Unit 1

Introduction to Robotics

Robotics and Robots................

Definition: Robotics

- **T**he branch of technology that deals with the design, construction, operation and application of robots. The objective of the robotics field is to create intelligent machines that can assist humans in a variety of ways. A robot is normally designed to assist a human worker.

Definition: Robots

- Robot is formally defined by the International Standard of Organization (ISO) as a reprogrammable multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of variety of tasks.
- They are reprogrammable and multifunctional.

Origin of the word ‘robot’ can be traced in the Czech word ‘*robota*’, which means ‘forced’ or compulsory labor.

What are the four Ds of robotics …......................

Robots Helps Humans in the **Dull, Dirty, Dangerous and Dear Jobs**

Four D’s of Robotics are

- Dull
- Dirty
- Dangerous
- Dear

History: Evolution of Robots

The term "robot" originated from the play **"Rossum's Universal Robots" (R.U.R.)**, penned by the Czech writer Karel Čapek in 1921. In this play, Karel Čapek introduced the term "robot" to refer to mechanical creatures created by a fictional manufacturer, designed specifically to replace human workers.

Origin of the word ‘robot’ can be traced in the Czech word ‘*robota*’, which means ‘forced’ or compulsory labor.

- **What are the laws of Robotics?**

Laws of Robotics:

In 1941 and 1942, **Isaac Asimov** formulated the **Three Laws of Robotics,** and in the process coined the word "robotics".

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

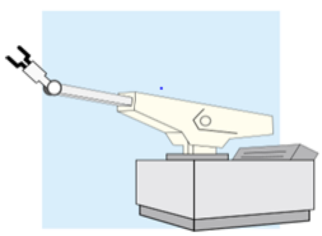
2. A robot must obey the orders given to it by human beings unless that is in conflict with the first law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

- Name the first industrial robot.

1961:

Unimate was the first industrial robot, installed in a **General Motors** automobile factory in New Jersey. It was invented by George Devol in the 1950s using his original patent filed in 1954 and granted in 1961.



Sketch of a Unimate robot

The machine undertook the job of transporting die castings from an assembly line and welding these parts on auto bodies, a dangerous task for workers, who might be poisoned by toxic fumes or lose a limb if they were not careful.

- Name the world's first humanoid intelligent robot

1972:

Waseda University initiated the WABOT project in 1967, and in 1972 completed the **WABOT-1**, the world's first full-scale humanoid intelligent robot.
The **WABOT-1** was able to communicate-with a person in Japanese and to measure distances and directions to the objects using external receptors, artificial ears and eyes, and an artificial mouth.

The **WABOT-1** walked with his lower limbs and was able to grip and transport objects with hands that used tactile-sensors.

WABOT-1 (1973)

1984:

In 1984 Wabot-2 was revealed; capable of playing the organ, **Wabot-2** had 10 fingers and two feet. Wabot-2 was able to read a score of music and accompany a person.

- Name a robotic dog capable of interacting with humans

1990's

Sony introduced the **AIBO**, a robotic dog capable of interacting with humans in 1999.

ERS-210

Sony created AIBO (Artificial Intelligence roBOT), an entertainment robotic pet and promotes AIBO as having the capability to interact with its human owner in many of the same ways a living pet would - without high maintenance.

2000- present

ASIMO ROBOT

The popular **Roomba**, a robotic vacuum cleaner, was released in 2002 by the company iRobot.
Self-driving cars had made their appearance by around 2005.
In 2005 Honda revealed a new version of **ASIMO** robot updated with new behaviors and capabilities.

- Name a vacuum cleaner robot by iRobot

Sophia in 2018

Sophia is a social humanoid robot developed by the Hong Kong based company Handson robotics. Sofia was activated on February 14th 2016 and made her first public appearance in mid-March 2016 at South by Southwest (SXSW) in Austin Texas United States.Citation : https://en.wikipedia.org/wiki/Sophia_(robot))

Classification of Robots

➢ What are the different types of Robots

Robots are broadly classified as

Industrial Robots......................

An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or special devices through programmable motions for the performance of variety of tools.

Special- purpose Robot………

It is the one that is used in places other than factories.

Automatic Guided Vehicles: An Automatic Guided Vehicle (AGVs) is type of mobile robot, which has wheels for its locomotion. Their movement is directed by a combination of software and sensor-based guidance systems.

Walking Robots: These robots walk like human beings. They are used in military, undersea exploration and places where rough terrains exist. They offer high precision and speed, and are generally used in pick & place applications.

Parallel Robots: Those robots with similarity as walking robots, have parallel configurations, in contrast to the serial-like structure of an industrial robot. A walking robot with all its legs touching the ground is a parallel robot. Such robots find applications in machine tools and medical surgery.

Note : There are other classifications also shown below

How They Move:

Stationary Robots: Stay in one place.

Mobile Robots: Move around, like robots on wheels or legs.

How They're Controlled:

Remote-Controlled Robots: Controlled by a person.

Smart Robots: Can do things on their own using sensors and programming.

Where They Work:

Underwater Robots: Work in the ocean.

Space Robots: Used for space exploration.

Aerial Robots (Drones): Fly in the air.

Ground Robots: Move on the ground.

Who They Work With:

Collaborative Robots (Cobots): Work alongside people.

Applications of Robotics:

- State different applications of Robot

Robotics finds applications across various industries, enhancing efficiency, precision, and safety. Here are some examples of how robotics is applied in different fields:

Manufacturing:

- Automated Assembly Lines: Robots are used for tasks like welding, painting, and assembly in manufacturing plants.
- 3D Printing: Robotic arms can be employed in 3D printing processes for precision and consistency.

Healthcare:

- Surgery: Robotic-assisted surgery allows for minimally invasive procedures with increased precision, like the da Vinci Surgical System.
- Rehabilitation Robots: Devices assist in physical therapy for patients recovering from injuries or surgeries.

Agriculture:

- Harvesting Robots: Autonomous robots can harvest crops, improving efficiency and reducing the need for manual labor.
- Weeding Robots: Robots equipped with computer vision can identify and remove weeds, reducing the need for herbicides.

Logistics and Warehousing:

- Automated Guided Vehicles (AGVs): Robots navigate warehouses to transport goods, optimizing logistics processes.
- Mobile robots are extensively used in warehouses for material handling and logistics. Autonomous Mobile Robots (AMRs) can navigate through the warehouse environment, pick up items, and transport them to designated locations.

Space Exploration:

- Rovers: Vehicles like NASA's Mars rovers, such as Curiosity and Perseverance, explore the Martian surface autonomously.
- Satellite Servicing: Robots are designed to repair and maintain satellites in orbit.

Automotive Industry:

- Robotic Welding: Industrial robots perform precise welding in car manufacturing.
- Automated Inspection: Robots with vision systems inspect and identify defects in the production line.

