Week 11

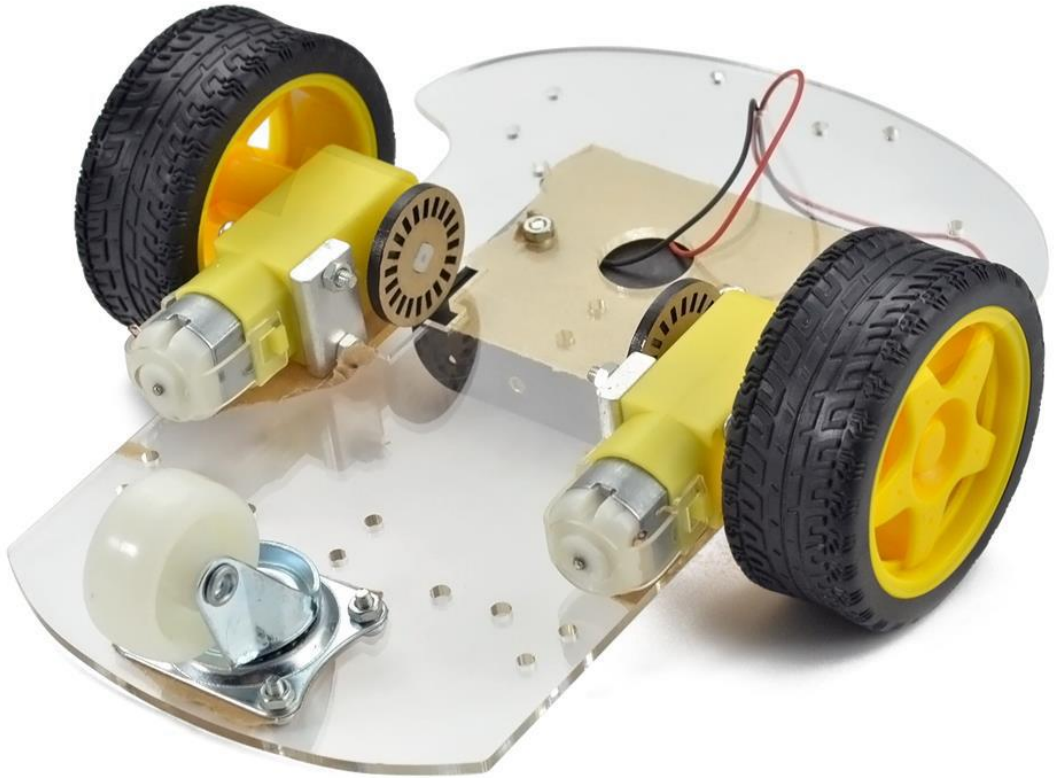
Module 5: EE100 Course Project
Making your first robot

Dr. –Ing. Ahmad Kamal Nasir

Office Hours: Room 9-245A

Tuesday (1000-1100)

Wednesday (1500-1600)

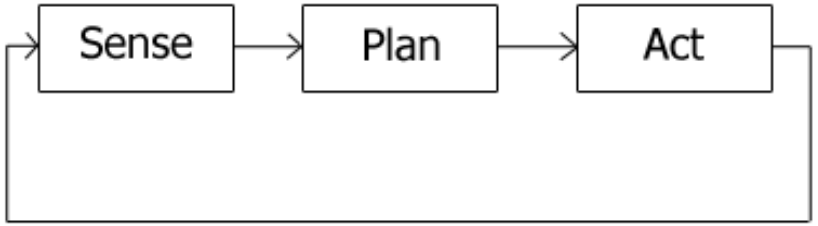


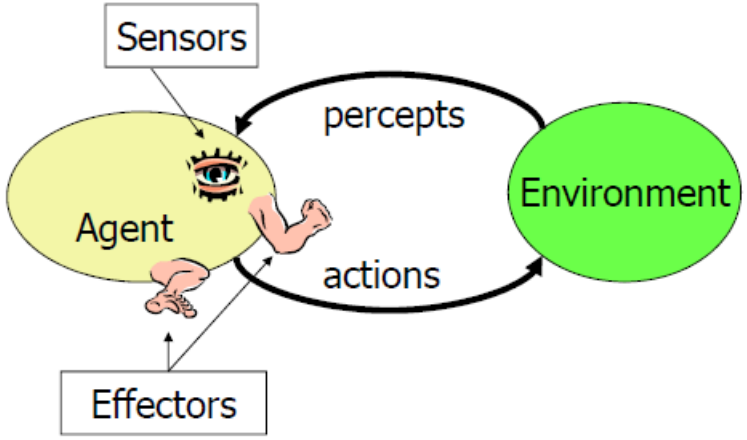
Course Project: Wall-Follower Robot

- Week 1
  - Introduction to Mobile Robot components
  - Teams Registration: (Max) 4 persons per group
  - In-Lab (Deliverable):
    - CAD Model (Parts + Assembly Drawings) for your mobile robot (2 Persons)
    - Solder and Debug your circuits using provided parts (2 Persons)
- Week 2
  - Introduction to Robot *Sensors* and Actuators and Programming
  - In-Lab: Hands-on programming of mobile robot
  - **Competition Rules**
- Week 3
  - Calibration and Testing of your Robot in Field
  - Final Competition
  - Submit Report (Template Provided)

What are Robots?

- A mechanical system that has sensing, computation and actuation capabilities.
- A robot is an intelligent connection of perception to action.





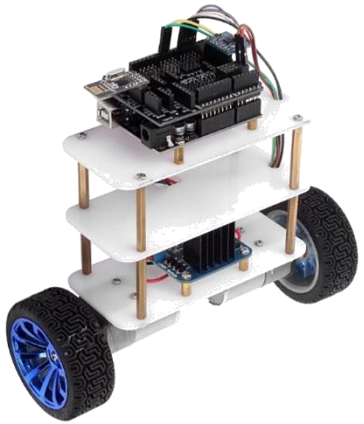
- A robot is an autonomous system which exists in the physical world, senses its environment and acts in it to achieve some goals.

