18MED41

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

Scheme of Evaluation

November,2022	**Mechanical Engineering**
Seventh Semester	**Robotics**
Time: Three Hours	**Maximum: 5**0 Marks
Answer Question No. 1 Compulsorily.	(10X1 = 10 Marks)
*Answer **ANY ONE** question from each Unit.*	(4X10=40 Marks)

1. a) Define Robot. CO1(BL1) **1M**

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

b) List out robot like devices. CO1(BL1) **1M**

Prostheses
Exoskeleton
Telecherics
Locomotive mechanisms

c) Define repeatability of a robot. CO1(BL1) **1M**

It is the measure of the ability of a robot to continuously reach the targeted point

d) What is meant by a gripper? CO2(BL1) **1M**

Grippers are end effectors used to **grasp and manipulate** objects during the work cycle

e) Give some examples of tool as robot end effector. CO2(BL1) **1M**

- Spot welding gun,
- Arc welding tool,
- Spray painting gun,
- Rotating spindle for drilling,
- Grinding,
- Automatic screw driver,
- Heating torch,
- Ladle,
- Water jet cutting tool.

f) Distinguish between sensor and transducer? CO3(BL2) **1M**

A sensor detects a physical, chemical or biological quantity and converts the data it receives through this detection into an electrical signal. A transducer is a more general device for converting energy from a given form into a different form. A transducer may contain such a sensor and use it to obtain data, which it then translates into readable, meaningful information. A sensor is more of a detector, while a transducer is more of a translator

g) List some applications of proximity sensor. CO3(BL1) **1M**

Proximity sensors are used in phones, recycling plants, self-driving cars, anti-aircraft systems, and assembly line.

h) State the desirable features of sensor. CO3(BL1) **1M**

(Any 2-3 of the following can be written)
Frequency response
Reliability
Accuracy
Repeatability
Cost
Size
Weight
Sensitivity
Resolution
Interfacing
Type of output

i) What is inverse kinematics? CO4(BL1) **1M**

Inverse kinematics will enable us to calculate what each joint variable must be, if we desire that the hand be located at a particular point and have a particular orientation.

j) What is manipulator Jacobian? CO4(BL1) **1M**

The Jacobian matrix helps to convert angular velocities of the joints (i.e. joint velocities) into the velocity of the end effecter of a robotic arm.

For a robot that operates in three dimensions, the Jacobian matrix transforms joint velocities into end effector velocities using the following equation:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}_{6\times 1} = J_{6\times n} \begin{bmatrix} \dot{q}_1 \\ \dot{q}_2 \\ \cdots \\ \dot{q}_n \end{bmatrix}_{n\times 1}$$

Unit - I

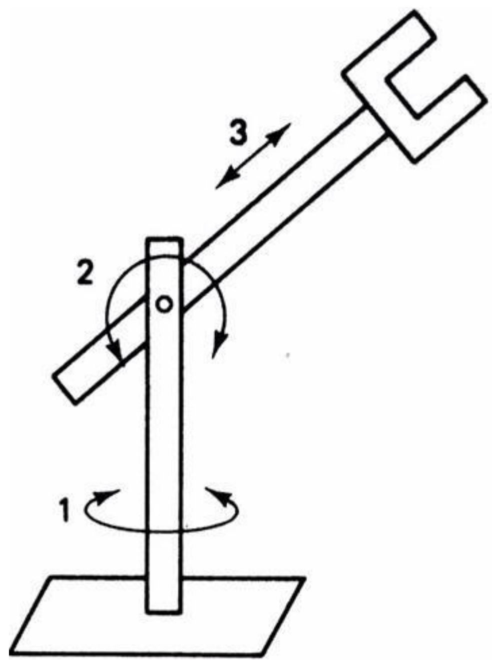
2. a) Sketch and explain the four basic robot configurations classified according to the coordinate system. CO1(BL2) **6M**

There are four basic configurations available in commercial industrial robots:

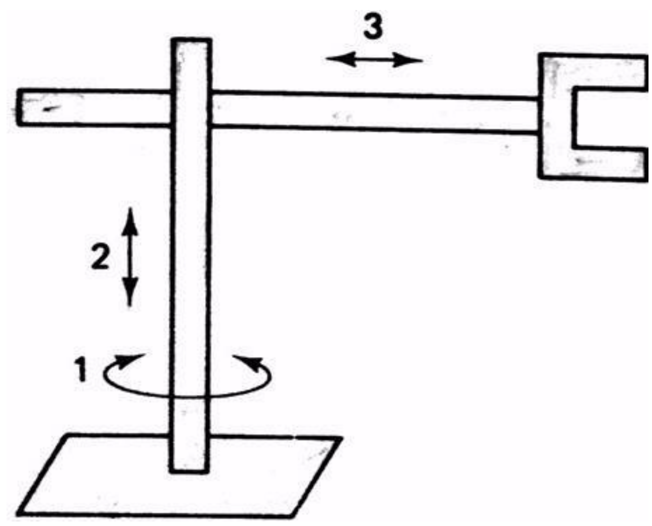
- Polar configuration
- Cylindrical configuration
- Cartesian coordinate configuration
- Jointed arm configuration