Construction:

- Bricklaying Robots: Autonomous machines can lay bricks with precision, speeding up construction processes.
- Drones for Surveying: Unmanned aerial vehicles equipped with cameras survey construction sites for planning and monitoring.

Environmental Monitoring:

- Underwater Robots: Autonomous underwater vehicles (AUVs) collect data on ocean conditions, marine life, and pollution.
- Agricultural Drones: Drones equipped with sensors monitor crop health and optimize irrigation.

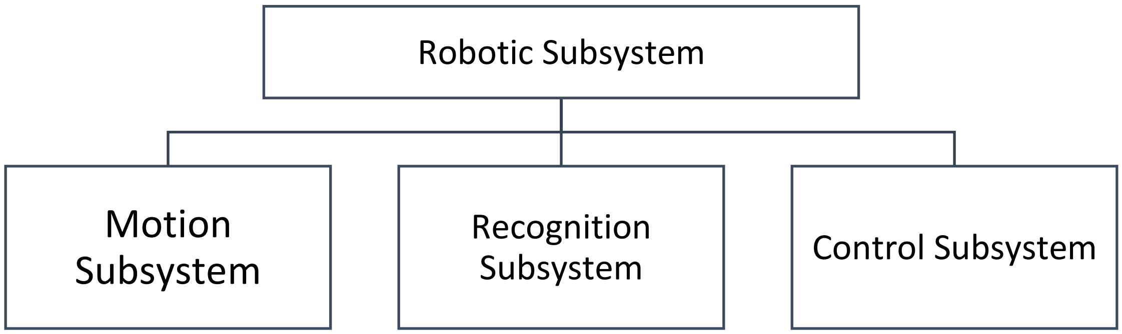
Entertainment:

- Theme Park Animatronics: Robots are used in theme parks for creating lifelike characters and interactive experiences.
- These examples illustrate the versatility of robotics in addressing a wide range of tasks, from mundane and repetitive to highly complex and specialized, across various industries and sectors.

Security and Surveillance:

- Mobile robots equipped with cameras and sensors are utilized for security and surveillance purposes. These robots can patrol predefined areas, monitor for unusual activities, and provide real-time video feeds to security personnel.

Block diagram representation of Robotic System



A robotic system generally consists of three subsystems, namely a motion subsystem, recognition subsystem and control subsystem

Motion Subsystem: The motion subsystem is the physical structure of the robot that carries out desired motion similar to human arms.

Recognition Subsystem: The recognition subsystem uses various sensors to gather information about the robot itself and any object being acted upon and about the environment. Based on sensor data, it recognizes the robot's state, the objects and the environment.

Control Subsystems: The control subsystem is a device or a set of devices to manage, command, direct or regulate the behavior of the process. The control subsystem influences the robot's motion to achieve a given task using the information provided by the recognition subsystem.

Automation System

What is automation?

Automation is like having a robot do a job instead of a person. It's when we use technology, like machines or computer programs, to do tasks without needing someone to do it by hand. This can make things faster and more efficient, and sometimes even save money.

It is used in many different fields like making things in a factory, driving cars and trucks, and even in hospitals. Automation helps in making the work easy, efficient and save time and money.

Example of automation:

1. One example of automation is a car assembly line in a factory. Instead of having workers manually assemble each car, robots and machines are used to perform tasks such as welding, painting, and installing parts. This automation increases production speed and accuracy, while reducing the need for manual labor.

2. ATM (Automated Teller Machine) machine, which allows customers to withdraw cash, deposit money, and check their account balance without the need for a human teller.

3. An example of automation in healthcare is Electronic Health Records (EHRs) which allow doctors and nurses to easily access patient information, schedule appointments, and order tests without the need for paper records or manual data entry.

Can you name different types of industries that use automation?

- In the manufacturing industry, automation is used to improve the efficiency and productivity of assembly line production. Automation is used to perform repetitive tasks such as welding, painting, and installing parts on an assembly line, which eliminates the need for human intervention and reduces errors. This improves the speed and accuracy of the production process and increases the overall output of the factory.

- The transportation industry has begun to use automation in a variety of ways to improve efficiency, safety, and overall performance. One of the most notable areas of automation in transportation is the development of self-driving cars.

- The retail industry is using automation to improve customer service and streamline back-end operations. One way that automation is being used in retail is through the use of self-checkout machines. Self-checkout machines allow customers to scan and pay for their items without the need for human assistance, which can help to reduce waiting times and improve the overall shopping experience. Additionally, self-checkout machines can also help to reduce labor costs for retailers.

- The agriculture industry is using automation to improve efficiency and yields in crop production. One way that automation is being used in agriculture is through precision farming.

Why is automation required?

Increased Efficiency: Automation can increase the speed and accuracy of tasks, leading to higher productivity and output.

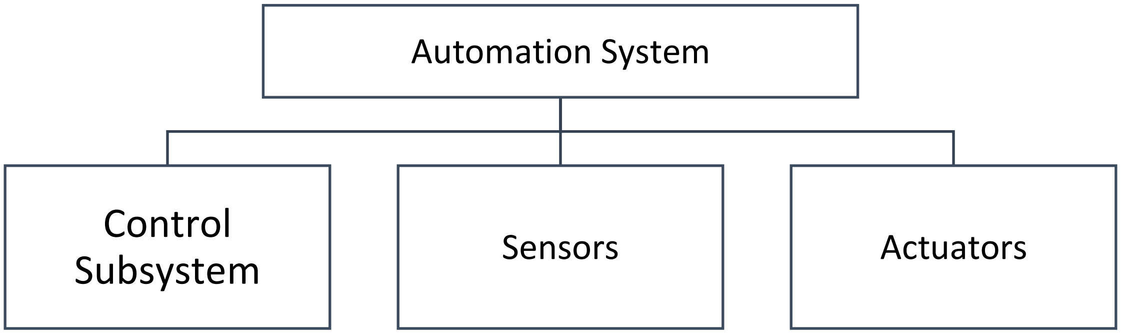
Cost Savings: Automation can reduce labor costs and increase efficiency, leading to cost savings for businesses.

Improved Quality: Automated systems can be programmed to ensure consistent quality, reducing the chances of human error.

24/7 Operation: Automated systems can run continuously, allowing for round-the-clock operation and increased output.

Safety: Automation can improve safety by reducing the need for human intervention in potentially dangerous tasks.

Block Diagram of Automation System:



Control SubSystems: Automation requires a control system to manage the process. Control systems can be divided into two categories: open-loop and closed-loop. An open-loop system does not use feedback to control the process, whereas a closed-loop system uses feedback to monitor and adjust the process.

Sensors: Sensors are devices that detect changes in the environment and send signals to the control system. These signals are used to monitor the process and make adjustments as needed. Examples of sensors include temperature sensors, light sensors, and proximity sensors.

Actuators: Actuators are devices that carry out the actions specified by the control system. They convert the electrical signals from the control system into physical actions, such as moving a robotic arm. Examples of actuators include motors, solenoids, and pneumatic cylinders.