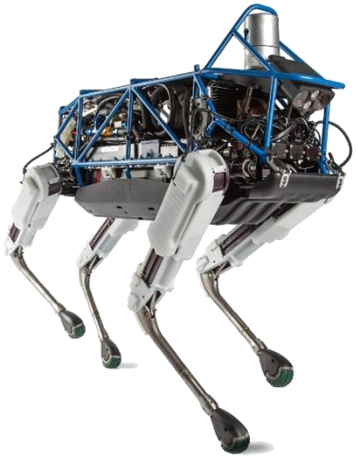
Mobile Robot: Chassis

Locomotion techniques for mobile robots

Two Wheel **Vs** Four Wheel **Vs** Legged Robot

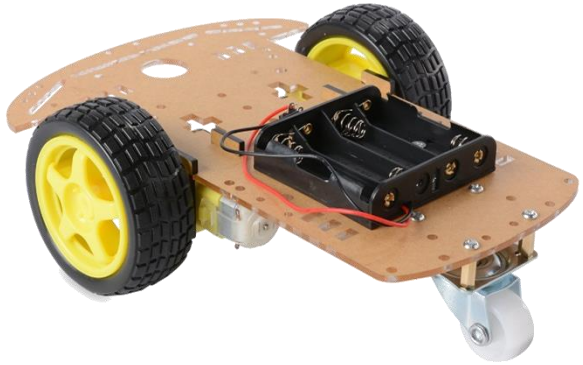
- Two Wheel
  - Advantages:
    - Small Size
  - Disadvantages:
    - Instability in off-road condition
- Four Wheel
  - Advantages:
    - More weight carrying capacity
    - Efficient locomotion
  - Disadvantages:
    - Complexity of steering control
    - More space requirement for turning(Ackerman)
- Legged
  - Advantages:
    - Suitable for all type of terrain
  - Disadvantages:
    - Greater mechanical complexity

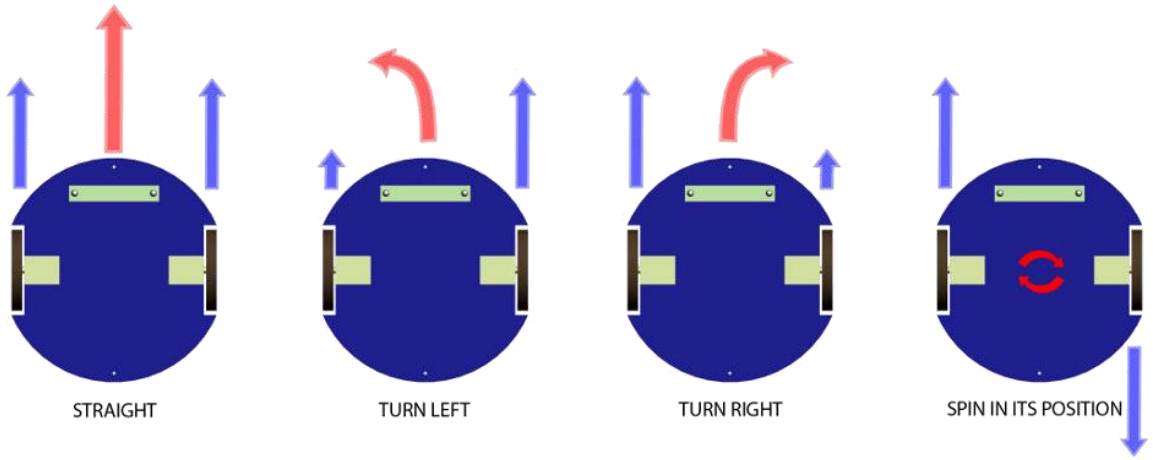




Differential Drive

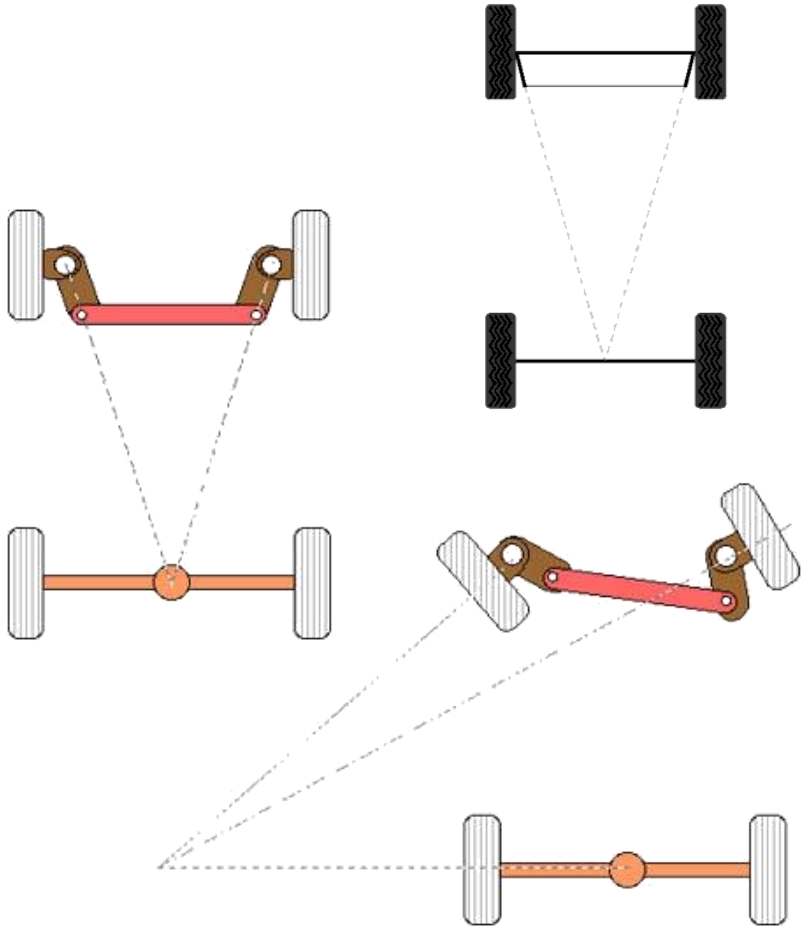
- Easier mechanical construction
- Two powered wheel and one/two idler wheel
- Navigation using motor speed and direction control
- Statically and dynamically stable
- Can rotate about a point
- Commercial robots are Segway, IRobot Create.
- **Can’t move sideward**





Ackermann Drive

- Car like steering mechanism
- Both steered wheels are at different angle
  - Otherwise slip occures
- Single Ackermann steering
  - Only front wheels are steerable
- Double Ackermann steering
  - Both front and rear wheels are steerable
- Complex mechanical construction
- **Can’t move sideward**
- **Can’t rotate on a point**