Polar Configuration

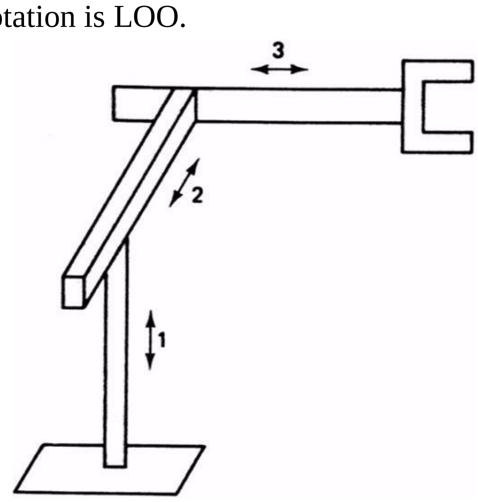
This configuration consists of sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and a horizontal axis (R joint). Joint notation is TRL.



Cylindrical Configuration robot (RPP):
This robot configuration consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in and out relative to the axis of the column. Joint notation is TLO.

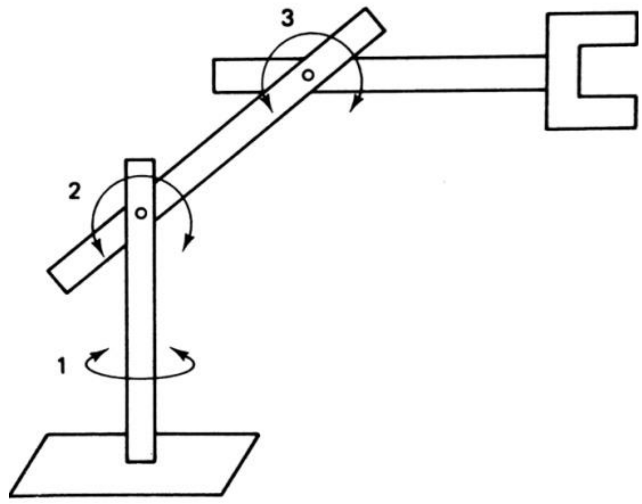


Cartesian coordinate robot (PPP):
The other names for this configuration are rectilinear robot, xyz robot. As shown in fig, it is composed of three sliding joints, two of which are orthogonal. Joint notation is LOO.



Jointed arm robot (RRR):

This robot manipulator has the general configuration of a human arm. The jointed arm consists of a vertical column that swivels about the base using a T joint. At the top of the column is a shoulder joint (shown as R joint), whose output link connects to an elbow joint (another R joint). Joint notation is TRR.



b) Briefly explain present and future applications of robots. CO1(BL1) **4M**
(Can be discussed any 5-6 points of the following in detail)

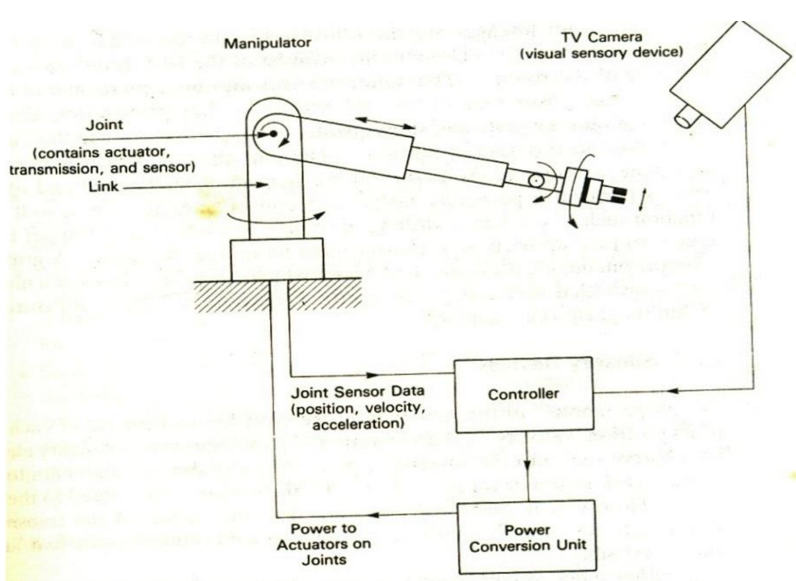
- **Dangerous**
  - Space exploration
  - chemical spill cleanup
  - disarming bombs
  - disaster cleanup
- **Boring and/or repetitive**
  - Welding car frames
  - part pick and place
  - manufacturing parts.
- **High precision or high speed**
  - Electronics testing
  - Surgery
  - precision machining.