Advantages

- **Scalability**: Automation can be scaled up or down depending on the needs of the business, allowing for flexibility in growth.
- **Job Automation:** Automation can help to automate repetitive and mundane tasks, freeing up human resources for more valuable and creative work.
- **Data Processing**: Automation can be used to process large amounts of data quickly and accurately, which is especially useful in fields such as finance, healthcare, and logistics.
- **Consistency:** Automation can ensure consistent results across a process, leading to higher quality and less human error.
- **Predictability:** Automation can create a more predictable workflow and output, which can lead to better planning and forecasting.
- **Remote control:** Automation allows systems to be controlled remotely, which can be useful in cases where a human operator is not present, such as in hazardous environments or where a human operator would be impractical.

Application

Manufacturing: Automation is widely used in manufacturing to improve efficiency and productivity. Automated systems such as robotic arms, conveyor belts, and assembly lines are used to improve the speed and accuracy of manufacturing processes.

Transportation: Automation is used in transportation to improve safety and efficiency. Self-driving cars, drones, and autonomous vehicles are examples of automation in transportation.

Healthcare: Automation is used in healthcare to improve patient care and increase efficiency. Automated systems such as robotic surgeons, automated medication dispensers, and remote monitoring systems are used in healthcare.

Agriculture: Automation is used in agriculture to improve crop yields and reduce labor costs. Automated systems such as precision agriculture, robotic harvesting, and autonomous tractors are used in agriculture.

Logistics and Supply Chain: Automation is used in logistics and supply chain to improve efficiency and accuracy. Automated systems such as warehouse robots, automated packaging, and drone delivery are used in logistics and supply chain.

Project Management

Five Stages of Project Management

Project management process is usually divided into different phrases that take the project from the beginning to the end. These stages include:

- initiation
- planning
- execution
- monitoring and control
- closure

These steps help you to determine the right flow and sequence of operations to bring your project to conclusion.

1. Project Initiation

Initiation is the formal start of a project. At this stage, you should define the project at a broad level.

We should create a project initiation document (PID). This is the foundation of your project and a critical reference point for the next stages. Key components of your PID should be:

- Project goals, scope and size
- Project organization (defining the 'who, why, what, when and how' of the project)
- Project constraints
- Bill of Materials

- Project Framework (Time)
- Criteria for closing and assessing the project

2. Project Definition and Planning

Project planning is key to successful project management. This stage typically begins with **setting goals**.
At this stage, we will define the project scope, and develop a project plan and work breakdown schedule. This involves identifying:

- time, cost and resources that are at your disposal
- roles and responsibilities for the project
- quality
- milestones
- progress checkpoints

3. Project launch and implementation

- Implementation (also called project execution) means putting your project plan into action. It often begins with a project 'kick-off meeting'.
- During this phase, you will carry out the tasks and activities from your project plan to produce the project deliverables.

4. Project monitoring and Control

- Monitoring and control often overlap with execution as they often occur at the same time.
- They require measuring project progression and performance, and dealing with any issues that arise from day-to-day work.
- Required to write the Report of the project.

5. Project Closing

- During this last phase, we will complete our work and dissolve the project.

Project Initiation Document

Project name:

Date:

Members List:

1.

2.

3.

Project background / introduction

Give a brief overview of the background to the project

Objectives and scope of the Project

Advantages of this project

Describe why you are doing the project and list the benefits.

Methodology

Procedure to execute the Project Step-Wise

Bill of Materials

S. No.	Name of the Components	Quantity	Cost

Project Planning

Week 1

- **Task**

Week 2

- **Task**

Week 3

- **Task**

Week 4

- **Task**

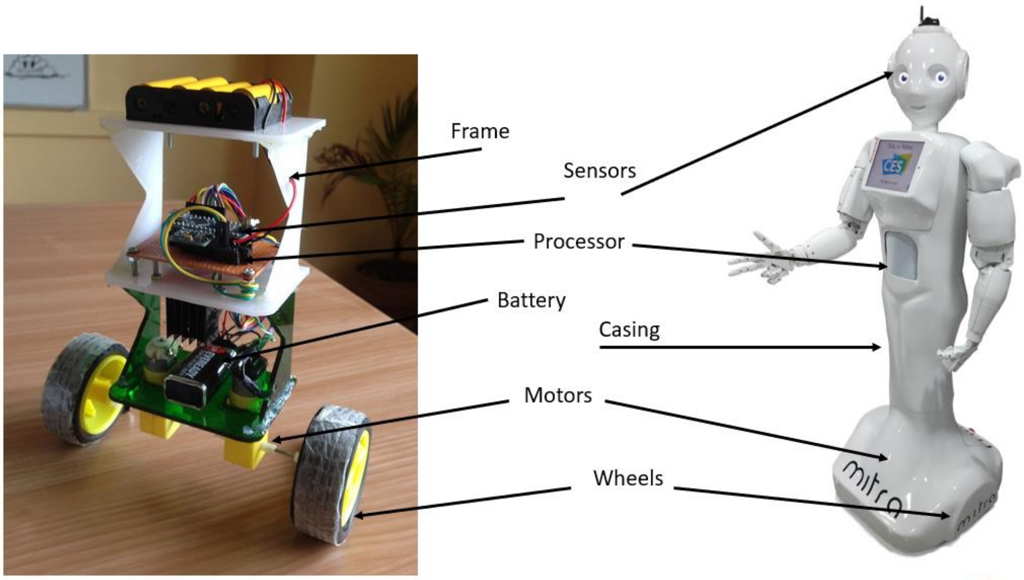
Materials and Mechanical Components

2.1. Can you name some components of a robot?

Source: Maker Pro

Source: Mitra Robot

A robot is made up of various components such as frame, sensors, processor, battery, etc. Some of the common components are labelled in the figures below.



Source: Maker Pro

Source: Mitra Robot

Figure 1. Various components of a robot

2.2. What are Frames?

A Frame or a Chassis is the base upon which a robot is built.

The functions of a frame can be listed as:

- To support mounting of various components of the robot.
- To give structural strength to the robot

Source: VVDOIT

Figure 2. An empty frame of a robot

2.2.1. Frame Materials: Frames of various materials can be used for a robot. Some of the common materials used are discussed below.

Medium Density Fibreboard (MDF): This is a type of engineered wood manufactured by compressing different hardwood and softwood residues using wax or resin.

Some of the properties of MDF are:

1. It is easy to cut and carve them to any shape
2. They are low-cost
3. They have relatively low load capacity
4. They deteriorate with age
5. They are not water resistant

Acrylic: These are transparent plastic sheets made of poly methyl-methacrylate.

Some of the properties of Acrylic are:

1. It gives a clean look and finish
2. They have a medium load capacity
3. They are water resistant
4. They are more durable

Aluminium: Aluminium is a metal, and various Aluminium alloys are used to manufacture robot frames.

