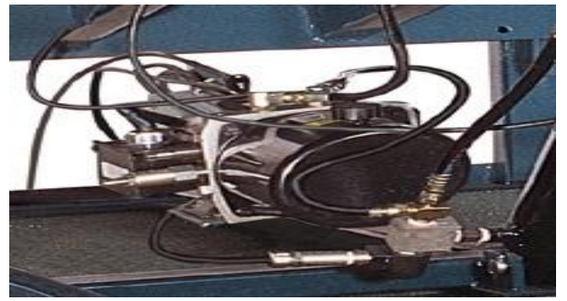
Chapter 3

Muscles: Actuators

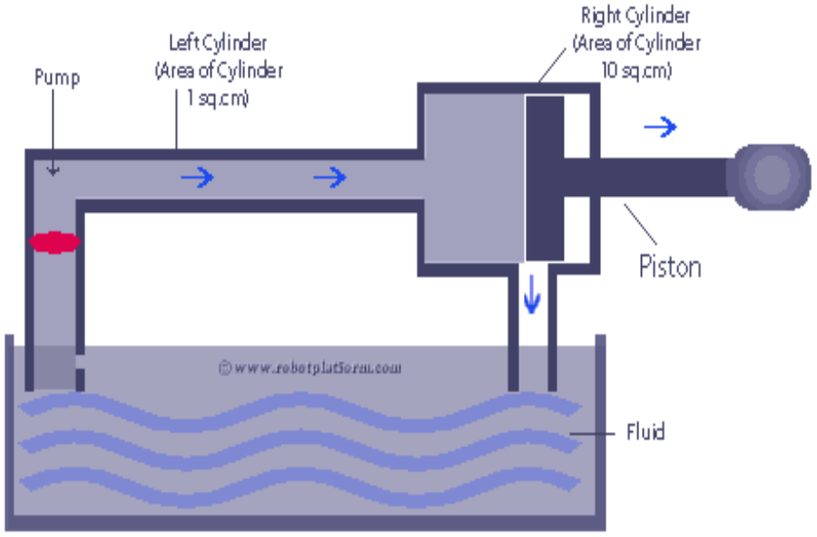
Robot Actuators

- Hydraulic actuators
- Pneumatic actuators
- Electrical actuators
- Others

Hydraulic Actuators

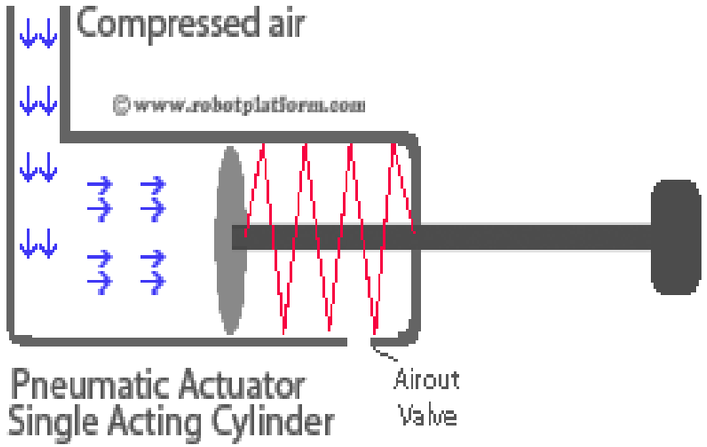


- Drive robot joints by using the pressure of oils, water, etc.
- Use liquid pressure to drive a cylinder
- Use valve to control the flow of the liquid.
- Advantages: High power output
- Disadvantage:
  - Difficult to control -->low accuracy
  - Slow response
  - Big size
  - Dirty
- Early robots used hydraulic actuation



Pneumatic Actuators

- Drive robot joints by the use of air pressure to drive a pneumatic cylinder.
- Advantages:
  - clean and small.
  - cheap
- Disadvantage:
  - difficult to control position precisely
- Mainly used in opening control of robot grippers.