Omnidirectional Robot

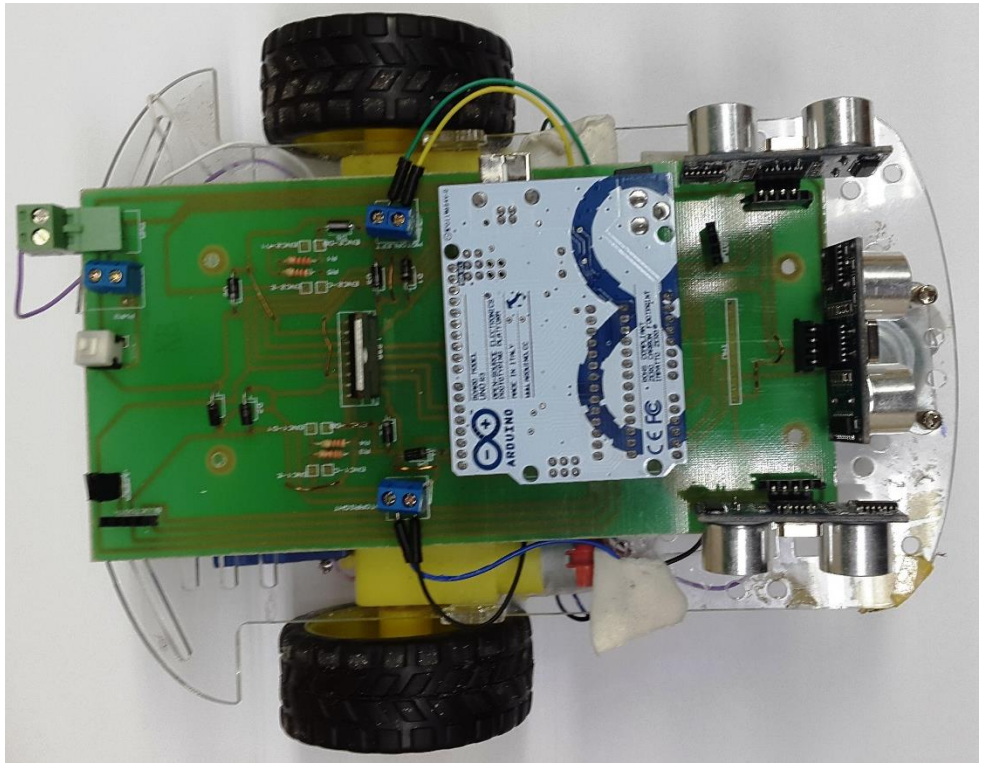
- All four wheels are powered and steerable
- Roller on the circumference of wheel 45° angle w.r.t wheel plane
- Robot can move sideward
- Robot can rotate at a point
- Swedish engineer worked at Mecanum
- US Navy bought the patent to built truck that can maneuvers on tight spaces of air craft carriers.
- **Expensive wheels**
- **Not suitable for off-road applications**

Legged Robot

- Natural because can operate on both flat and rough surface
- More degree of freedom, therefore, **more mechanical complexity**
- On flat surface wheeled locomotion is much more efficient
- On rough surface wheeled locomotion suffers more rolling friction
- Bipedal locomotion can be approximated by a rolling polygon
- Navigation depends on number of legs and configuration of each leg (gait)
- Walking, Galloping, Jumping, Running,

Your Robot Design

- This final robot assembly contains
  - 2x motors
  - 2x motor mounts
  - 2x driven wheels
  - 1x castor wheel
  - 1x Acrylic Chassis
  - 3 ultrasonic sensors
  - 1 battery
  - 1 Arduino microcontroller
  - PCB with Motor controller and other electronics components
  - Some nuts, bolts and fasteners

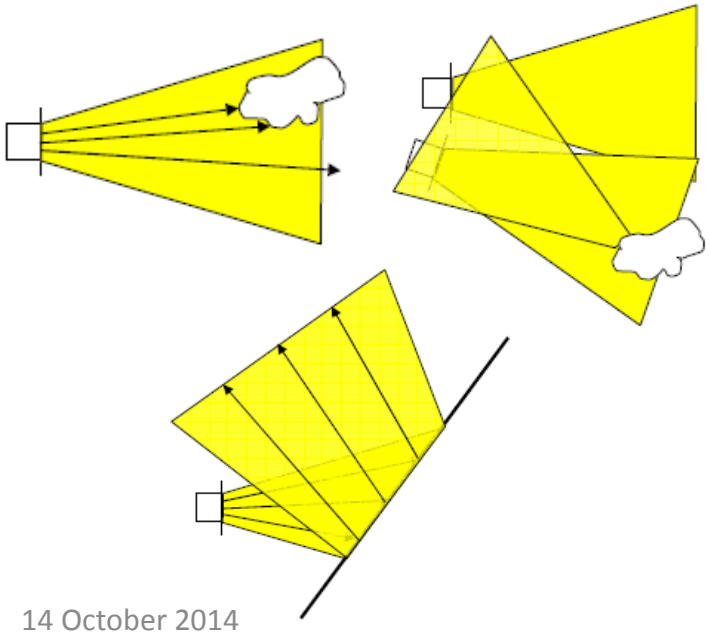


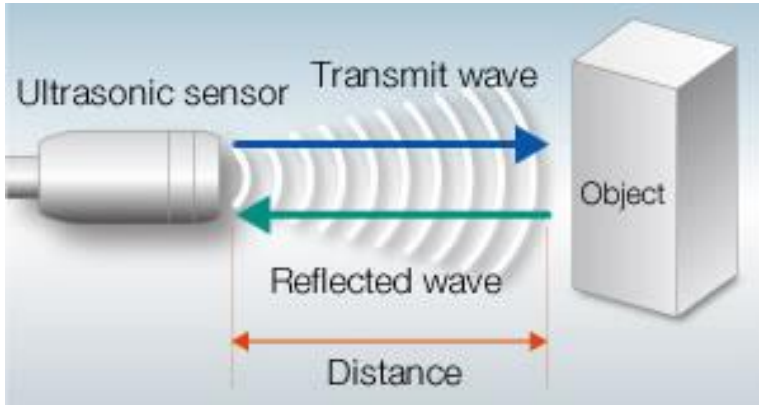
Mobile Robot: Sensors

Measuring robot's internal or environmental parameters

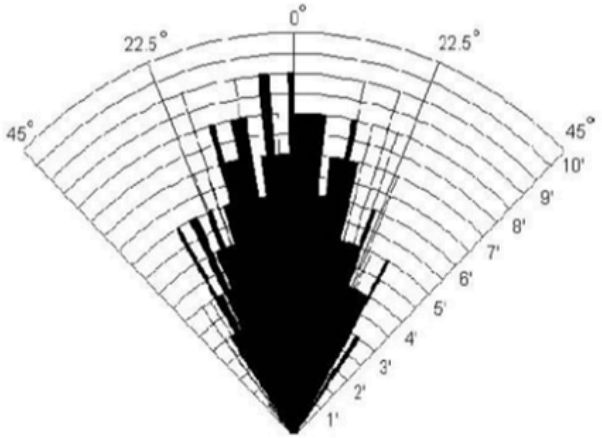
Ultrasonic

- Active time of flight sensor, emit an ultrasound signal and wait until it receive the echo
- Opening angle, crosstalk, specular reflection





$$d = v \times t / 2$$



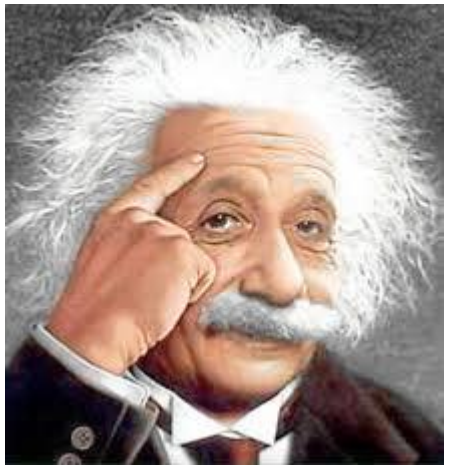
Practical test of performance,
Best in 30 degree angle

