here, in this figure, we can say that, the work done upon the weight against gravity is
- (Mass × acceleration due to gravity) × Displacement
- = (25 x 2 × 9.8) × 2 = 980 J



Work, Force and Distance

- Who has done the most work?
  - Work = Force x Distance



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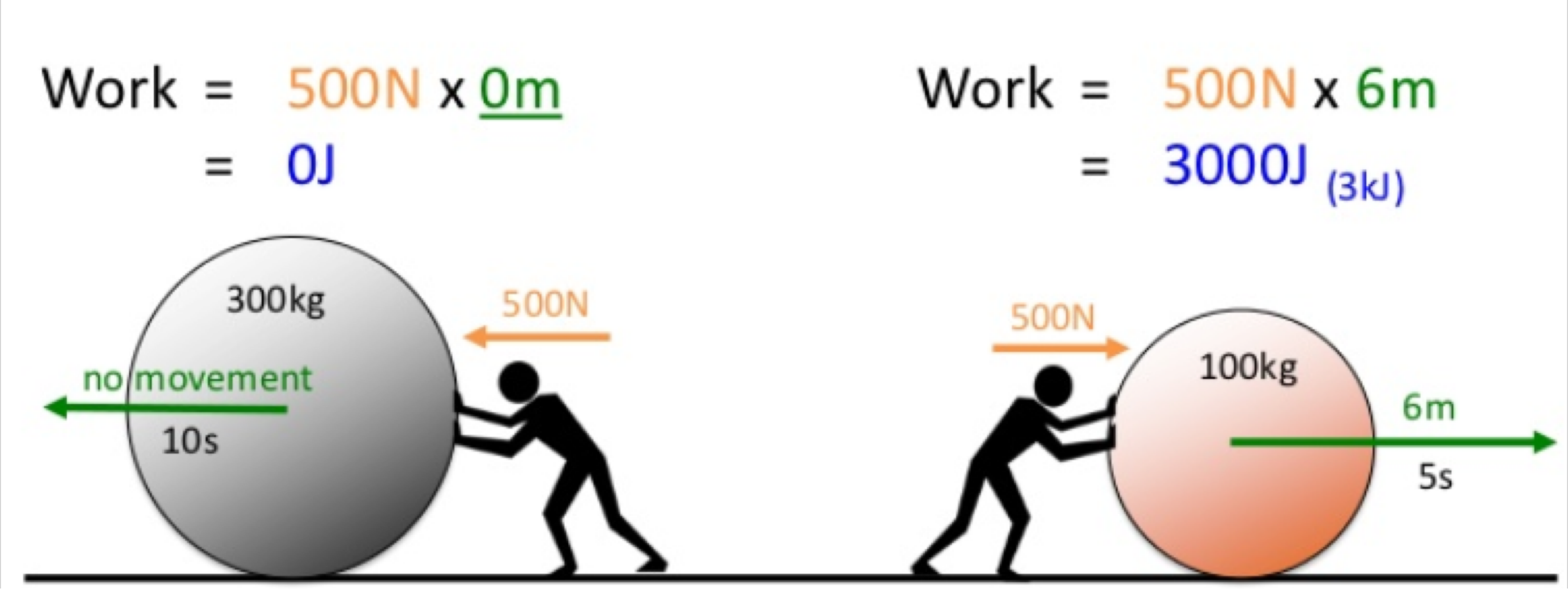


https://www.slideshare.net/gurustip/energy-work-power-10148820

Torque

- Torque is a measure of the force that can cause an object to rotate about an axis.
- TORQUE measures *ROTATIONAL FORCE*
- TORQUE = FORCE x DISTANCE
  - DISTANCE is equivalent to the RADIUS of the rotational circumference.