Pneumatic Cylinder

Watch a video

5-1 Actuators 1

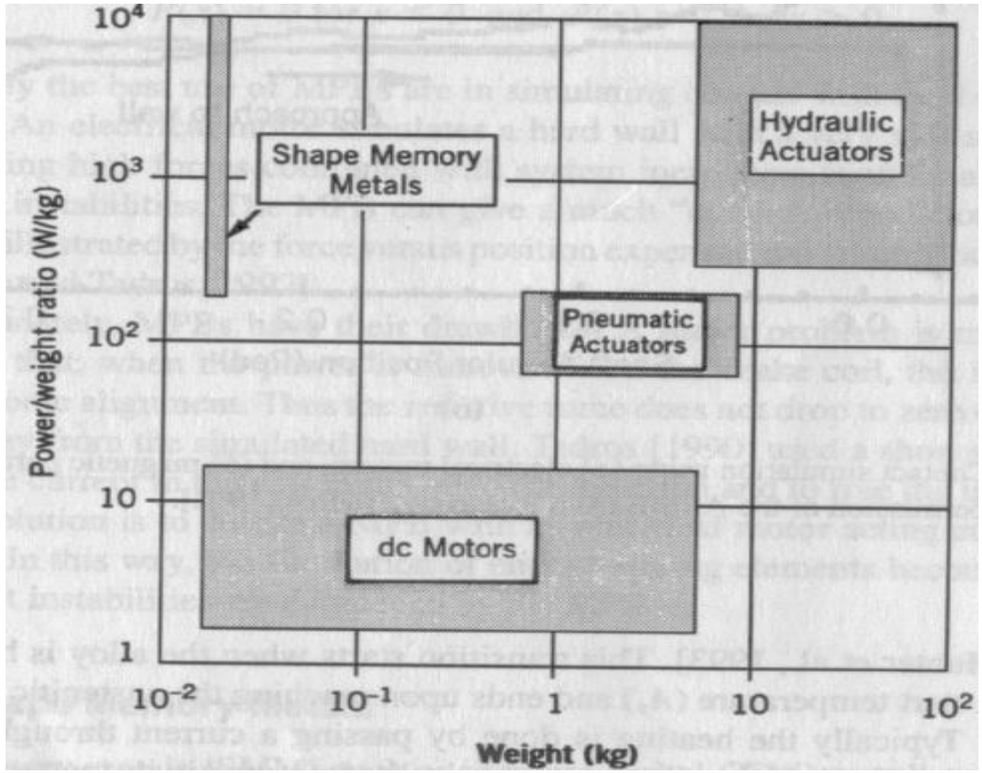
5-6 Pressure and flowrate

Mathematical Relations

$$Force\ (F) in\ Newton, N = Pressure, P, in\ Pa\ \times Area\ in\ m^2$$

$$Flow\ rate, Q = velocity\ in\ \ m/sec\ \times area\ in\ m^2$$

Power/Weight Ratio



Electrical Actuators

- Stepping motors, DC motors, AC motors and Servo motors
- Advantages:
  - small size
  - easy to control, high control accuracy
  - fast response
  - clean
- Disadvantages:
  - low power output compared to hydraulic actuators