Mobile Robot: Microcontrollers

Arduino for sensor data acquisition, actuator controls and computation

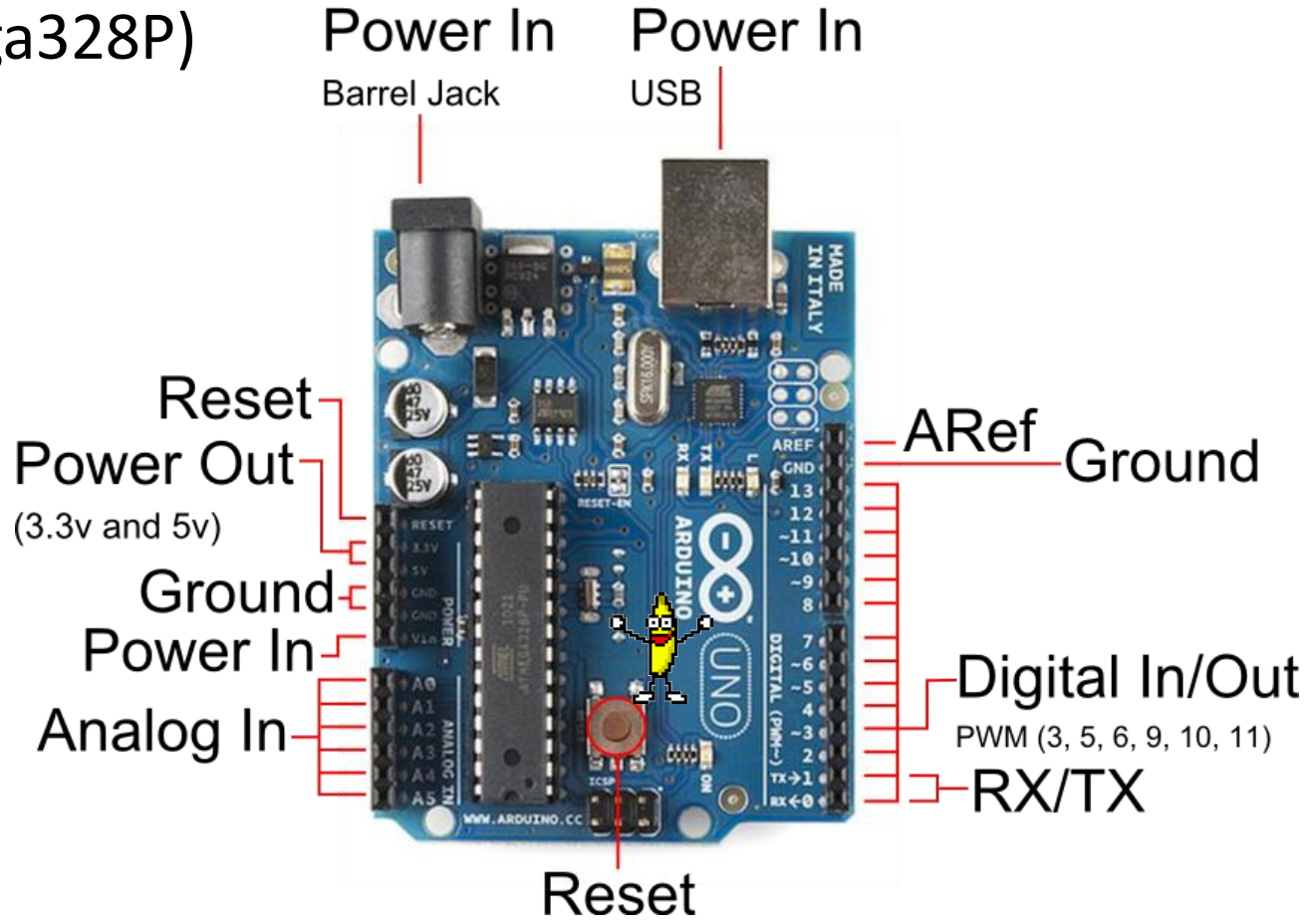
Robot Brain

- Capable of storing and executing your algorithm.
- Can timely execute actions through actuators.
- Can periodically acquire information through sensors.
- Can communicate with computer or other robots.
- Elements of a microcontroller:
  - Pins for digital inputs and outputs
  - Pins for analogue inputs and outputs
  - Pins for priority signals (interrupts)
  - Timers for delays and task scheduling
  - Communication ports/buses



Arduino Uno– Hardware Overview

- 8-Bit Microcontroller (ATmega328P)
  - Clock Speed: 16MHz
  - 32 KB Flash memory
  - 2 KB RAM
  - 1 KB EEPROM
- Operating Voltage, 5V
- 14 Digital I/O
  - 6 can provide 8-bit PWM
  - 20mA per I/O pin
- 6 Analog Inputs
- 1 Serial Port (RX/TX)
- 1 I2C (TWI) Port

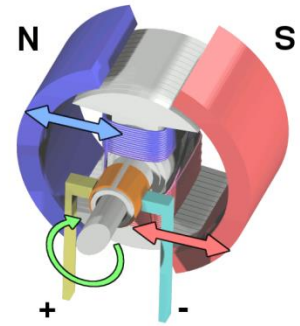


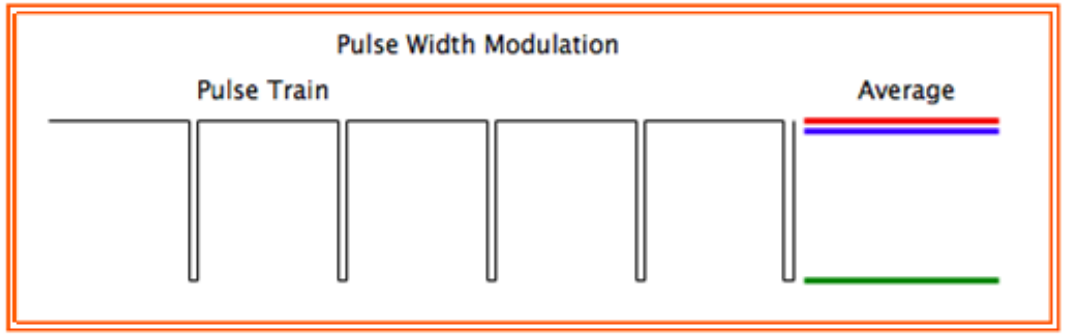
Mobile Robot: Actuators

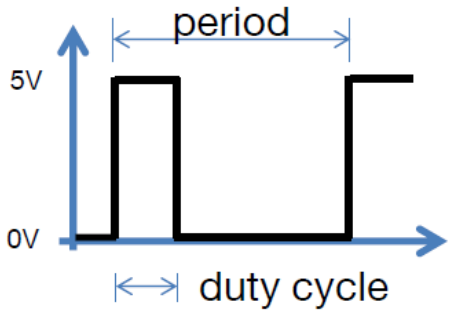
Interaction with environment

How to control a DC brush motor?