(OR)

3. a) What are the basic components of Industrial Robot? Explain them briefly with sketch. CO1(BL2) **6M**

Although the mechanical, electrical and computational structure of robots can vary considerably, most of the robots have the following four major components in common.

- A Manipulator (or) Arm (The mechanical unit)
- One or more sensors
- A Controller (The brain)
- Power supply unit



1. **Manipulator**

- The manipulator of an industrial robot consists of a series of **joints and links**.
- Robot anatomy is concerned with the **types and sizes of these joints and links** and other aspects of the manipulators physical construction.
- In fact, robot and manipulator are often used interchangeably, although strictly speaking this is not correct.
- A joint of an industrial robot is similar to a joint in the human body.
- It provides relative motion between two parts of the body.

2. The controller

Robot controllers generally perform three functions:

- They initiate and terminate the motion of the individual components of the manipulator in a desired sequence and at specified points.
- They store position and sequence data in their memory.
- They permit the robot to be interfaced to the outside world via sensors mounted in the area, where work is being performed. (i.e the work station)

3. Sensors

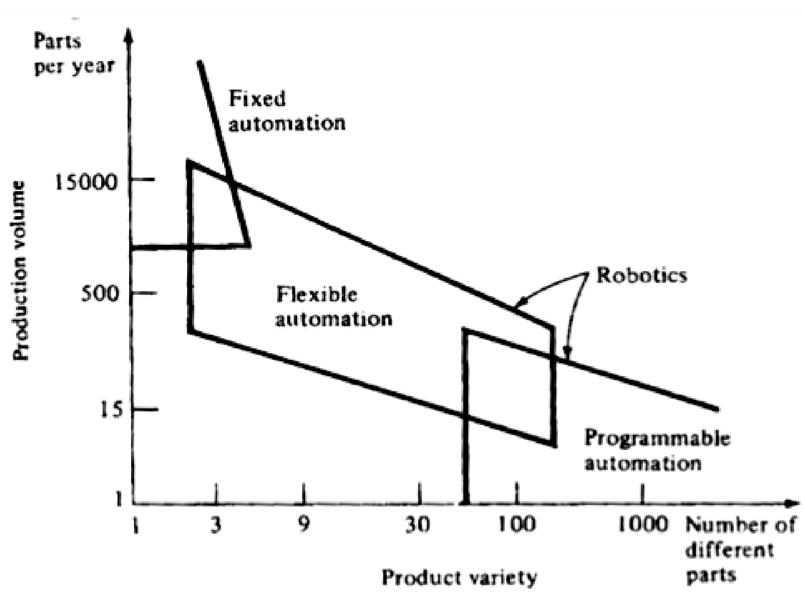
- These elements inform the robot controller about the status of the manipulator. This can be done continuously or only at the end of a desired motion. Regardless of how it is used, the information provided by the sensors can be analog, digital or a combination.

- Sensors used in modern robots can be divided in to two general classes.
- Non Visual (Proximity sensors, photo electric, mechanical position sensors, optical encoders, potentiometers, resolvers etc)
- Visual (Vidicon, Charge Coupled Device (CCD), Charge Injection Device (CID), TV cameras coupled to appropriate image-detection hardware etc. essentially used for object recognition or object grasping etc)

4. Power source

- The purpose of this part of the robot is to provide the necessary energy to the manipulator's actuators.
- (eg: power amplifier in case of servo motor controlled actuated system, remote compressor system, Hydraulic power pack, AC motors, DC motors, Stepper motors etc)

b) Explain the importance of Robotics in automation. CO1(BL3) **4M**



Increased Productivity

Robots can carry out the most repetitive or dangerous tasks in a facility with complete precision and consistency, every time. In addition to freeing human workers to complete more engaging (and better-paying) tasks, robots can reduce scrap and waste through improved accuracy, increase efficiency, and operate around the clock. All these benefits add up to much higher productivity in manufacturing operations.

Increased Accuracy

Once programmed, robots can repeat the same task or process over and over again without deviation. This means fewer rejected parts.

Lower Costs

With increased productivity, efficiency and accuracy come cost benefits as well, as robots help facilitate more work being completed in less time.