Some of the properties of Aluminium are:

1. Light weight
2. It is durable and does not rust
3. Requires machining to cut and shape
4. It is slightly expensive

Steel: Steel is an alloy made of iron and carbon.

Some of the properties of Steel are:

1. Steel is a strong and hard material
2. It is suitable for rough-use robots
3. Steel can be welded
4. It is a heavy material
5. It is relatively difficult to machine steel

Source: EXPE Technologies

(a)

Source: sgbotic

(b)

Source: Generation Robots

(c)

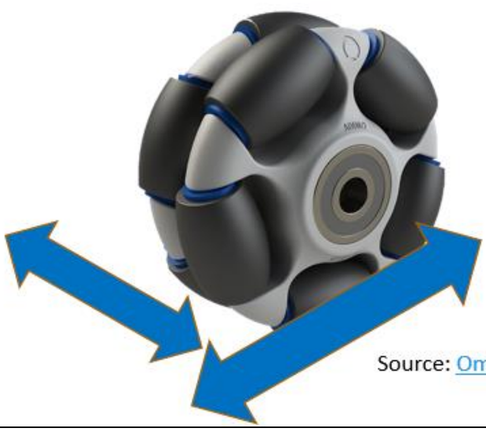
Source: ecadio

(d)

Figure 3. Various frame materials (a) MDF (b) Acrylic (c) Aluminium (d) Steel

2.3. What are some of the types of wheels used in a robot?

Different types of wheels used in building robots are shown below:

 Source: robu.in	**Standard Wheel** ● Motion in one direction ● Can be driven
 Source: The Home Depot	**Caster Wheel** ● Can orient in any direction ● Cannot be driven
 Source: Omnia	**Omni Wheel** ● Can travel in multiple directions ● Can be driven ● Perpendicular rollers

Mecanum Wheel

- Can travel in multiple directions
- Can be driven
- Multi-direction rollers

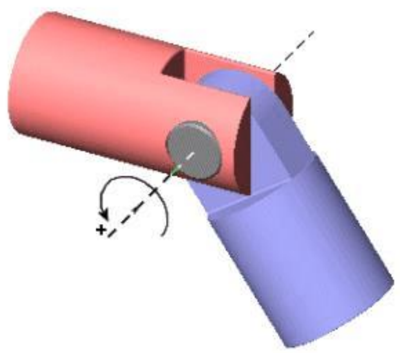
2.4. What are Links and Joints?

The individual bodies of a robot are known as links. Links are connected to each other by joints.

2.4.1. Types of joints: Joints couple the links together and facilitates various motions between

Figure 4. Links and Joints of a robot

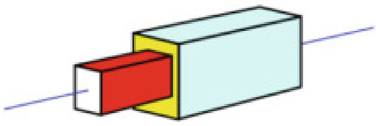
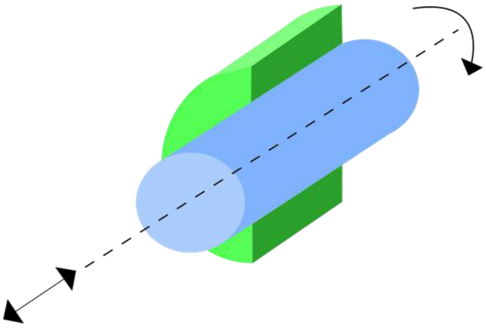
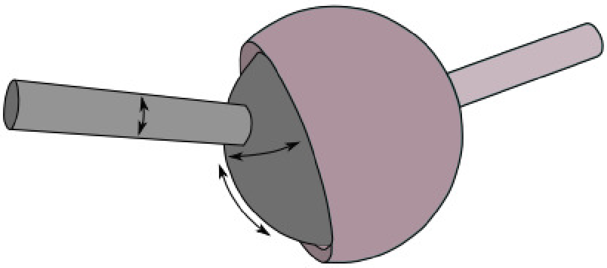
them. Based on the type of motion, joints are classified into different types. Some of them are listed below.

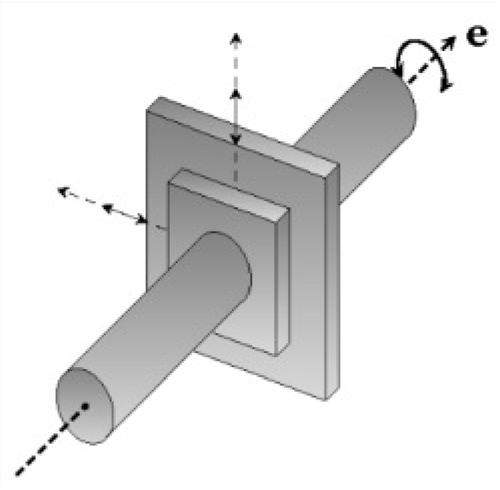


Source: researchgate.net

Revolute Joint

- Allows rotation about one axis
- Only one degree of freedom

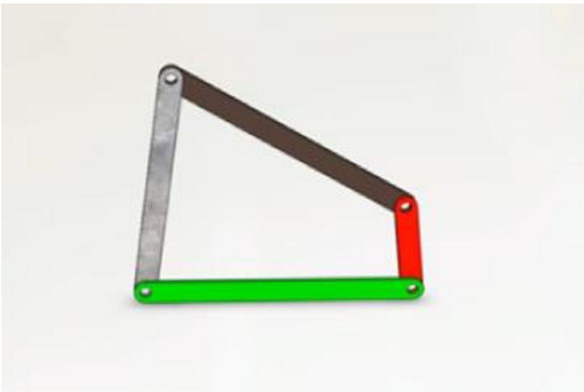
 Source: Springer	**Prismatic Joint** ● Allows translation ● Only one degree of freedom
 Source: Quora	**Cylindrical Joint** ● Allows translation and rotation ● Two degrees of freedom
 Source: skill-lync	**Spherical Joint** ● Allows rotation about three axes ● Three degrees of freedom

 Source: comsol	**<u>Planar Joint</u>** ● Allows translation and rotation ● Three degrees of freedom

Exercise:

Q. Identify the different links and type of joints for the given mechanisms.

1. **Four-bar mechanism**



Source: 4 Bar Mechanism - YouTube

Answer: Four links; Four revolute (R) joints

R2

Link 3

Link 2

R3

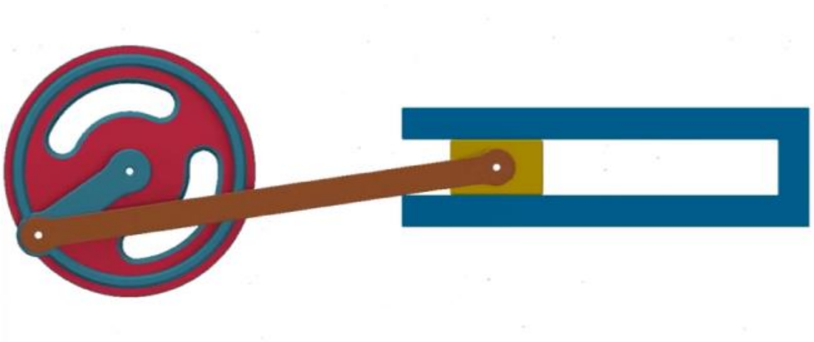
Link 4

R1

R4

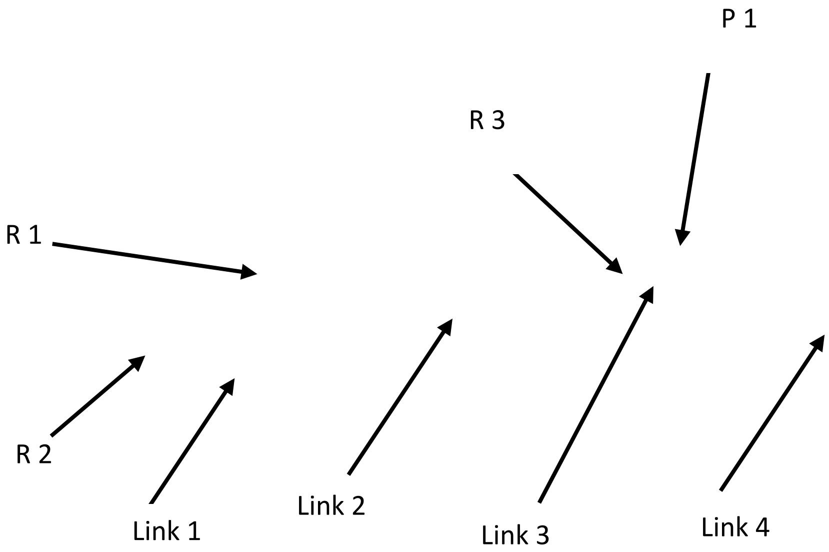
Link 1

2. Slider-crank mechanism

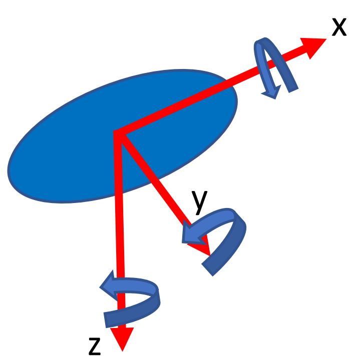


Source: [How Slider Crank Mechanism Works - YouTube]()

Answer: Four links; 3 revolute (R), 1 Prismatic (P) joint.



2.5. Degrees of Freedom (DoF): It can be defined as the number of independent motions allowed for a body. A free rigid body has six degrees of freedom in terms of three translations and three rotations.

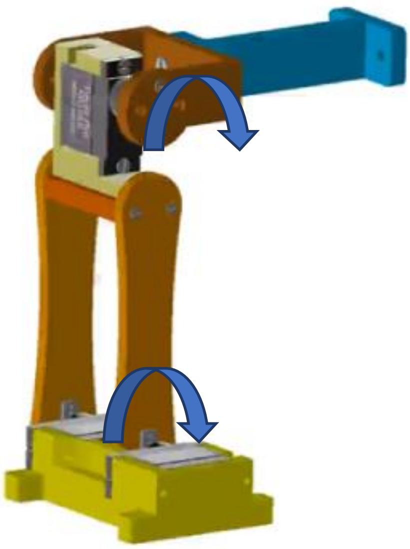


Exercise:

Q. Find out the degrees of freedom of the robot

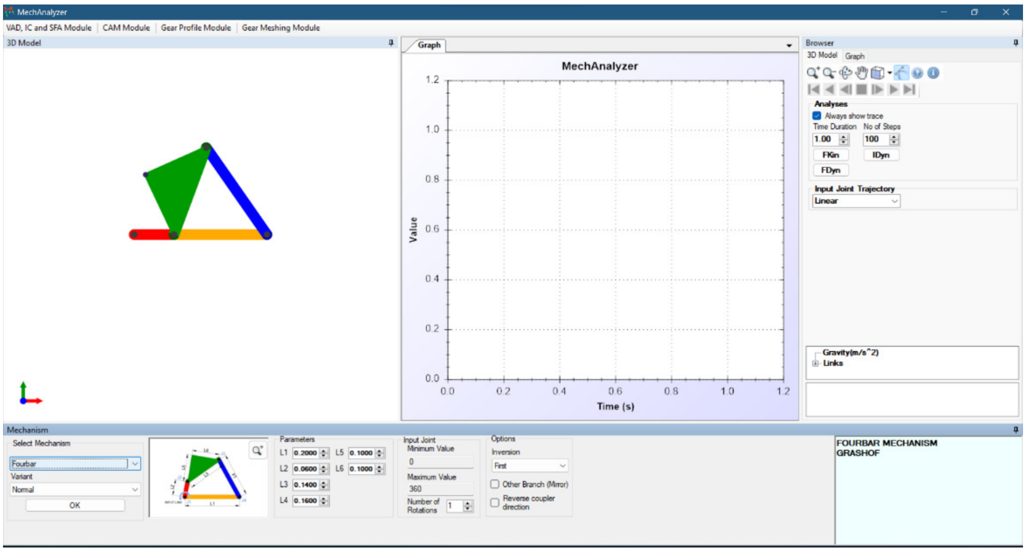
Source: [2 link robot arm animation with MG90S. - YouTube]

Answer: 2 rotational degrees of freedom



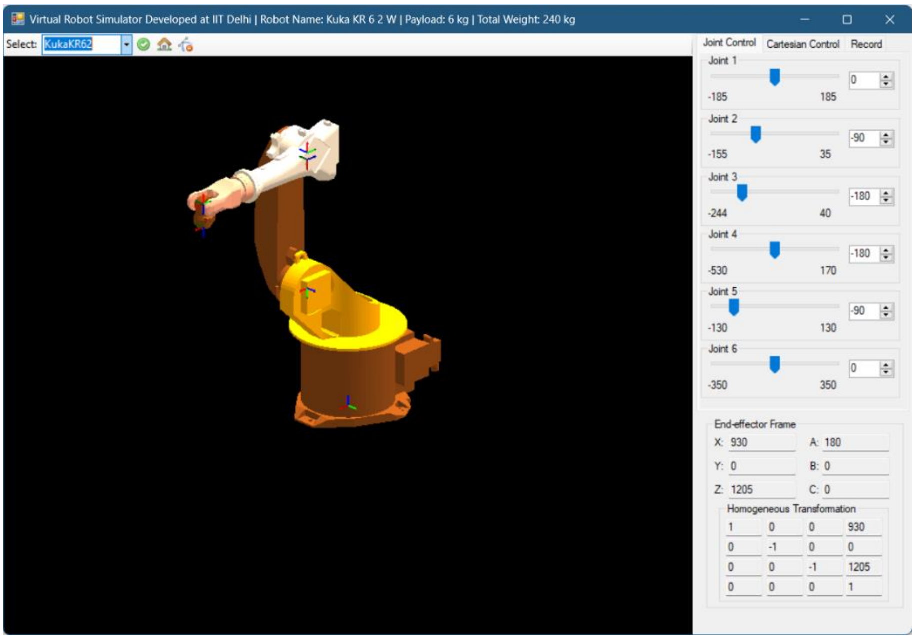
Demonstration – Mechanalyzer® Software

Mechnalyzer® is a 3D model-based software developed by researchers in the Mechatronics Lab of IIT Delhi. It is freely available for academic usage and can be downloaded from mechanalyzer.com. This software can be used to study various mechanisms, gear meshing, velocity and acceleration analysis, etc. The snapshot of the user interface of the software is shown below.