- Converts electrical energy into motion
- It has a permanent magnet on outer-side
- A set of coils are attached on the shaft
- A pair of metal brushes that switch power from one coil to another
- More applied DC voltage results into faster shaft rotational speed
- DC Voltage is modulated using PWM (Pulse Width Modulation)







$$\text{duty cycle} = \frac{t_{ON}}{t_{ON} + t_{OFF}}$$

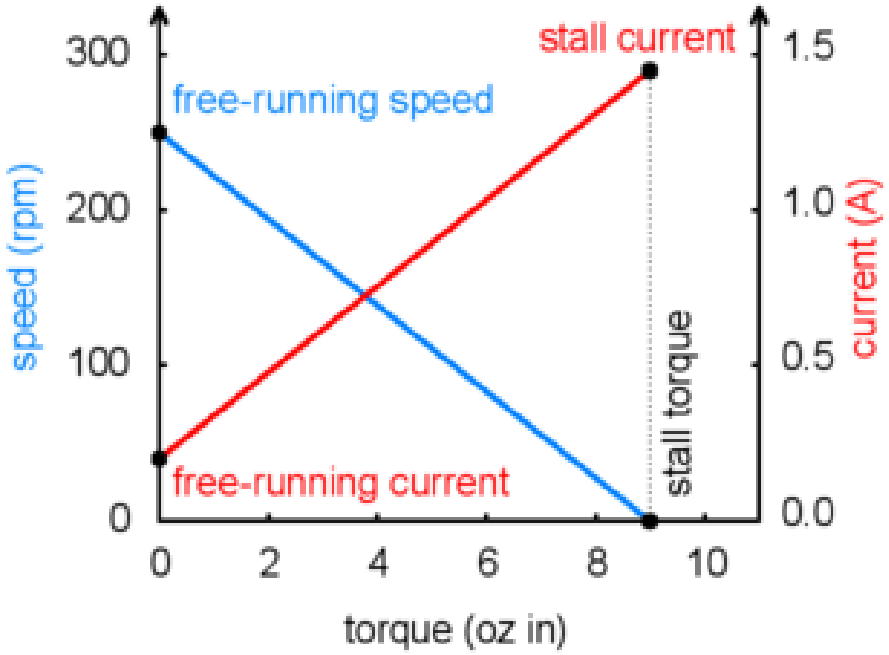
t_{ON} = ON time

t_{OFF} = OFF time

$t_{ON} + t_{OFF}$ = Time period

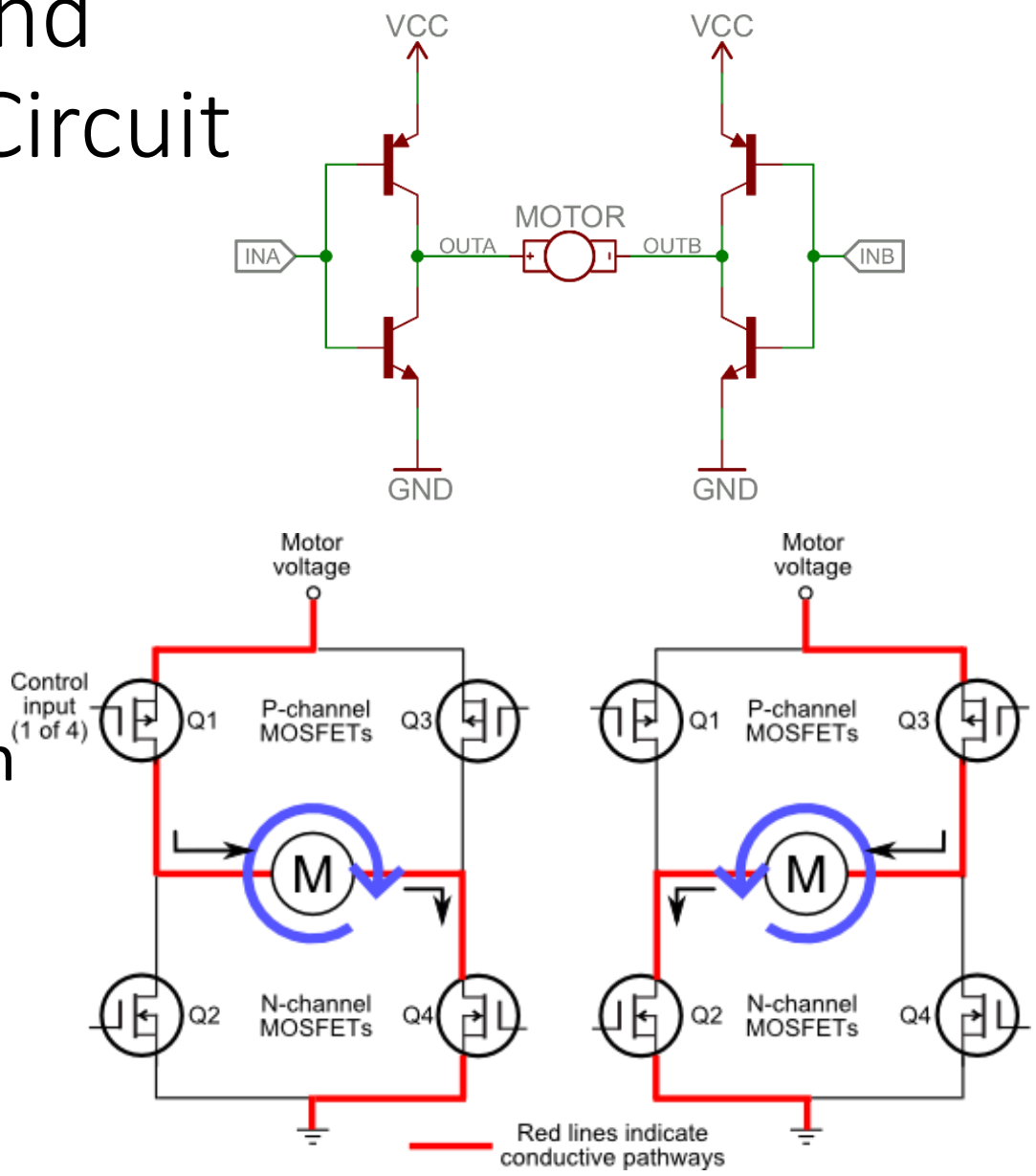
DC brush motor characteristic: **Speed Vs Torque**

- Speed and Torque are used to describe a running motor.
- If one increases then other decreases
- Mechanical Power = Speed X Torque
  - Adding load on motor shaft decreases its speed at the cost increase in output torque
  - Motor power is constant
- Electrical Power = Voltage X Current
- More applied torque requires more current to be drawn by motor
- Gearbox are used to increase/decrease one quantity at the cost of other.



