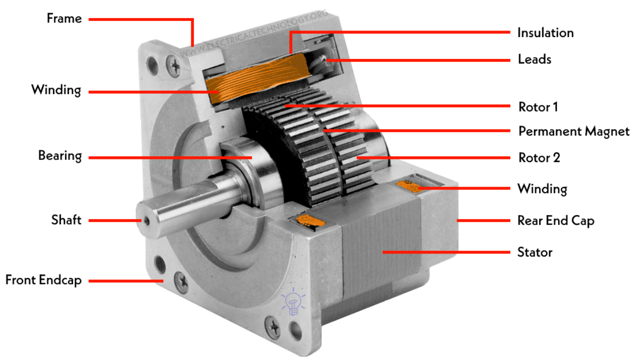
Degrees of Freedom and Range of Motion

Actuators Outputs

- **Linear Actuators**: Produce straight-line motion (e.g., hydraulic pistons, lead screw actuators).
- **Rotary Actuators**: Produce rotational motion (e.g., motors, rotary solenoids).
- **Combination Actuators**: Use mechanisms like cams or gears to combine motions.

Electric Actuators - Motors

- **Purpose:** Convert electrical energy into mechanical movement (rotation or motion).
- **How they work:** When an electric current flows through a coil inside a magnetic field, it produces a force (the motor effect) that makes the shaft turn.
- **Common Types:**
  - DC Motors – simple, rotate when powered; speed changes with voltage.
  - Stepper Motors – rotate in precise steps, useful for positioning.
  - Servo Motors – allow controlled angle or position movement.
- **What happens when voltage increases:**
  - More current flows → motor spins faster or with more torque (depending on type).

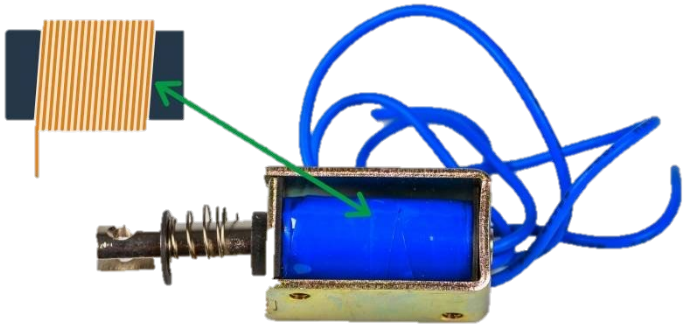


A stepper motor
Output – Rotary
Input – Power & Control Signal

An electric motor
Output – Rotary
Input – Power

Electric Actuators - Solenoid

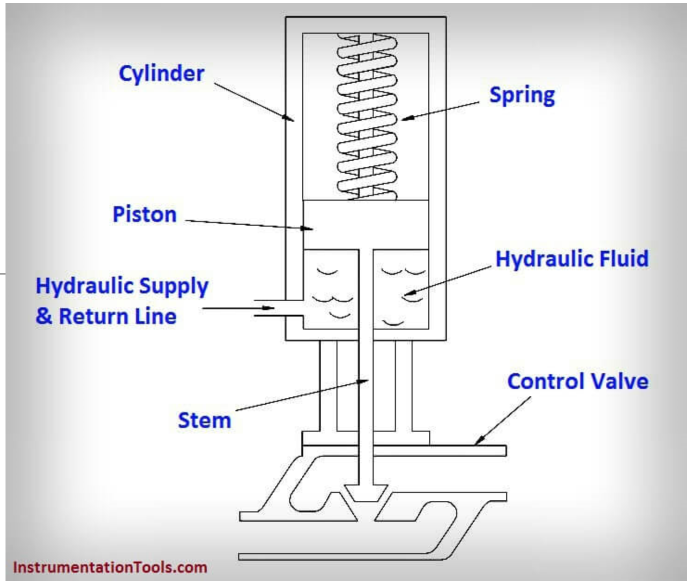
- **Purpose:** Convert electrical energy into a linear (straight-line) pushing or pulling motion.
- **How they work:** A coil of wire creates a magnetic field when current flows. This magnetic field pulls or pushes a metal rod (plunger) inside the coil.
- **What happens when voltage is applied:**
  - Current flows through the coil → magnetic field is created → plunger moves in or out.
- **Types of Solenoids:**
  - Pull-type – plunger is pulled into the coil.
  - Push-type – plunger is pushed out when activated.