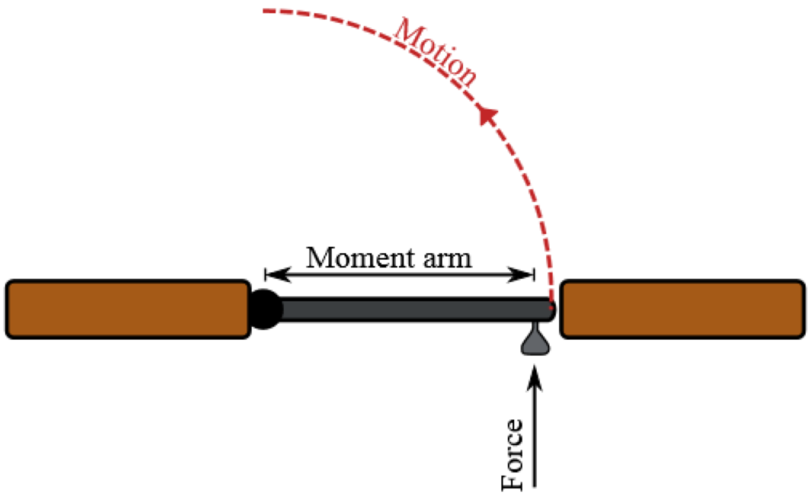
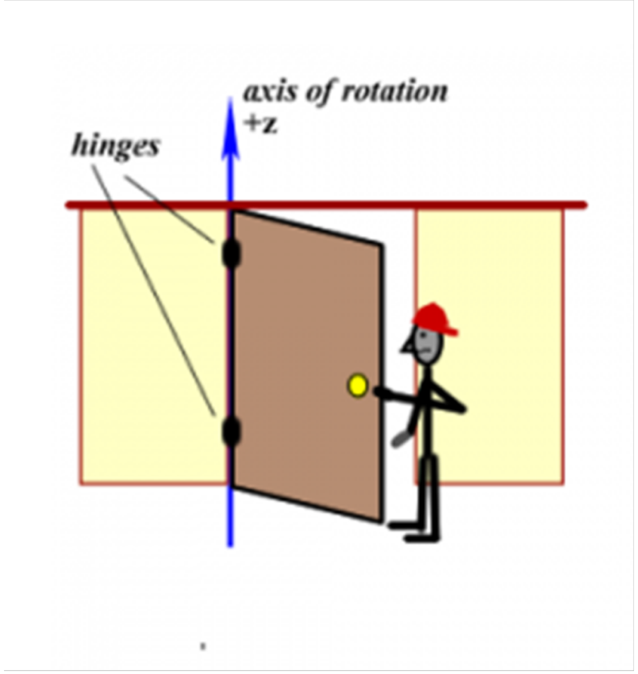


Figure 1: Opening a door with maximum torque.

Torque

- Example: opening a door:
  - Torque is the angular force that the person exerts



Gearing of motors

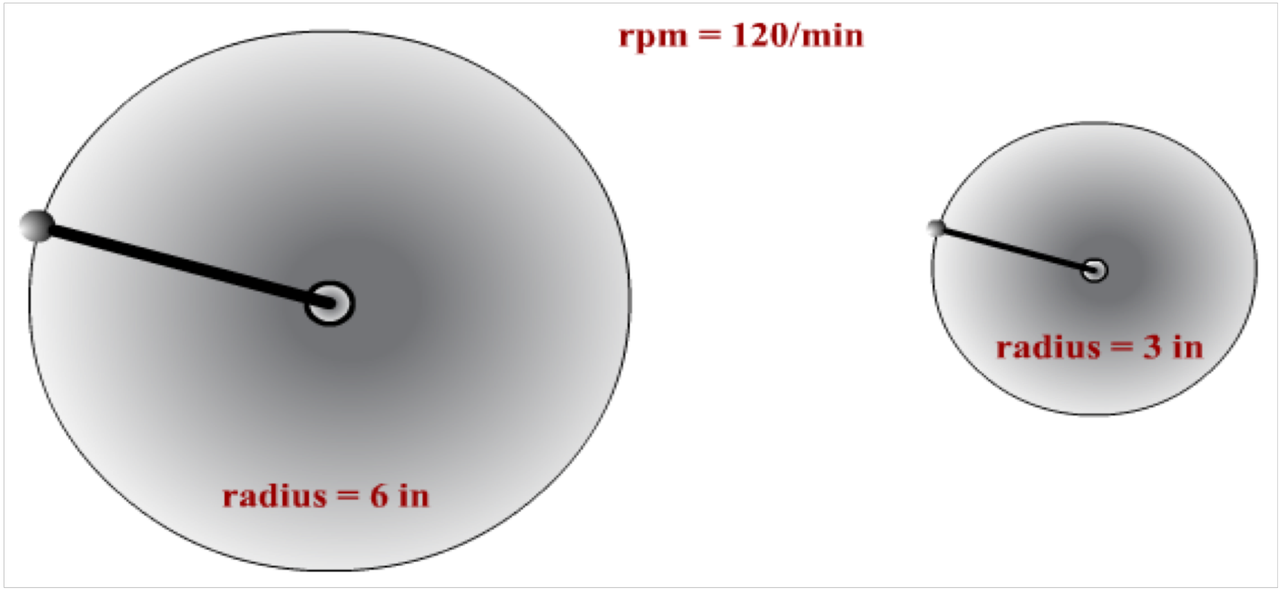
- Combining different *gears* is used to change the speed and torque (turning force) of motors.
- Work, as defined in physics, is the product of force and distance.
  - Work = force × distance
  - Distance moved in the direction of the force
- Gears rotate around their axis in a certain velocity
  - Rotational Velocity is specified in Rotations Per Minute.