Watch Videos

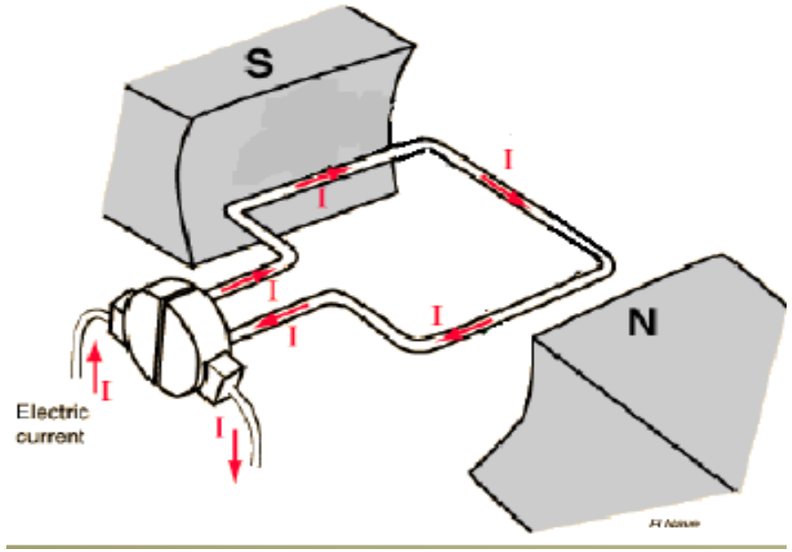
5-4 How does electric an motor work

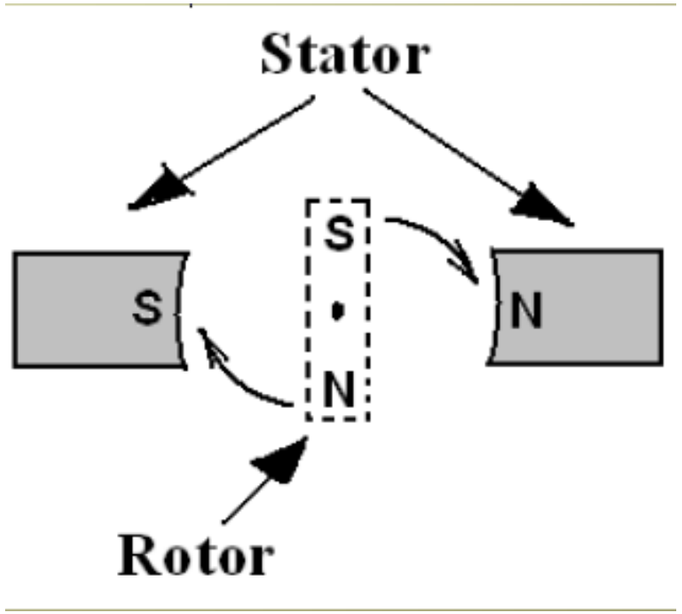
5-2 Electric Motors 1

- The function of commutator ring in an electric motor is to reverse the direction of current flowing through the coil every time coil just passes the vertical position during a revolution. Hence as the direction of the current is reversed, the torque is changed in the direction.
- Brushes are the part of the stator of an electric motor that conduct the electrical current to the rotor.

Introduction to Motors

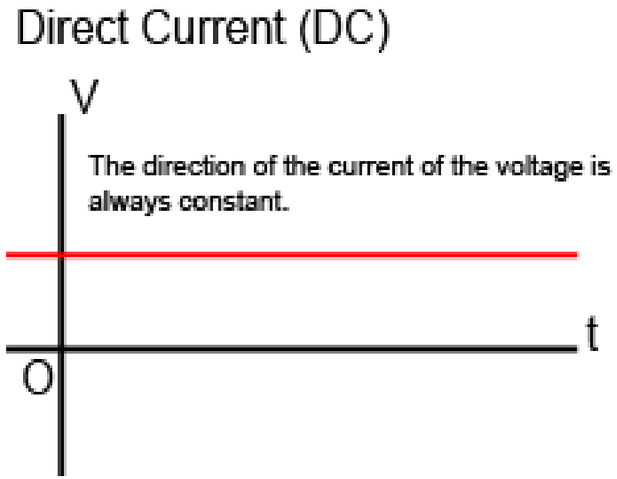
- Motors convert electrical energy to mechanical energy (rotation of motor shaft).
- The magnetic force turns the rotor of a motor.
- The speed of the motor can be controlled by changing the supplying voltage.

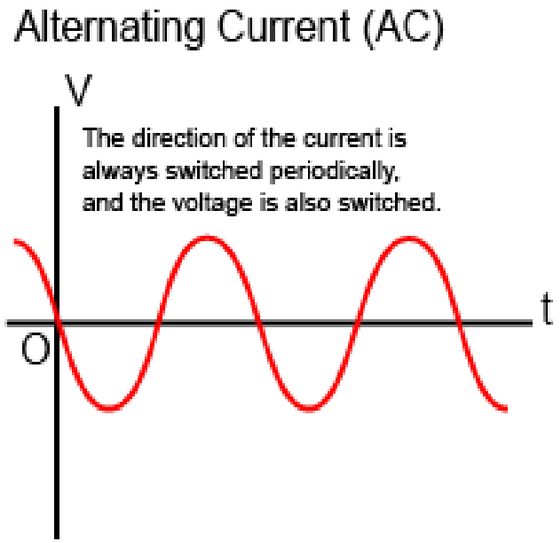




Direct Current (DC) and Alternating Current (AC)

- The types of sources used in a circuit determine everything about the currents and voltages that we see in the circuit.
- DC → does NOT change with time.
- DC sources lead to circuit current, voltage, and power that are constant – unchanging with time.
- There a numerous applications for DC circuits, but mostly used to supply power to electronic devices.
- AC → Everything else, i.e. anything that does change with time.
- square waveforms, sinusoids, triangle waveforms





DC Motors

- Input: Direct current (DC) or voltage
- By changing the excitation currents to control the rotational speed.
- Simple and easy in design
- cheap