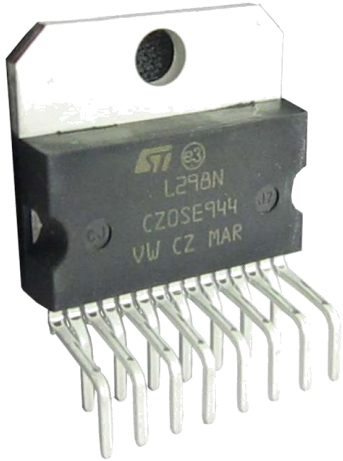
H-Bridge: DC-Motor Speed and Direction Control Circuit

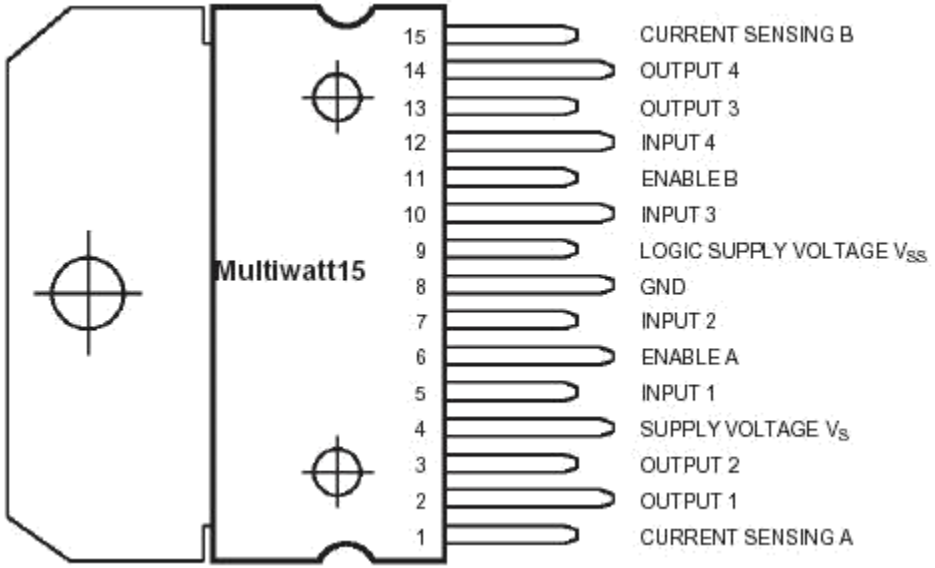
- It is used to electronically change a DC motor speed and direction
- It uses four electronic switches (Transistors) to control motor speed and direction
- When Q_1, Q_4 are turned on while Q_2, Q_3 are turned off, the motor runs in one direction and vice verse
- When a PWM is applied on the corresponding transistors then the motor speed can be controlled.



DC Motor Controller: **L298 Dual H-Bridge**

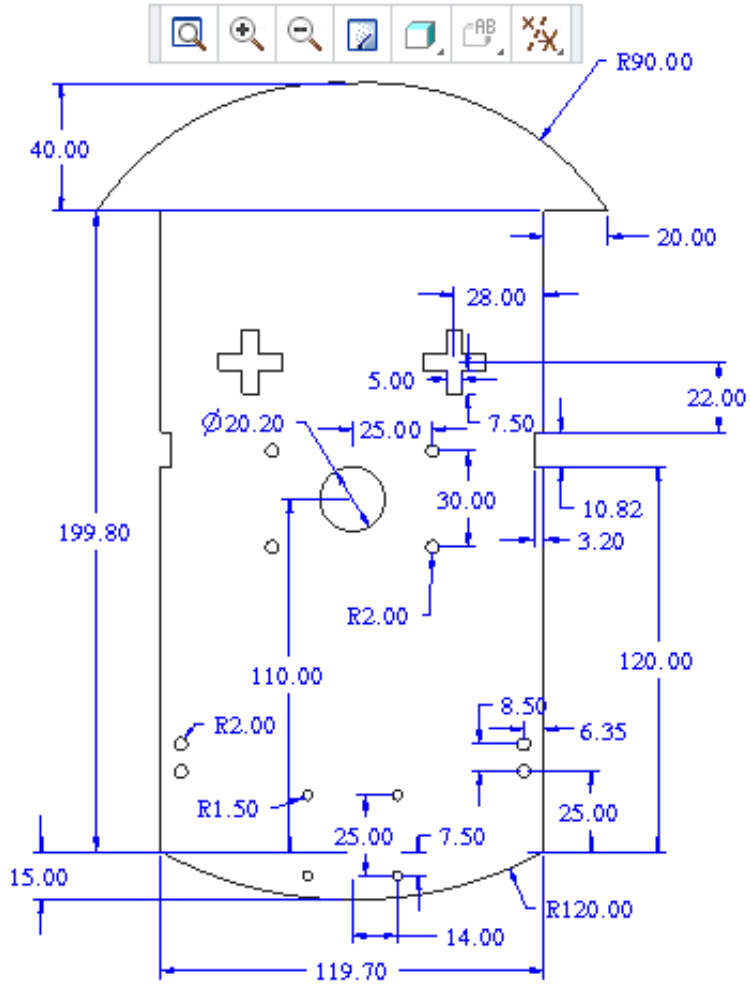
- Controls two DC motors **MotorA/B**
- Motor supply voltage: +5V to +35V
- Peak Current 2A/Motor
- Maximum power consumption (20W)
- Logical supply voltage (+5V to +7V), can be taken from motor supply voltage by “Enable Regulator” jumper
- Control signals voltage range
  - LOW: $-0.3V \leq V_{in} \leq 1.5V$
  - HIGH: $2.3V \leq V_{in} \leq VCC$





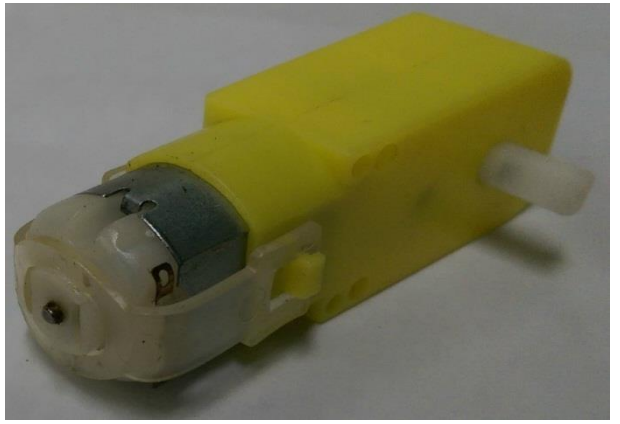
Robot Design: Chassis

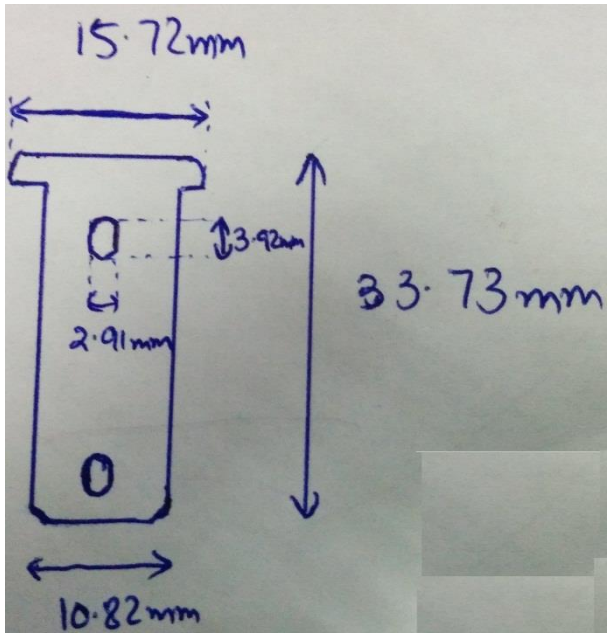
- The chassis will act as base for mounting motors, sensors, battery and circuits
- The chassis is made of 3mm Acrylic sheet