Gearing of Motors

- Torque provided by motor is typically constant
- For a wheel on the ground, torque needed to turn wheel equals to overcome friction
  - $Torque = F_f * Distance$
    - Distance = wheel radius
- For a larger wheel, smaller rotational force will be provided by same engine
  - Harder to turn larger wheels
    - Think of a truck vs. car, who has the bigger engine?

Rotational and Linear Velocity

- Both wheels touch the ground and rotate at 120rpm
- Which wheel will travel further?
  - Larger wheel will travel further!
    - Can we calculate its linear velocity?



Rotational and Linear Velocity

- Rotational Velocity (RV) to Linear Velocity (LV) conversion:
  - Find the Circumference (C) of the circles:
  - $C \quad = 2 \times \pi \times r$ inches (where r is the radius)

$$C_1 = 2 \times \pi \times 6 = 37.70\ inches$$

$$C_2 = 2 \times \pi \times 3 = 18.85\ inches$$

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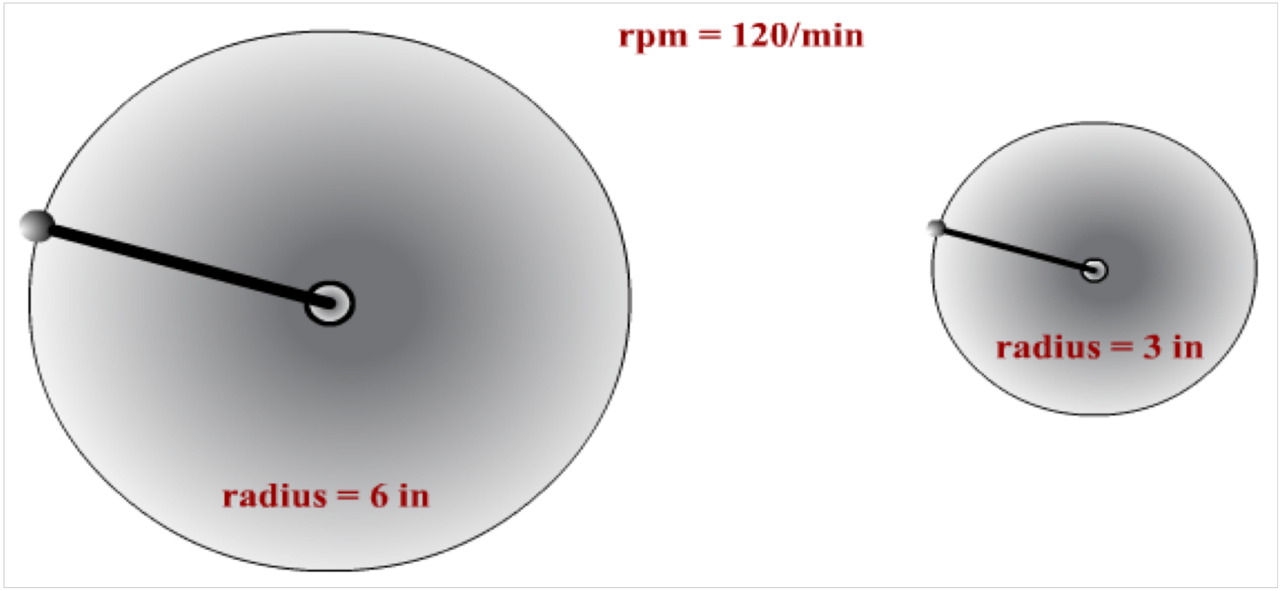
    $C_1 = 2 \times \pi \times 6 = 37.70\ inches$