Unit - II

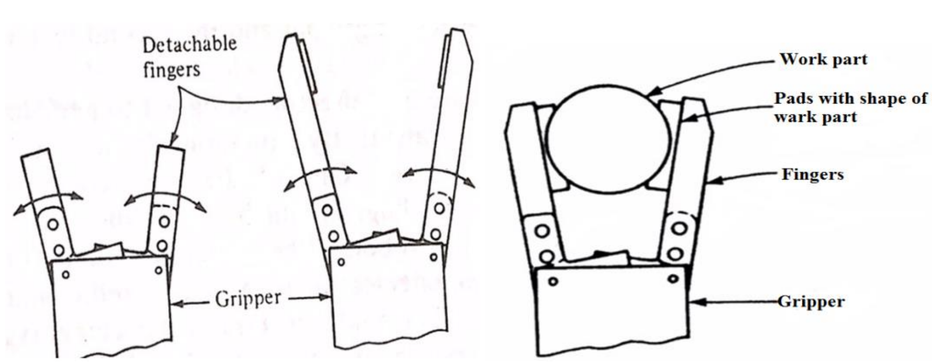
4. Explain mechanical grippers and their linkage mechanisms with neat sketches. CO2(BL2) **10M**

- Mechanical grippers are the most common gripper type.
- A mechanical gripper is an end effector that uses **mechanical fingers actuated by a mechanism to grasp an object**.
- The fingers, sometimes called jaws are the appendages of the gripper that actually make contact with the object.
- The fingers are either attached to the mechanism or an integral part of the mechanism.

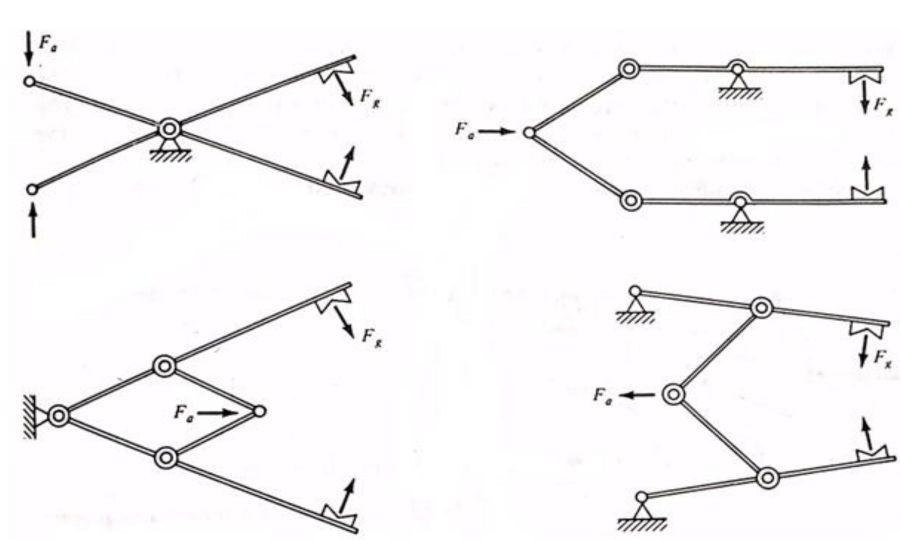
If the fingers are of the attachable type, then they can be detached and replaced. The use of replaceable fingers allows for wear and inter-changeability

Two ways of Constraining the part in gripper

- Physical Constriction method
- Friction method



Mechanical grippers constraining the motion



Linkage actuation in mechanical grippers

(OR)

5. a) Explain the general considerations in the selection and design of remote centered devices. CO2(BL2) **5M**

The parameters to be considered in selecting the remote center compliance device include the following:

1. *Compliance center (elastic center) is the point about which the forces acting on the object* being inserted are minimum. The remote center distance should be selected on the basis of the length of the part and the gripper

2. *Remote center distance: This is also called the center of compliance dimension. It is the* distance between the RCC bottom surface and the compliant center of the RCC device.

3. *Axial force capacity: This is the maximum force in the axial direction which the RCC* device is designed to withstand and still function properly.

4. *Compressive stiffness: This is also called the axial stiffness. It is the force per unit* distance or spring constant required to compress the RCC device in the direction of insertion. Generally, the compressive stiffness is relatively high to allow for press fitting of parts together.

5. *Lateral stiffness: This is the spring constant relating to the force required to deflect the* RCC laterally (perpendicular to the direction of insertion). This parameter should be determined according to the stiffness of the robot and the delicacy of the parts being assembled.

6. *Angular stiffness: This is also called the cocking stiffness. It is the rotational spring* constant that relates to the force required to rotate the part about the elastic center by a certain amount.

7. *Torsional stiffness: This is the torsional spring constant which relates to the moment* required to rotate the part about the axis of insertion. This parameter becomes important when the insertion task requires orientation relative to the axis of insertion.

8. *Maximum allowable lateral and angular errors: These errors are generally determined by* the relative size of the product and by its design (e.g., design of chamfers).

b) Briefly explain various methods of programming of robots. CO2(BL2) **5M**

Programming an industrial robot is not just about coding instructions using a programming language.