An electric solenoid
Output – Linear
Input – Power

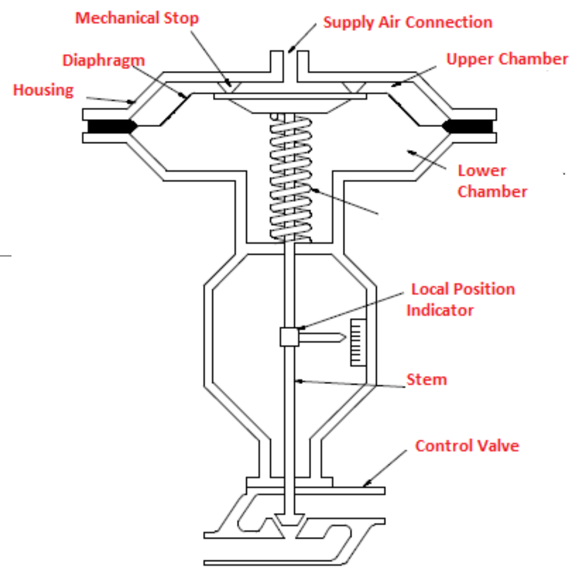
Hydraulic Actuators

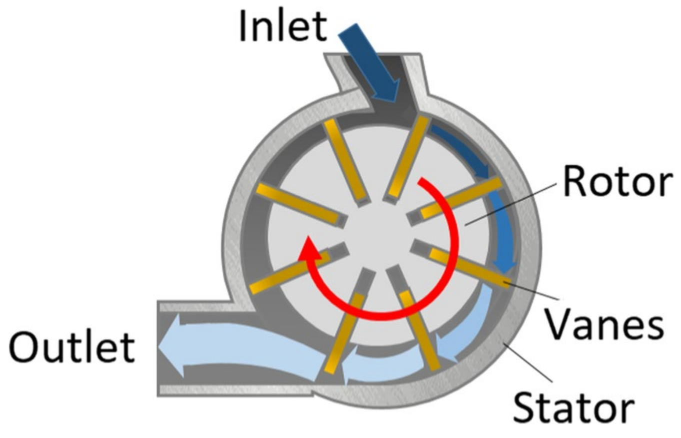
- **Purpose:** Use pressurised liquid (usually oil) to create linear or rotary movement with high force.
- **How they work:** A pump forces fluid into a cylinder or motor. The fluid pressure pushes against a piston (linear motion) or rotates a shaft (rotary motion).
- **What happens when pressure increases:**
  - More fluid pressure → greater force or torque output.
- **Types of Hydraulic Actuators:**
  - Hydraulic Cylinder – produces straight-line (linear) movement.
  - Hydraulic Motor – produces rotary motion.