AC Motors

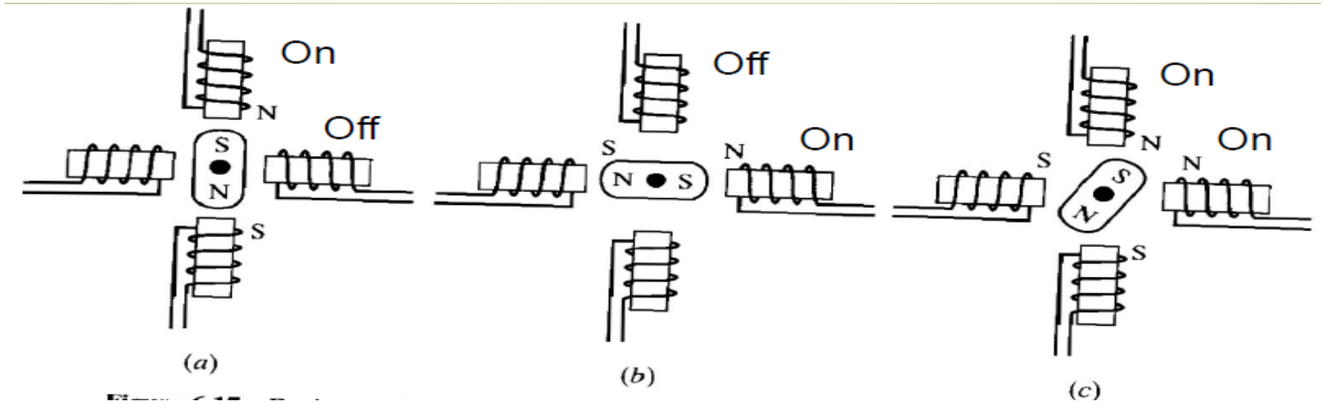
- Input: Continuous alternating current (AC) or voltage.
- Working principle: Similar to that of DC motors.

Stepping Motors

The input pulse of a stepping motor

- A stepping motor converts electrical pulses into specific rotational movements.
- Input: a pulse train
- Output: rotation of the motor shaft in small discrete steps.

- Rotator is a permanent magnet
- Coils in the stator are turned on and off to rotate the stator
- As the coils on stators are turned ON/OFF, the rotor rotates to align itself with the magnetic field.



Servo Motors

- Servo motors can rotate the motor shaft to a specified angular position.
- Input: coded signals
- Output: a specific angular position.

Torque Calculation

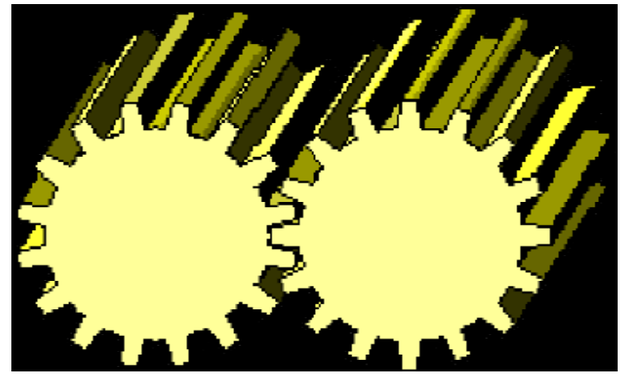
5-3 Rotary Actuators

https://www.youtube.com/watch?v=AXV8dKb9_Dg&list=PL6FPxL5CnQeV83TAH2wk18ieaU78ruwU9

Motion Transmission

- Why do we need a motion transmission mechanism?
  - transfer motion from one type to another
  - Change direction
  - Change speed of motion
  - Deliver big force

- Gears are most commonly used transmission devices in robots
- Gears are wheels with teeth.
- Gears are used to transfer motion or power from one moving part to another.

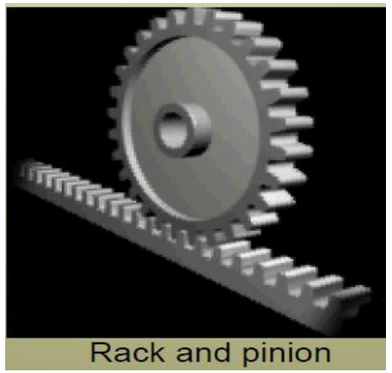


Motion Transmission with Gears

- Spur gears:
  - Change speed of rotation.
  - Spur gears are the most common type of gears.
  - They connect parallel shafts.