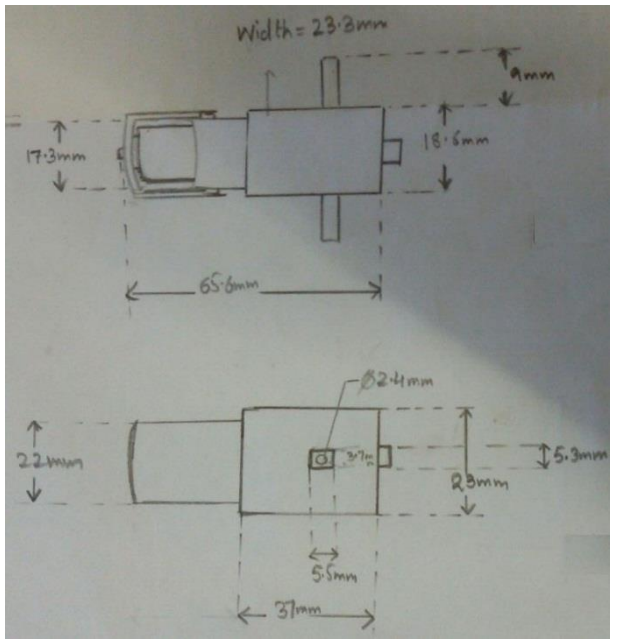


Robot Design: Motors

- Motor will provide the necessary torque to the robot wheels
- There is compromise between motor torque and speed. (Torque decrease as speed increases)
- Two brackets are required to attach motor with robot base.
- A wheel will be attached at the end of motor shaft.
- Two wheel and motor assembly are required to drive the mobile robot.