Pneumatic Actuators

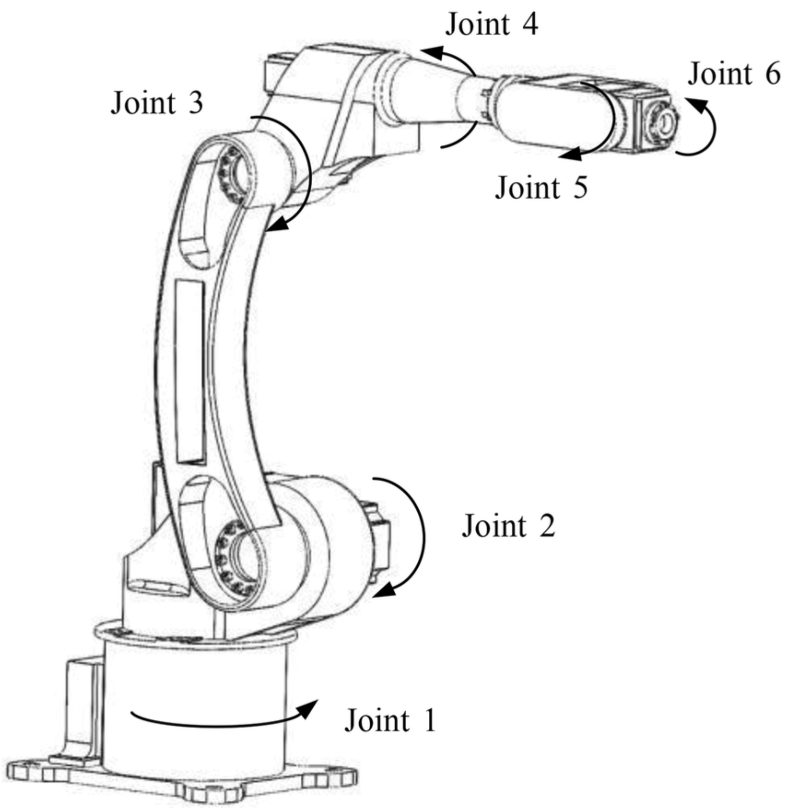
- **Purpose:** Use compressed air to create linear or rotary motion.
- **How they work:** Air pressure is applied to a piston inside a cylinder (for linear motion) or to a vane/rotor (for rotary motion). The expansion of compressed air pushes the actuator into movement.
- **What happens when air pressure increases:**
  - Higher pressure → stronger movement or force output.
- **Types of Pneumatic Actuators:**
  - Cylinders – provide straight-line pushing or pulling.
  - Pneumatic motors/rotary actuators – provide rotation.





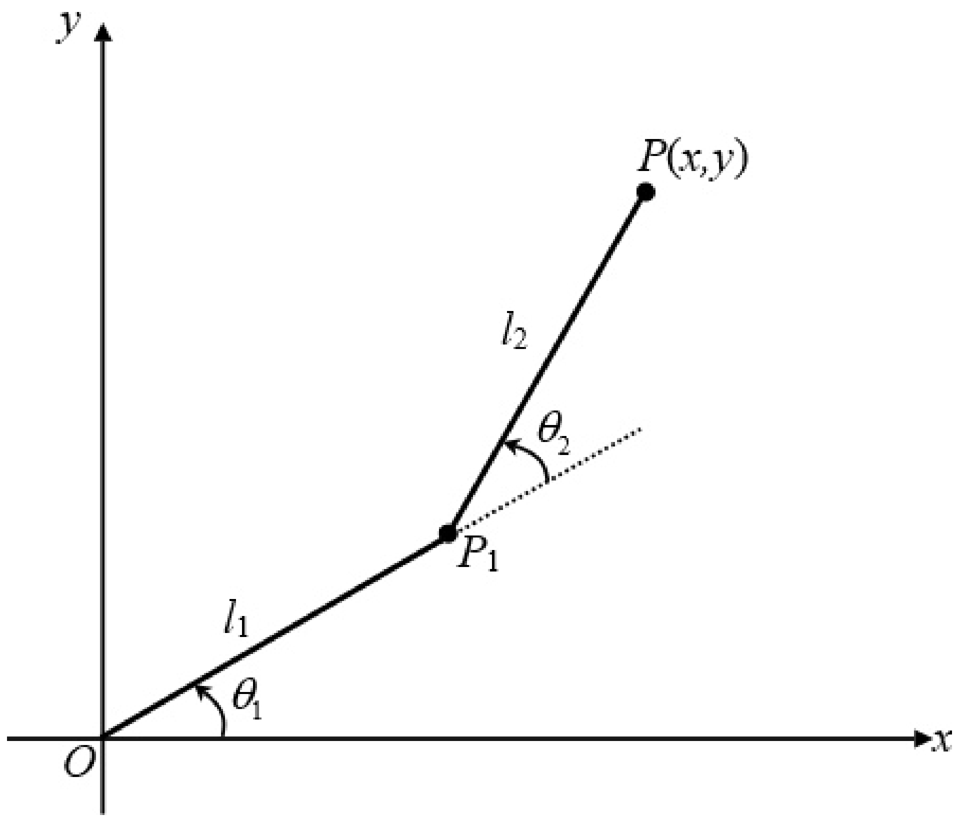
Degrees of Freedom (DoF)