Motion Transmission with Gears

- Pinion and worm gear:
  - Change the rotation direction by 90 degrees;
  - deliver big torque.

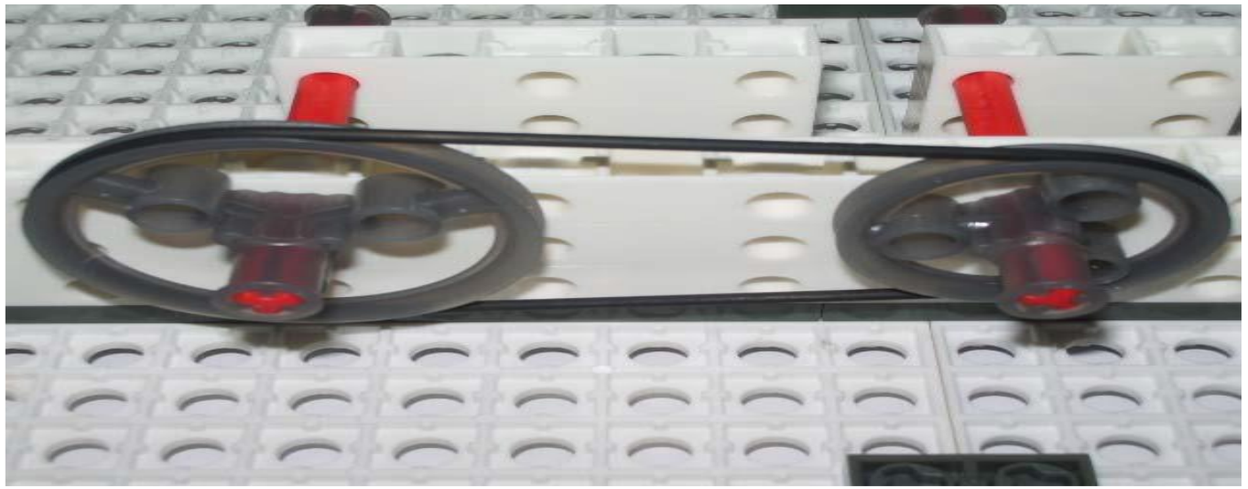

Rack and pinion

Motion Transmission with Gears

- Bevel gears:
  - Change in the axes of rotation of the respective shafts, commonly 90˚.

Motion Transmission with Belt

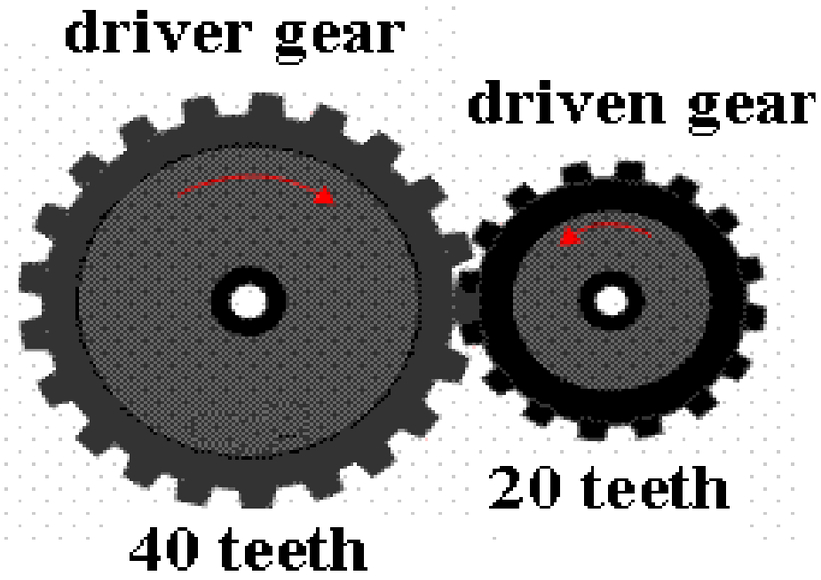
- Belt drive:
  - Enable the transmission of power between shafts by means of a belt connecting pulleys on the shafts.
  - Belt drive is simple, quiet and economical.