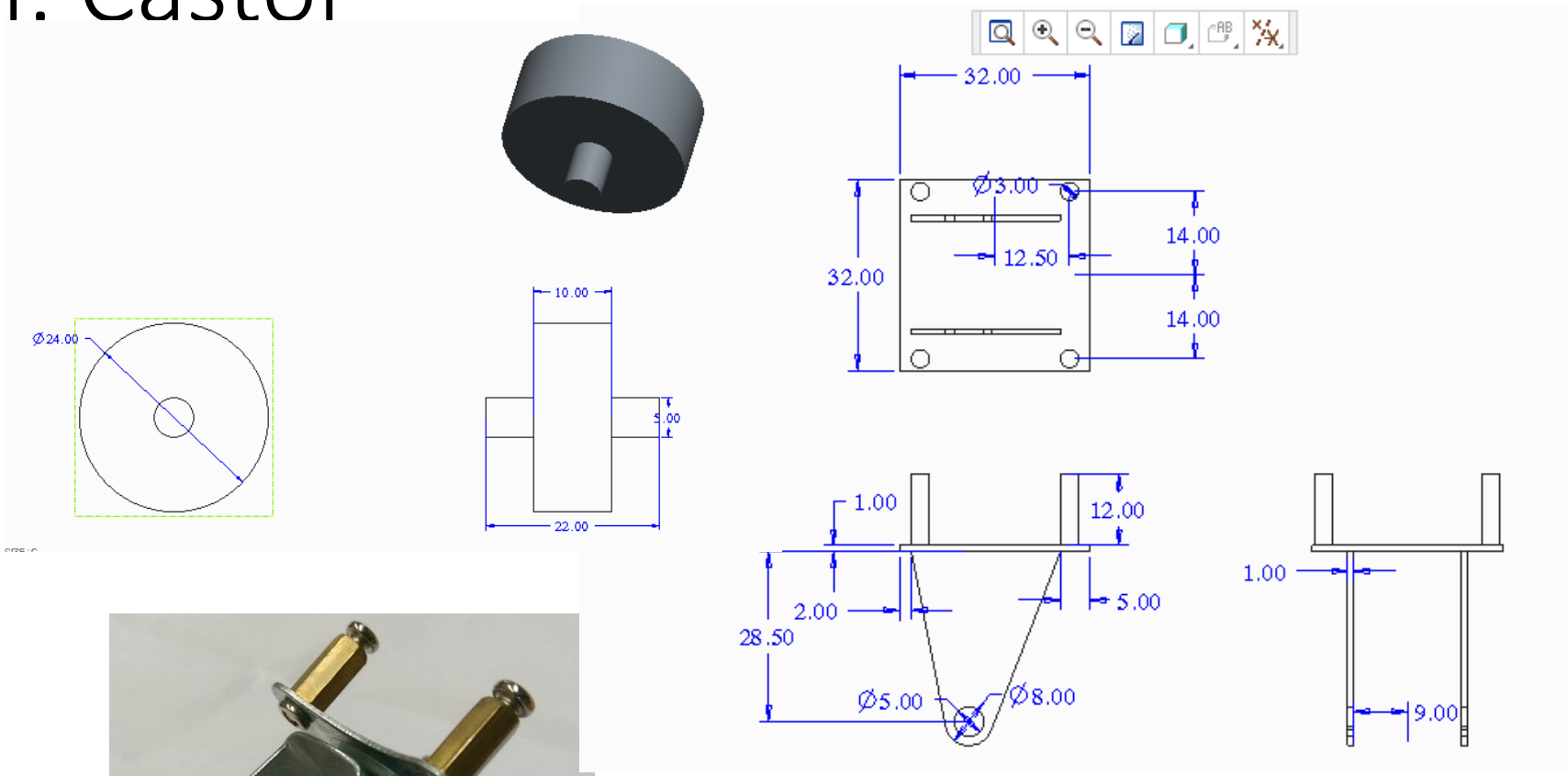






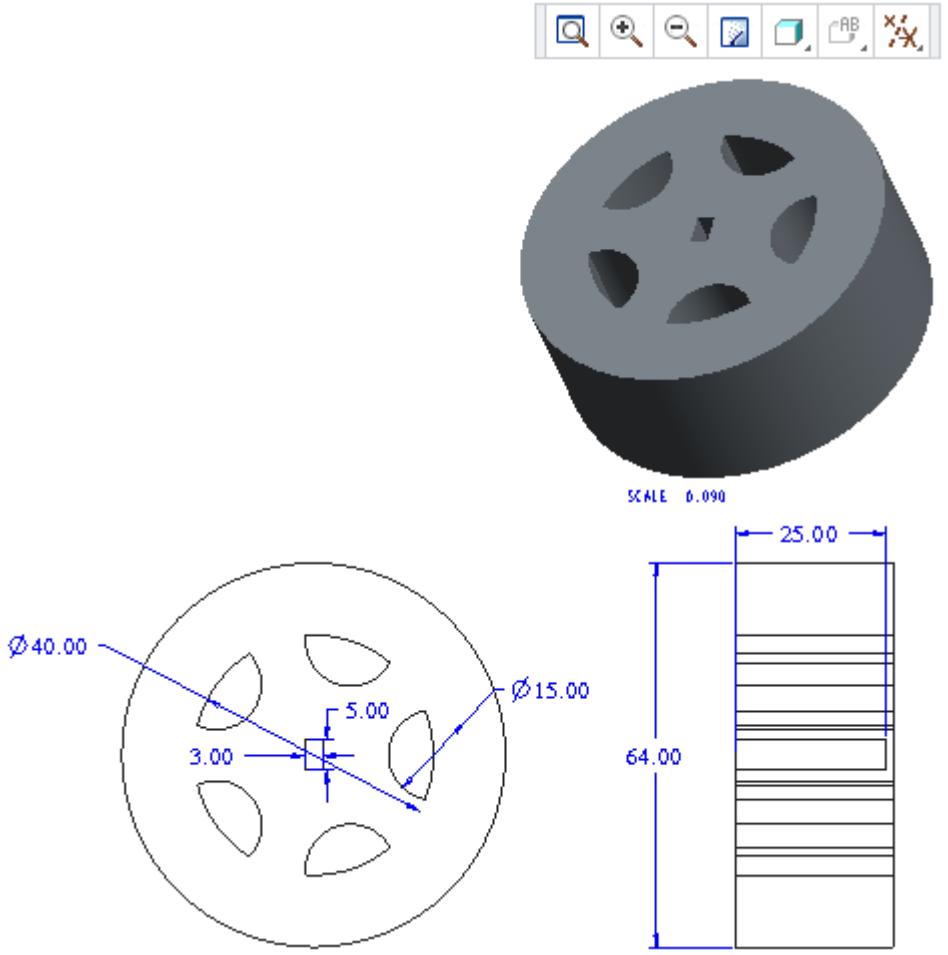
Robot Design: Castor

- At-least three ground contact points are required for stability
- The castor is a non-motored or driven wheel.
- It will not hinder (assumed) the motion of the robot and is used only used to **balance** the robot on ground.



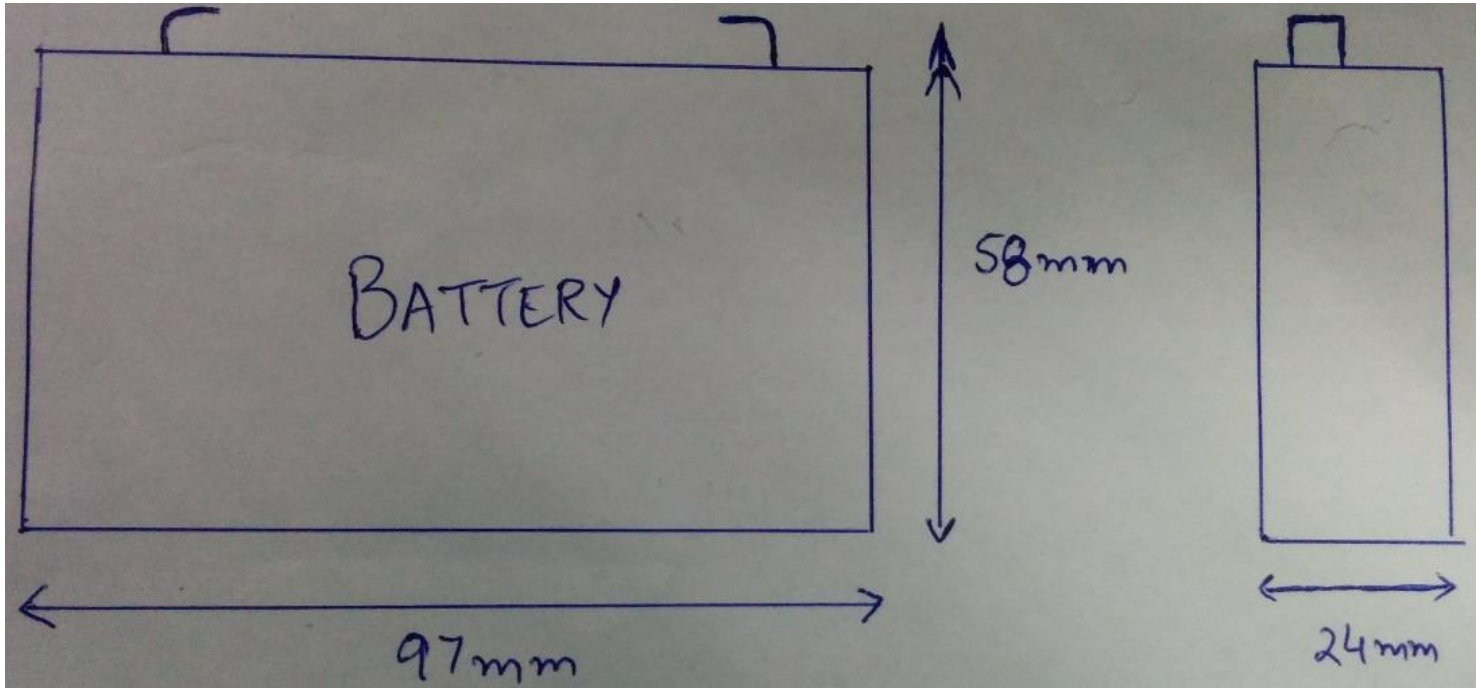
Robot Design: Wheels

- Wheel is rigidly attached at the end of the motor shaft, therefore, there is no relative motion between motor shaft and wheel
- At least two wheels are required to create a differential drive mobile robot.
- Each wheel is separately driven by a DC motor



Mechanical Design: Electrical Components

- Two 4V Batteries connected in series will be used to power the robot



TO-DO:

- Create the Creo part models of the following **(IN-LAB) [Two Persons]**
  - Chassis or base plate
  - DC motor
  - Motor bracket
  - Castor wheel
  - Motor wheel
  - Battery model
  - Circuit model
- Create Assembly drawing of the **(IN-LAB)**
- Assemble PCB of your robot **(IN-LAB) [Two Persons]**
- Assemble robot chassis using provided components **(IN-LAB)**

Please make a tuple of four persons, collect your robot chassis and familiarize yourself with it!

Please Wait, Loading...

Deliverables:

- CAD Model (Parts + Assembly Drawings) for your mobile robot (2 Persons)
- Solder and Debug your circuits using provided parts (2 Persons)