    $C_2 = 2 \times \pi \times 3 = 18.85\ inches$
- $Linear\ Velocity\ = \ C\ x\ Rotational\ Velocity$ (120 rpm speed of both circles)
  - $V_l = 37.70\ * 120 = 4524\ inches/min$
  - $V_2 = 18.85\ * 120 = 2262\ inches/min$

http://domarcompanies.com/velocity-business-systems/

Rotational and Linear Velocity

- Both wheels touch the ground and rotate at 120rpm
- Which wheel will travel further?
  - Larger wheel will travel further!
    - Can we calculate its linear velocity?
- Note:
  - Rotational Velocity is specified in Rotations Per Minute.
  - Linear Velocity is usually specified in Feet Per Minute.



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

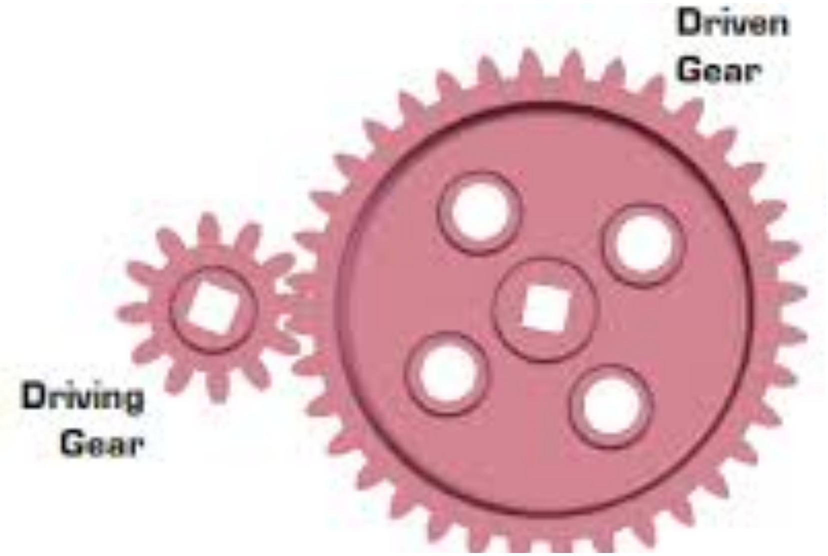
Gears and Torque

- A motor that is VERY fast but has only a little bit of torque would not be suitable to lift a heavy load
- in these cases it is necessary to use gear ratios to change the outputs
    - to a more appropriate balance of torque and speed

Gears

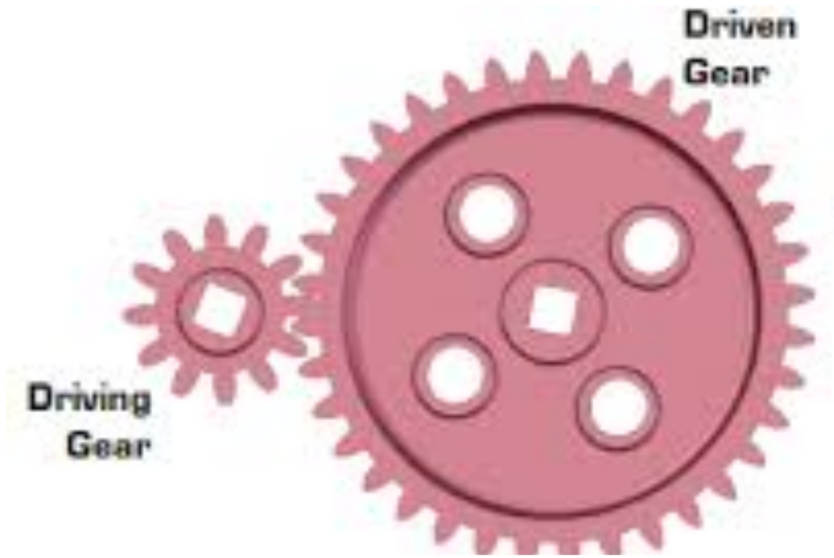
- **Output Speed** = (*Input gear* / *Output gear*) * *Input Speed*
- **Output Torque** = (*Output gear* / *Input gear*) * *Input Torque*