Gear Ratio/Velocity Ratio

It is the ratio between the rotational speeds of the meshing gears.

$$GearRatio = \frac{number\ of\ teeth\ on\ driven\ gear}{number\ of\ teeth\ on\ driver\ gear} = \frac{Radius_{driven}}{Radius_{driver}}$$



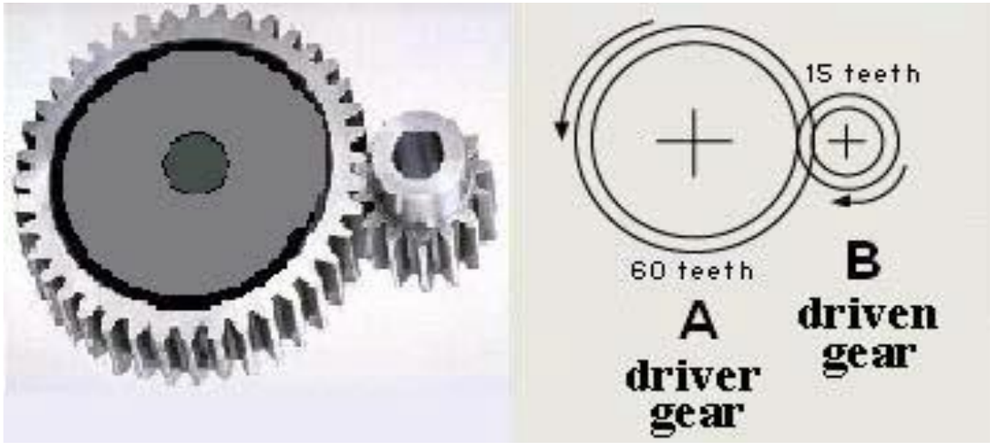
$$gr = \frac{20}{40} = \frac{1}{2}$$

Rotation Speed Vs Gear Ratio

- Relationship between rotation speed and gear ratio

$$\frac{speed_A}{speed_B} = gear\ ratio = \frac{Radius_B}{Radius_A}$$

If the gear B is revolving at 200 rpm (revolutions per minute), the output speed of gear A is:



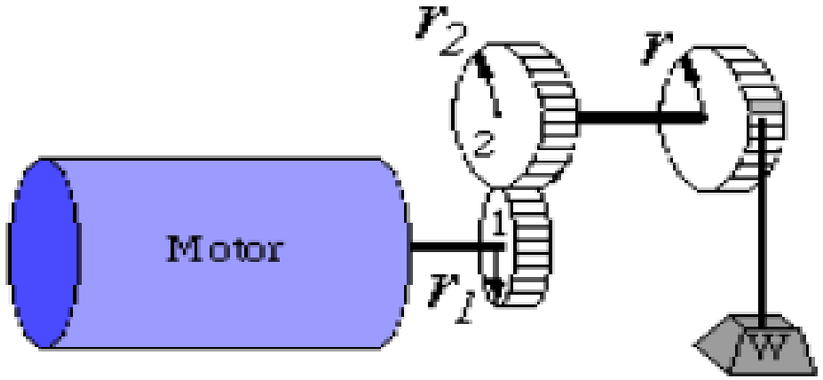
$$speed_A = \frac{Radius_B \times speed_B}{Radius_A} = 50\ rpm$$

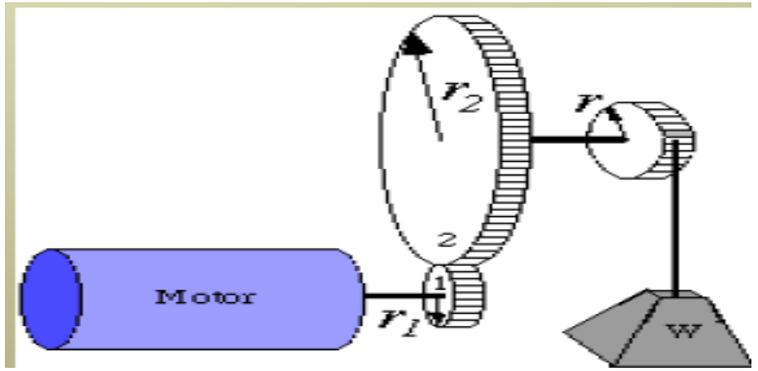
Torque Vs Gear Ratio

- Relationship between torque and gear ratio

$$\frac{torque\_load}{torque\_motor} = gear\ ratio = \frac{Radius_2}{Radius_1}$$

- For a motor with a larger gear ratio, it can lift larger object.





Watching a Video

5-5 Gearbox