Demonstration – Roboanalyzer® Software

Roboanalyzer® was also developed in Mechatronics lab, IIT Delhi. This software can be used to study concepts of robot mechanics and dynamics. It also has a virtual robot model where various industrial robots can be viewed in 3D and manipulated.

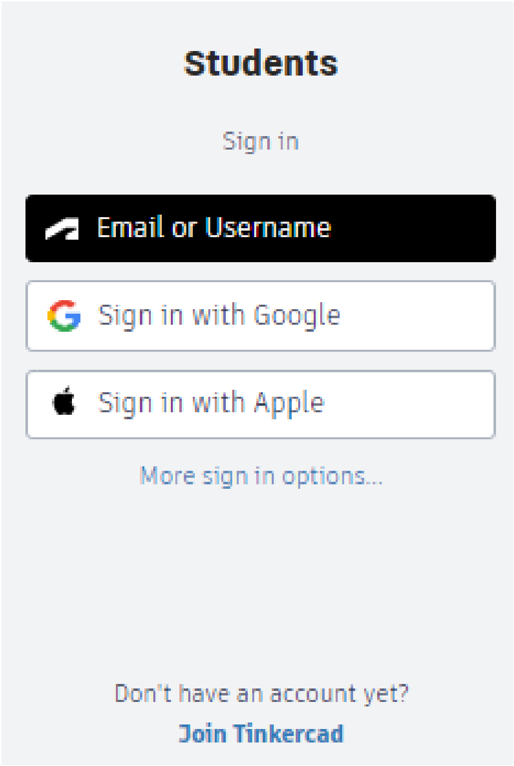


SPHERE

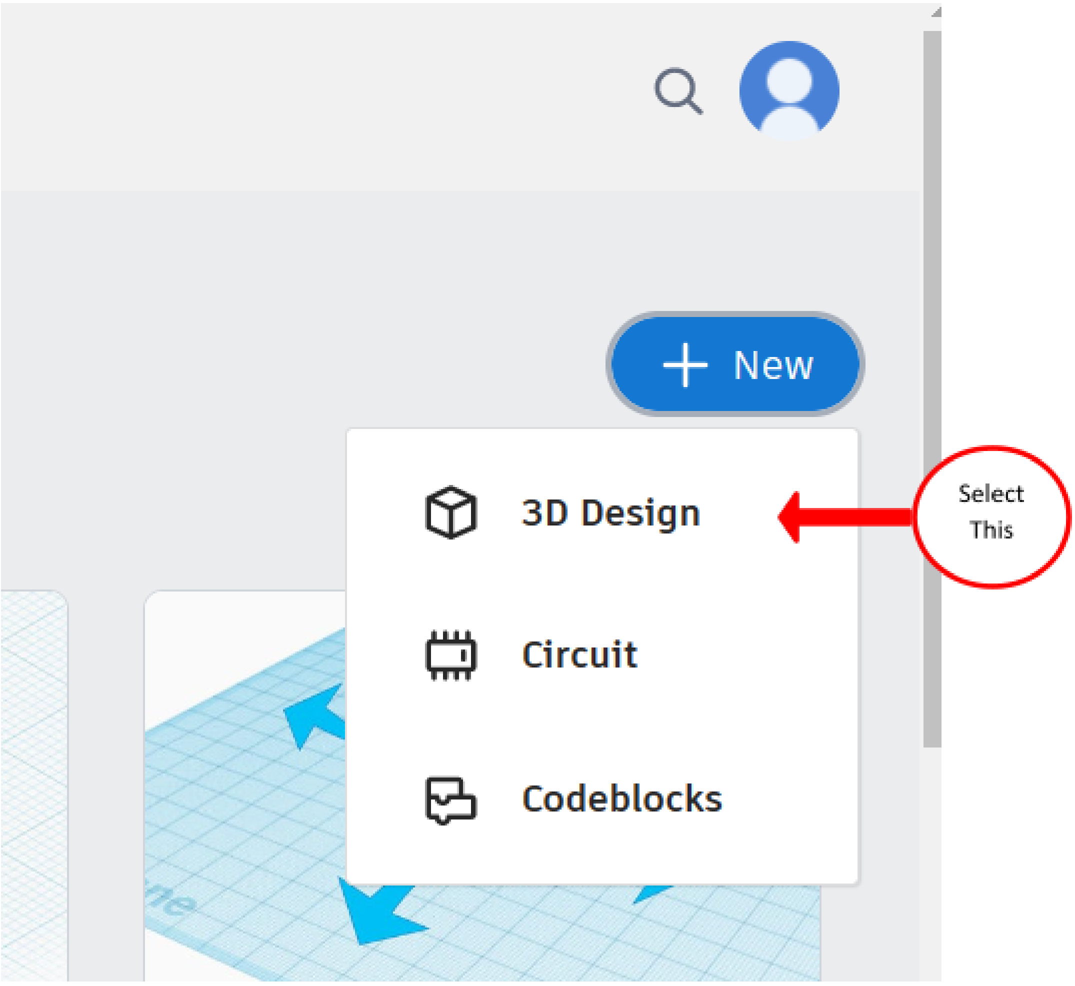
STEPS –

1) Go to tinkercad.com

2) Sign-in page for students will appear on the screen, you can either select either 'Sign –In with Google' or 'With Email or Username', one more suitable for you.