As the technology behind robotics continues to evolve, new programming methods meant to make it easier for end-users have emerged.

Today, three main methods are used to issue instructions to modern robots

. 1. The Teach Method
2. Hand Guiding/Lead-Through Programming
3. Offline Robot Programming

1. The Teach Method

- This method involves using a teach pendant to guide the robot through a series of points and having it store them in memory.
- The process of guiding and recording these points or coordinates in space is called teaching in robotics.
- A majority of modern industrial robots in the market today come with a teach pendant that allows even non-engineers to guide the robot and program it to perform a set of functions as desired.
- Modern teach pendants are just custom applications loaded into a special tablet or touchscreen device.
- It is the most intuitive and preferred way to program and reprogram industrial robots today.

2. **Hand Guiding/Lead-Through Programming**

Hand hiding or lead-through programming involves physically moving the robot arm over a series of points and axis to "teach" it how to perform a desired function.
For instance, an operator can guide a robot on how to reach for a tool on a workstation and use it to do some operation. After the instructions have been recorded by the robot's memory, it will continue following the same path on its own.
Hand guiding is especially preferred for smaller modern robots that are designed to work alongside human operators. These robots can be taught to do very complex tasks such as painting, sorting items, precision welding, engraving, etc.
Advantages of lead-through or hand guiding:

- Intuitiveness
- Safety
- Collaboration
- Great for complex tasks or movements

However, hand guiding fails as a programming method when precision is required.
It is also not practical to use this method for large industrial robots that are not designed to work alongside humans.
The method is the most preferred for modern collaborative robots used in smaller industrial setups.

3. Offline Robot Programming

This robot programming method involves writing instructions on a separate system and using virtual models of an industrial robot for testing.
After the instructions have been written and tested, they are uploaded to the robot's memory.
This method is preferred where a lot of instructions need to be written and tested before being deployed in real life.

Advantages of offline programming:

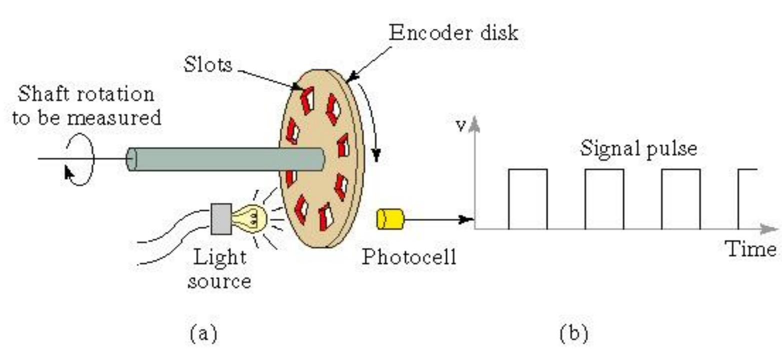
- Allows for more complexity
- Can lead to more efficient robot operation
- Supports precision
- Guarantees safety

Offline programming can be technical and therefore not suitable for non-engineers who do not understand low-level robotics programming or coding.
All programming methods are very much in use today in most industries.

Unit - III

6. Explain the working principle of following sensors related to their linear and rotary measurement: CO3(BL3) **10M**
   i) Encoders
   ii) Potentiometers

Encoders



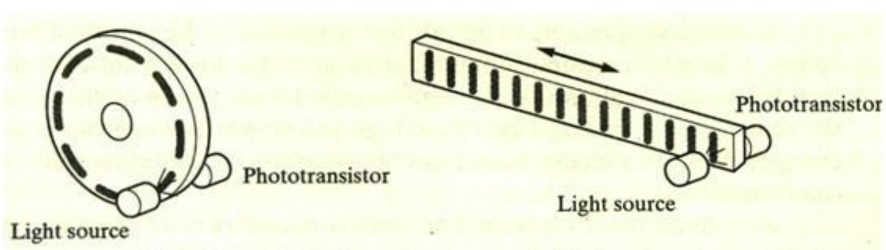
One of the most widely used position sensors is the optical encoder.

Capable of resolutions that are more than adequate for robotic applications, these noncontact sensory devices come in two distinct classes.
(a) Absolute
(b) Incremental

- In the case of **absolute**, the encoder is able to give the actual linear or rotational position if power has just been applied to the electromechanical system using the sensor.
- Thus a robot joint equipped with an absolute encoder will not require any calibration cycle since the controller will immediately, upon power-up, know the actual joint position.
- In the case of **incremental encoder**, the encoder provides positional information relative to some reference point.
- A robot utilizing an incremental encoder must, therefore, first execute a calibration sequence before true positional information can be obtained.