Combining Gears



Combining Gears

- What happens to the speed?
- What happens to the torque?



Combining Gears

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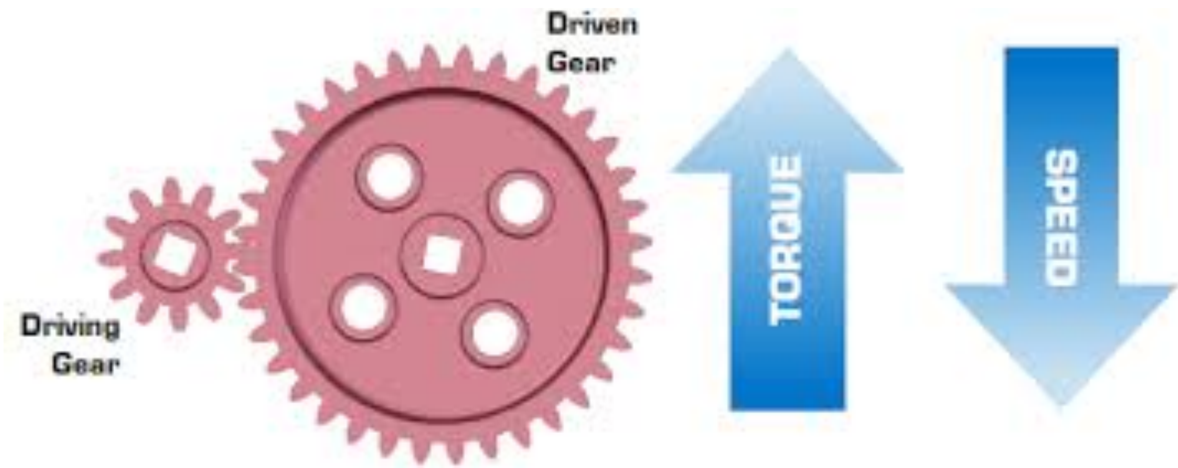
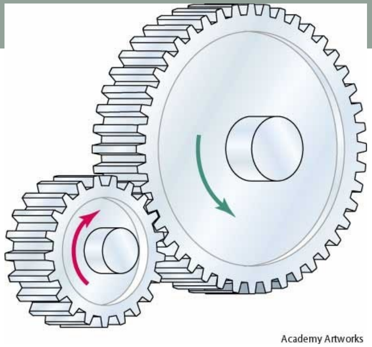


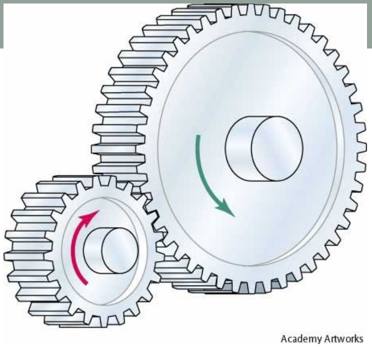
http://klinikrobot.com/product/gear-sets/plastic-gear-fs5-0508-000-gear-14-32t.html

Gears - example



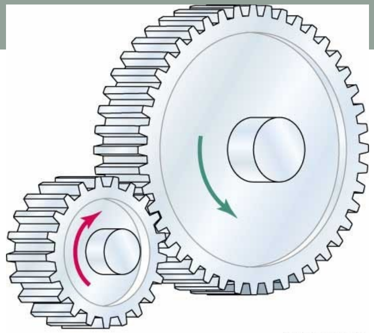
- A motor is attached to a 10 tooth spur gear
  - Gear spins at 100 rpm (rotations per minute)
  - Gear has a torque of 1 joule
- 20 tooth gear attached to the 10 tooth gear
- What are the output speed and torque?