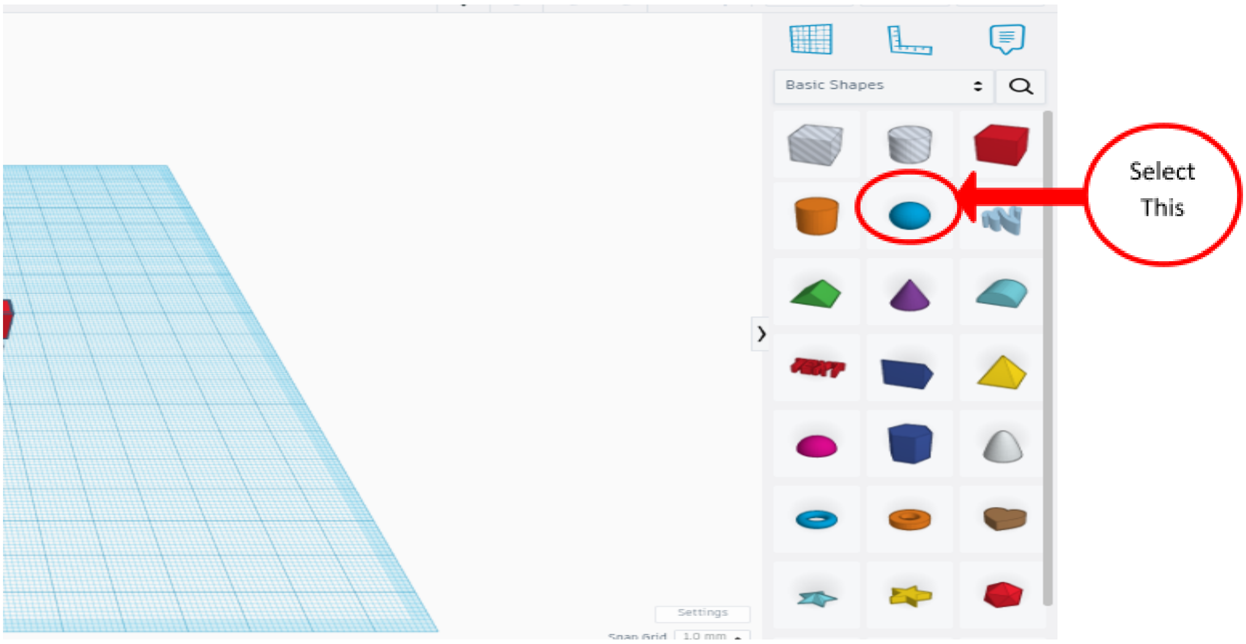


3) Click on 'New' on the right side of the page and select '3D Design'.

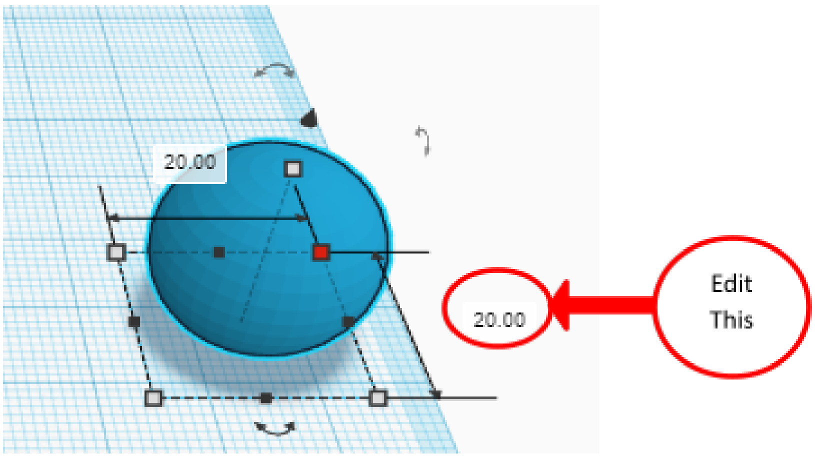


4) You can see some basic shapes on the right side of the screen, Sphere can be chosen from the same. Place the shape by clicking on the workplane.

(as seen in the red circle)



5) You can set the diameter of the sphere by clicking on it.