Although either linear or rotary encoders for both of the foregoing classes are available, the rotary device is almost exclusively used in robotic applications. One of the most important reasons for this is that revolute joints far outnumber prismatic ones in robots currently being manufactured. As such linear encoders are much costlier than rotary encoders

The **absolute encoder** is capable of giving the correct rotary position at all times even after power-up has occurred.
The device produces a separate and unique coded word for each shaft position.
A major advantage of the absolute encoder is that even if system power is accidentally lost (due to a power outage or relay trip, for example) the device will remember where it is and will report this to the system as soon as power is restored.



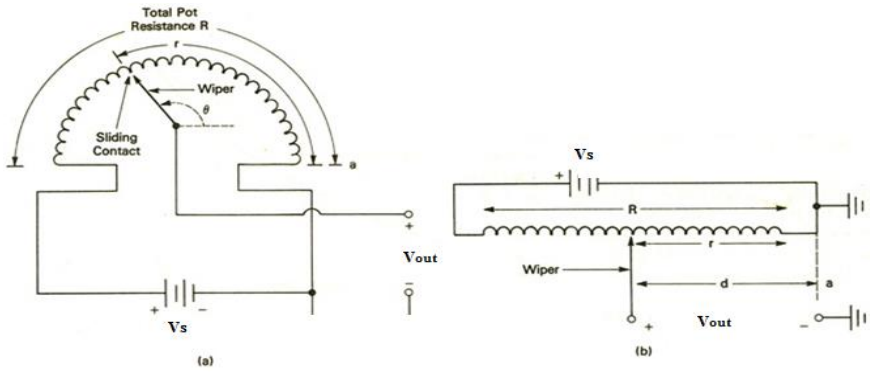
Optical incremental encoders are widely used to monitor joint position on robots.
In addition, they are the sensor of choice in a variety of machine tools, including lathes, x-y tables, and electronic chip wire and hybrid die bonders.

- The major reason is that they are capable of producing excellent resolution at a significantly lower cost.
- It is important to understand that if power is accidentally lost during an operation, calibration must be performed again since the incremental encoder has no memory.

Potentiometers

- Potentiometers are analog devices whose output voltage is proportional to the position of a wiper.
- A voltage is applied across the resistive element.
- The voltage between the wiper and ground is proportional to the ratio of the resistance on one side of the wiper to the total resistance of the resistive element.
- Essentially the pot acts as voltage divider network. That is, the voltage across the resistive element is divided into two parts by a wiper.

- Measuring this voltage gives the position of the wiper.

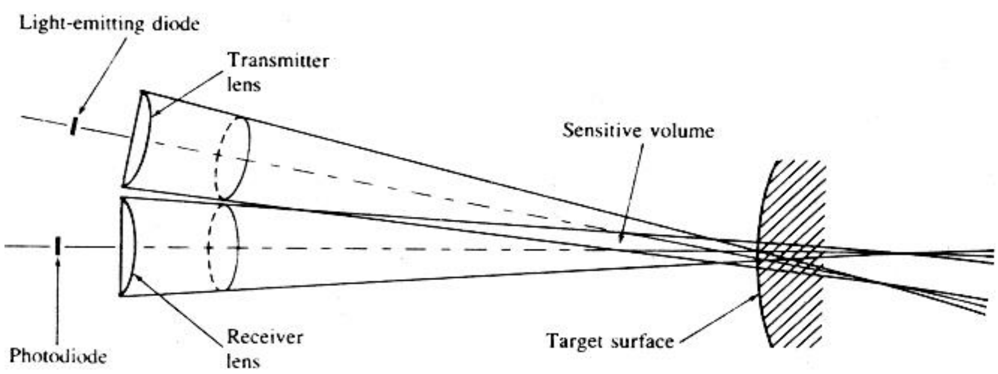


The wiper makes physical contact with wires on the resistive coil. Point "a" in the figure corresponds to zero output (i.e. zero resistance). In the rotary design, the output resistance is proportional to θ, while in linear case it is "d".

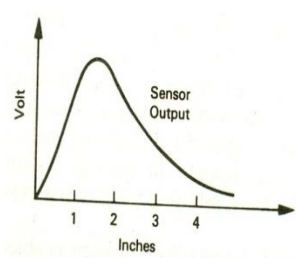
(OR)

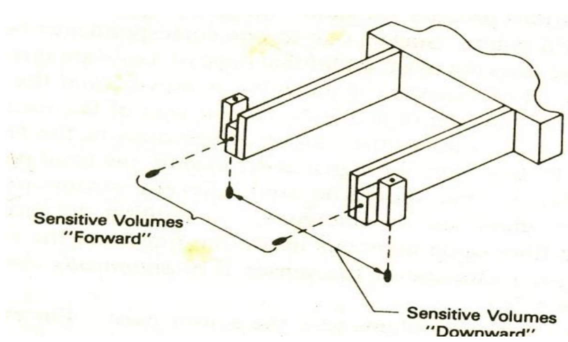
7. a) Explain the working of proximity sensor using reflected light against a sensor array with a schematic sketch. CO3(BL2) **5M**

One of the simplest types of proximity sensors that uses light reflected from an object and has been used experimentally on a robot gripper is shown in figure



The sensor consists of a source of light and a photo-detector separated by about 8 mm and tilted symmetrically toward one another.
This, together with lenses mounted in front of the assembly, produces focused incident and reflected beams.