- **Definition**: *The number of independent ways a robot or mechanism can move.*
- *Each DoF = one type of motion (translation or rotation).*
- *More DoF = more flexibility and complexity.*



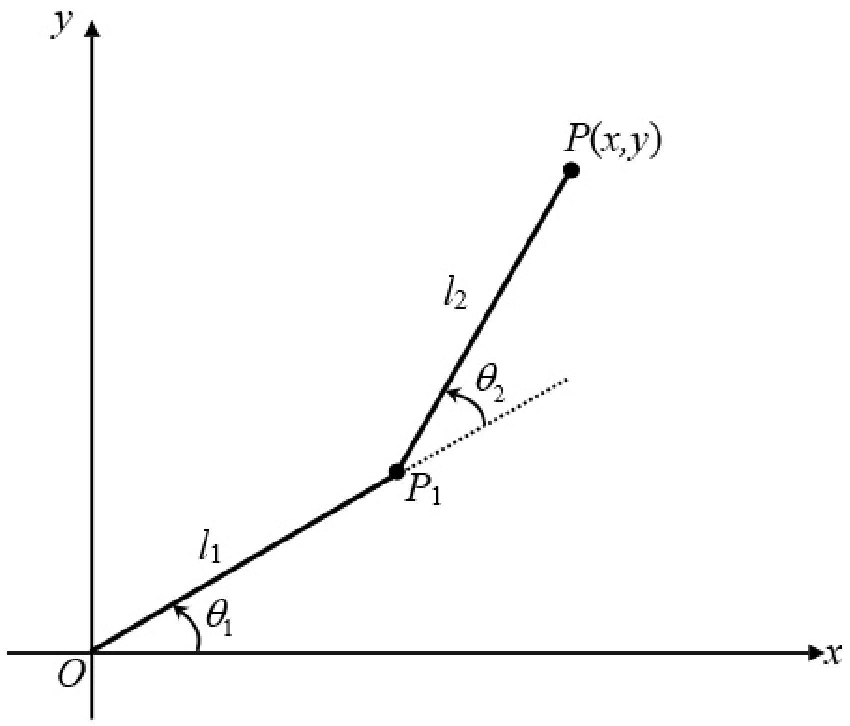
2D Motion

- To understand DoF we will start with 2D motion
- In 2D motion we have 3 possible motions:
  - Move around increasing or decreasing x and y
  - Rotate on a fixed point



2D Motion

- So, for a robot arm which only exists in 2d space its joints can either:
  - Extend and retract linearly changing x or y
  - Rotate around a fixed-point changing x and y of a different part of the arm