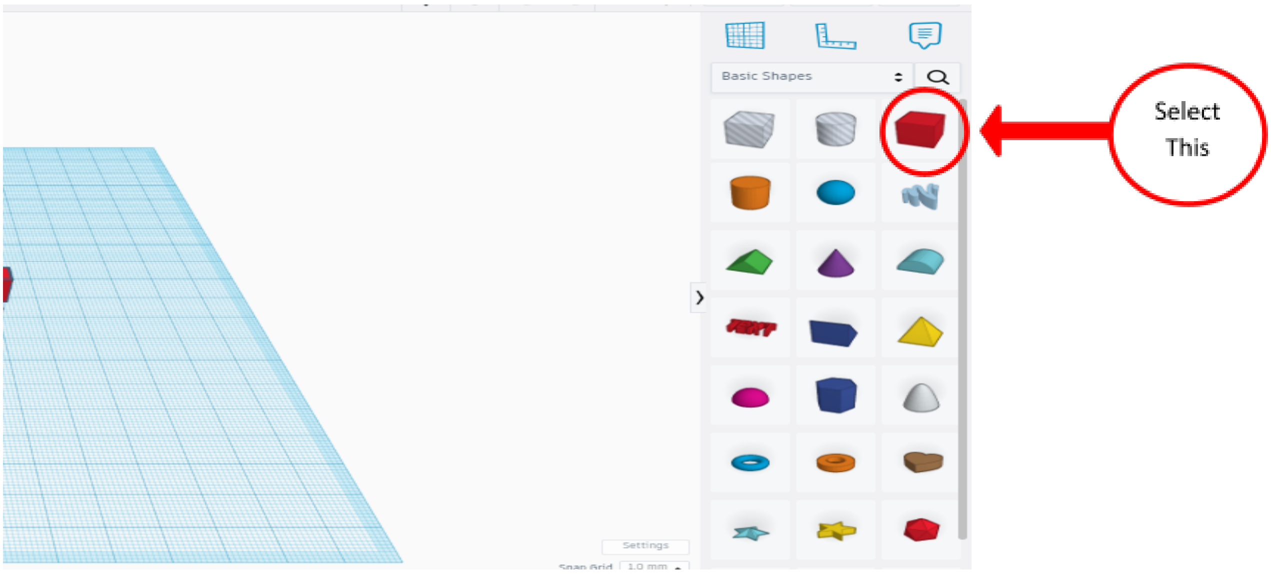


CUBE

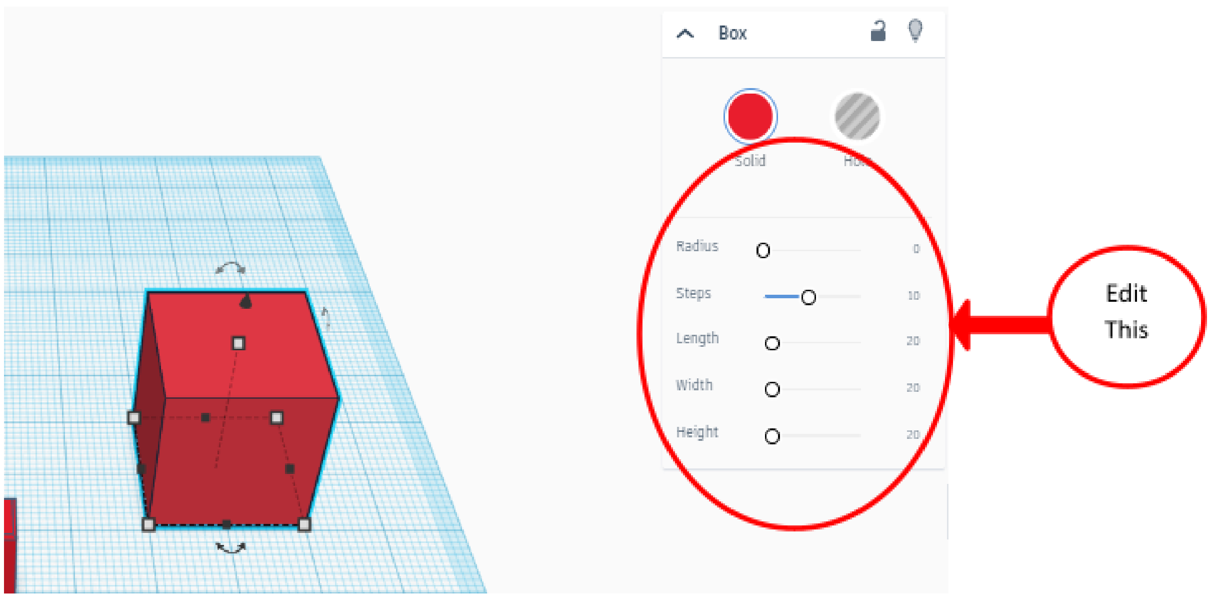
STEPS –

1) You can see some basic shapes on the right side of the screen, Cube can be chosen from the same.

(as seen in the red circle)



2) You can set the length, width and height of the cube by clicking on it.

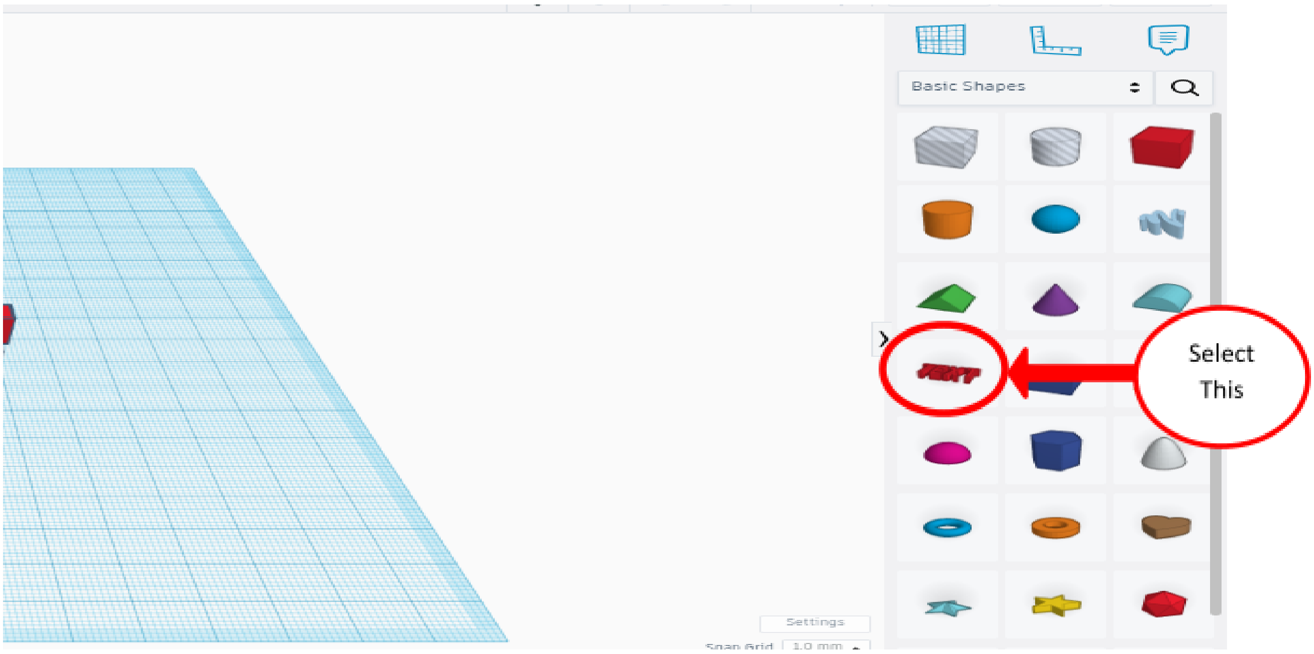


NAME

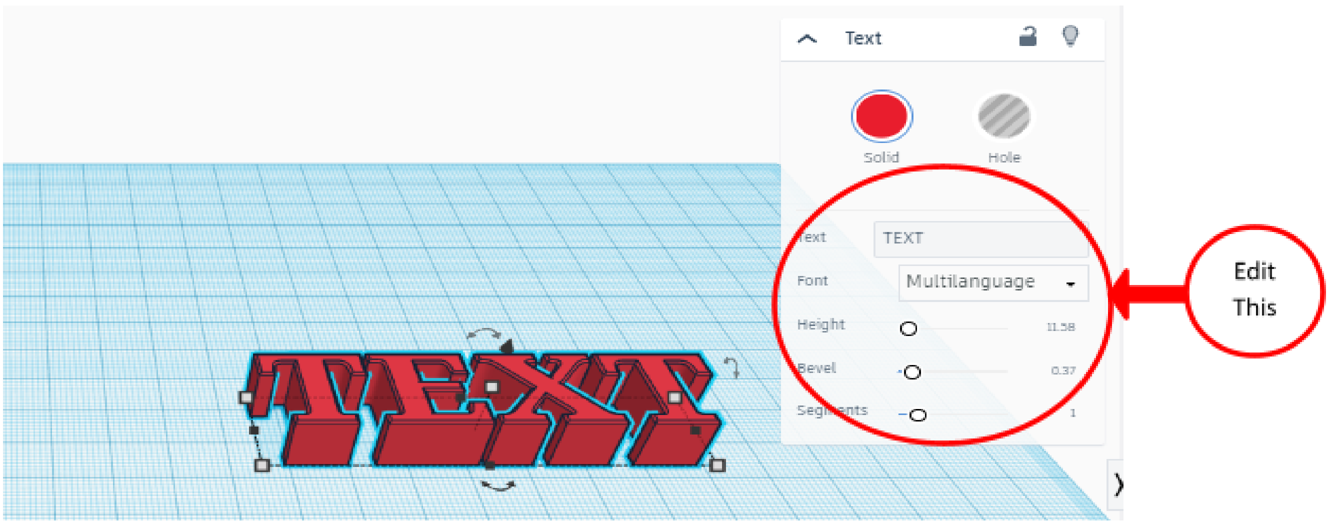
STEPS –

1) You can see some basic shapes on the right side of the screen, Text can be chosen from the same.

(as seen in the red circle)



2) Then write your text and select the font and height of the text according to your need.



Exercise - Create a dice on Tinkercad

Dice dimensions: 15 mm x 15 mm x15 mm

Edge radius: 3mm