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 are the output speed and torque?
  - Output speed = (10 /20) * 100 = 50 rpm
  - Output torque = (20 / 10) * 1 = 2 joules

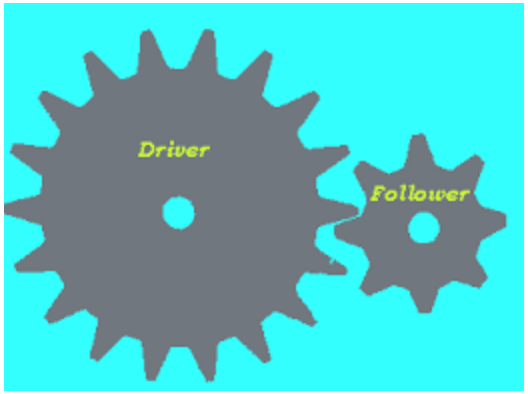
Gears – The Purpose



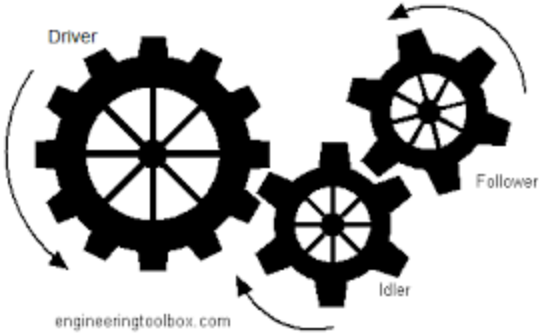
Gears are generally used for one of four different reasons:

- 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

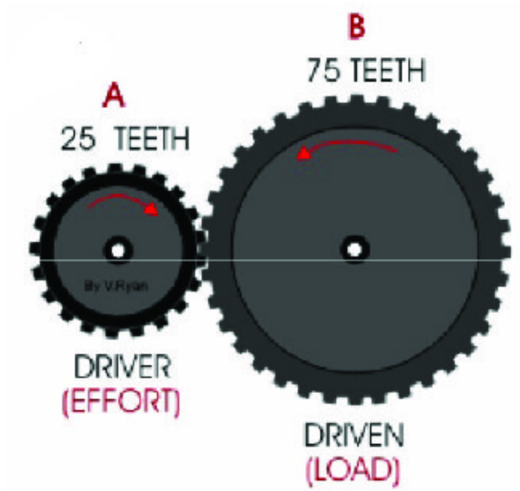
Gear System



- Compound Gears



Gear Ratio



$$\frac{\textbf{Driven}}{\textbf{Driving}} = \frac{75}{25} = \frac{3}{1} \longrightarrow \mathbf{3:1}$$

PROGRAMMING FUNDAMENTALS

Creating a successful robot

- Creating a successful robot takes team effort
  - Between humans and robots
- Humans is responsible for:
  - identifying the task
  - planning out a solution
  - Explaining to the robot what he needs to do
    - To reach the goal
- Robot is responsible for:
  - Following the instructions it is given
  - Thereby carrying out the plan

Creating a successful robot

- Humans and machines do not speak the same language
- Therefore, a special language needs to be created
  - To translate the necessary instructions from human to robot
    - Such as the NXT-G we are working with
  - These are called programming languages

Programming Language

- Instructions written in programming languages are called programs
  - Created by the programmer
- The programmer needs to:
  - identify the task
  - plan a solution
  - Produce a program that the robot will understand
- The robot will run the program
  - And accomplish the task it was given
    - Assuming the program is correct

Programming Language

- What are the challenges?
- The robot only follows the program
  - It does not think by itself
  - Only has the capabilities that the program gives it
  - The programmer is responsible for:
    - designing a solution
    - Programming the robot to follow it

Lab time!

- Let's work with our robots!