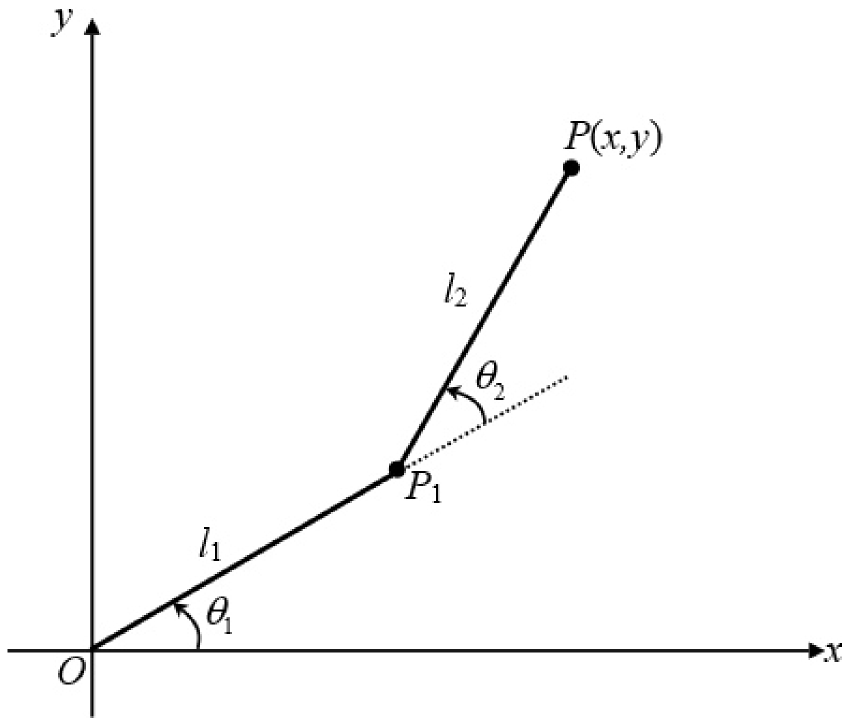
2D range of motion

- So now we can explain the possible ways the whole arm can move

- Each joint in our 2D arm has a limited range of movement:

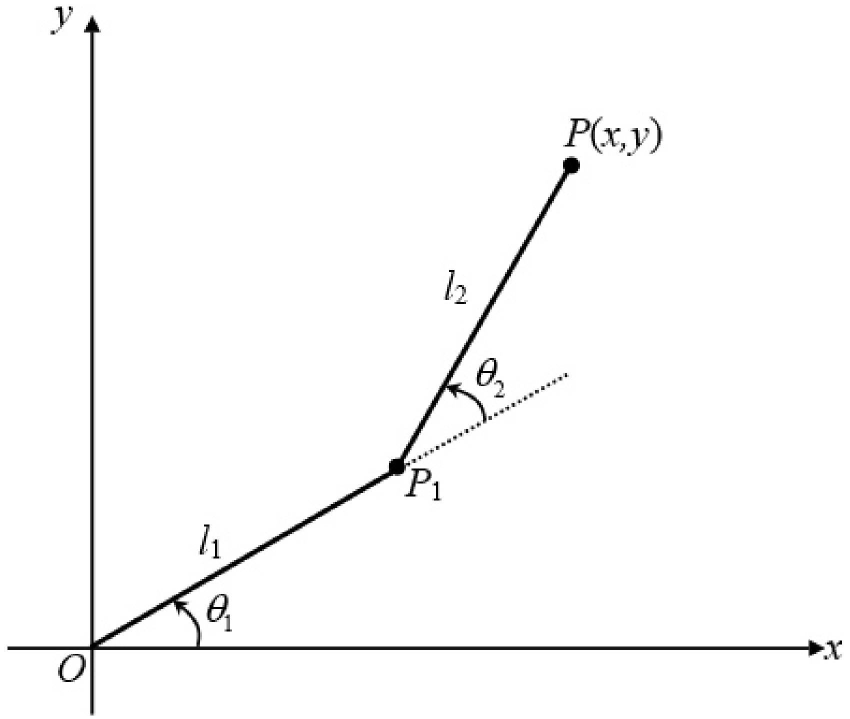
  - A limited extension length for a piston in x and y

  - A limited rotation based on motor limits or collision with other parts of the arm



2D Degrees of Freedom

- So, for this 2D arm we can simplify it drastically into a collection of joints
- And for each joint which makes up the arm we can take its motion and record it as a degree of freedom
- Typically, one joint = one DoF (but not always; some joints allow more than one type of movement).



2D Degrees of Freedom

- The arm on this slide has 2 joints (θ_1 and θ_2)
- Each of these joints only has rotational motion
- So, the arm has 2 joints, each with 1 motion
- This means the arm has 2 DoF