The maximum sensor output will occur, when an object is at the focal point. However, there are several difficulties with this type of sensor.

1: As shown in figure (a), **two different object positions produce the same voltage**, except when the object is at the focal point. Since a one-to-one correspondence between position and detector voltage does not exist, **additional logic or hardware is required to eliminate the ambiguity**.
For example, if the robot is moving and the sensor signal is increasing, it is clear that the object is on the far side of the focal point (i.e., has yet to reach this point, and so the output corresponds to the larger of the two position

values). If, however, the signal is decreasing, the focal point has been passed and the smaller distance should be used. Another way to avoid this ambiguity is to place several sensors at different angles.

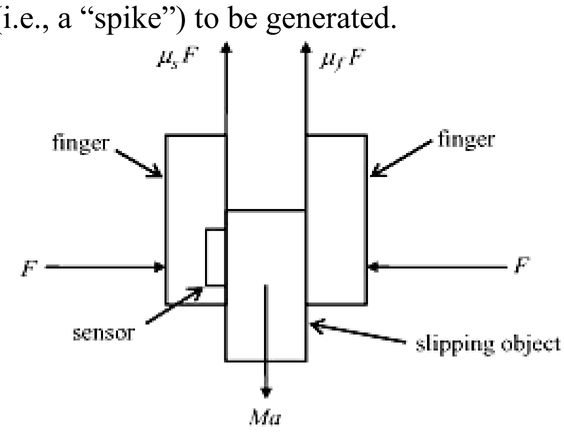
2: **Ambient light will shift the curve** in figure (a) up or down depending on the intensity. It can be avoided by pulsing the light frequency at about 6 kHz rate.

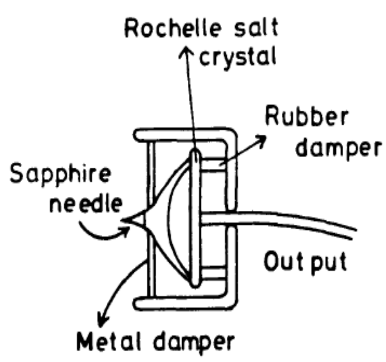
3: A more difficult and perhaps impossible problem to overcome is the sensor is sensitive to the reflectivity of the object or obstacle.

It would be difficult to use this sensor for absolute position measurement because of its sensitivity to variations in light source output, drift in the detector characteristics (due to ambient temperature fluctuation) and environmentally caused changes in reflectivity of the object.

b) With a neat sketch explain forced oscillation slip sensor. CO3(BL2) **5M**

- This is one of methods developed for detection of slippage.
- Forced oscillation is used whereby any translation of the part in a direction tangential to the surface of the gripper jaws (i.e., orthogonal to the direction of the applied gripping force) caused a short burst of voltage (i.e., a "spike") to be generated.





- As shown in figure, a sapphire needle protrudes from the surface of the sensor and is in contact with the object being grasped.
- If the part begins to slip, the needle will be displaced and will produce mechanical deformation in a piezoelectric crystal (e.g., Rochelle salt).
- The resultant generated voltage spike can be sensed using a threshold detector and the gripping force increased incrementally until the part stops slipping.

The main drawback of the above device is the rubber damper is sensitive to non-slip related motion.

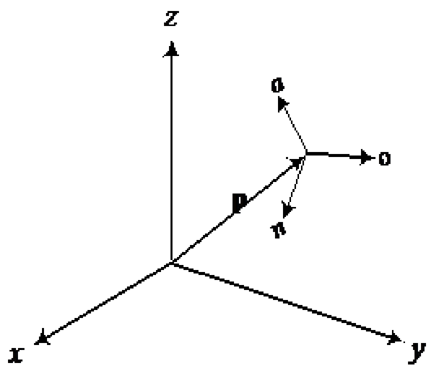
It is important to note that such a detector must be able to sense slippage accurately while a part is being moved.

It is necessary to reduce as much possible this sensitivity to non-slip related motions.

Another problem with the above slip sensor is wear of the needle and periodic replacement of the same.

Unit - IV

8. a) What is homogenous transformation matrix? Explain translation and rotation transformations. CO4(BL2) **4M**



$$F=\begin{bmatrix} n_x & o_x & a_x & P_x \\ n_y & o_y & a_y & P_y \\ n_z & o_z & a_z & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n & o & a & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

the first **three vectors** are directional vectors with w=0, representing the directions of the three unit vectors of the frame **F n,o,a,**
The fourth vector with w=1 represents the location of the origin of the frame relative to the reference frame.

Adding the fourth row of scale factors to the matrix makes it a 4 x 4 or ***homogeneous matrix.***

The matrix ${}^1T_2$ can be divided into four parts as indicated by dotted lines in Eq. (2.27). The four submatrices of a generalized homogeneous transforın T are as shown below:

$$T=\left[\begin{array}{c|c} \text{Rotation matrix} & \text{Translation vector} \\ (3\times 3) & (3\times 1) \\ \hline \text{Perspective} & \\ \text{transformation matrix} & \text{Scale factor} \\ (1\times 3) & (1\times 1) \end{array}\right] \qquad (2.28)$$

b) Determine the transformation matrix T that represents a translation of 3 units along X-axis, followed by a rotation of 60° about X-axis and followed by a rotation of 45° about Z-axis. CO4(BL3) **6M**

Transformation equation = Rot (Z, 45) Rot (X, 60) * Trans (3,0,0)

$$= \begin{matrix} \text{Cos }45 & -\sin 45 & 0 & 0 \\ \text{Sin }45 & \cos 45 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \quad \begin{matrix} 1 & 0 & 0 & 0 \\ 0 & \cos 60 & -\sin 60 & 0 \\ 0 & \sin 60 & \cos 60 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \quad \begin{matrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

$$= \begin{matrix} 0.7 & -3.5 & 0.606 & 2.1 \\ 0.7 & 3.5 & -0.606 & 2.1 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

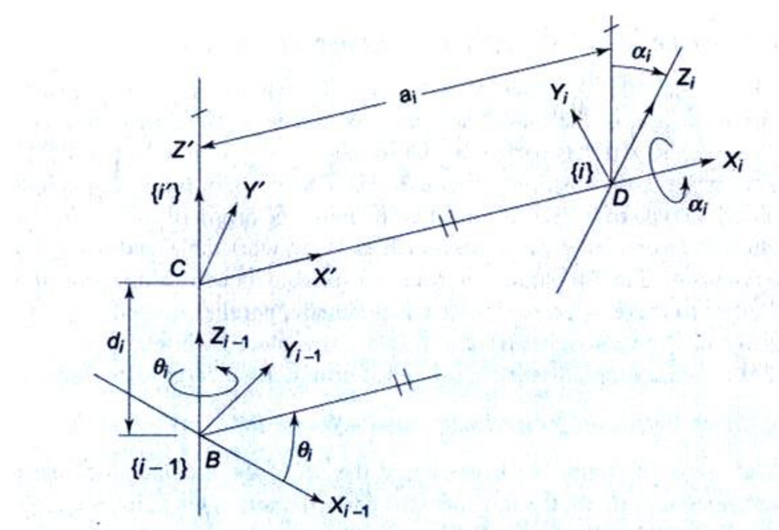
(OR)

9. What is a forward kinematics problem? Explain Denavit-Hartenberg convention for selecting frames of reference in two joint robotic applicationsand derive necessary equation. CO4(BL3) **10M**

The **forward kinematics** will enable us to determine where the robot's end (hand) will be, if all joint variables are known

The transformation of frame $\{i-1\}$ to frame $\{i\}$ consists of four basic transformations as shown in Fig. 3.9.

(a) A rotation about z_{i-1}-axis by an angle θ_i;
(b) Translation along z_{i-1}-axis by distance d_i;
(c) Translation by distance a_i along x_i-axis, and
(d) Rotation by an angle α_i about x_i-axis.



$${}^{i-1}T_i = T_z(\theta_i)T_z(d_i)T_x(a_i)T_x(\alpha_i) \quad (3.2)$$

From Eqs. (2.20), (2.54), and (2.55),

$${}^{i-1}T_i = \begin{bmatrix} C\theta_i & -S\theta_i & 0 & 0 \\ S\theta_i & C\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C\alpha_i & -S\alpha_i & 0 \\ 0 & S\alpha_i & C\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

or

$${}^{i-1}T_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3.3)$$

where $C\theta_i = \cos\theta_i$, $S\theta_i = \sin\theta_i$, $C\alpha_i = \cos\alpha_i$, and $S\alpha_i = \sin\alpha_i$.

To facilitate the calculation of the A matrices, we will form a table of joint and link parameters, whereby, the values representing each link and joint are determined from the schematic drawing of the robot and are substituted into each A matrix.

#	θ	d	a	α
0-1				
1-2				
2-3				
3-4				
4-5				
5-6				