VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

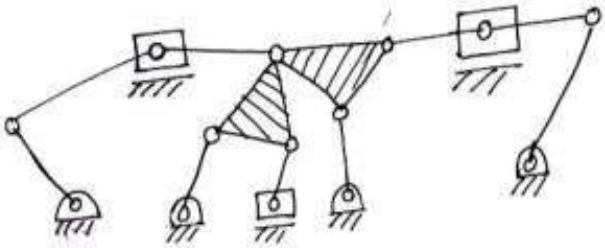
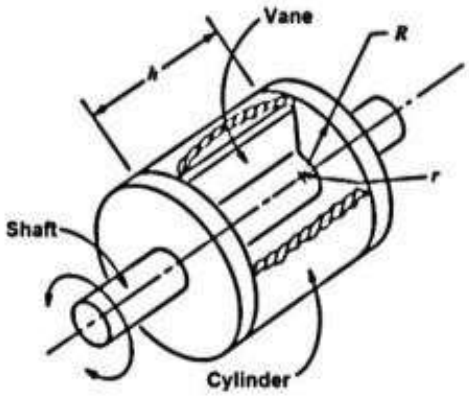
SCHOOL OF ELECTRONICS ENGINEERING
CAT-I Question Paper, FALL SEMESTER (2023-24)
BECE312L: ROBOTICS AND AUTOMATION

Course: **B. Tech (ECE)** Class NBR: **VL2023240102308, VL2023240102311** Course Mode: **CBL**

Course Type: **TH** Slots: **C2+TC2** Faculty: **Dr. M. Islam, Dr. T. K. Das**

Duration : 90 Minutes. **Max. Marks : 50M**

Answer All Questions

Q. No	Questions	Max. marks	CO	BL
Q. 1.	Describe the key components of a robot that you would have for pick and place application with neat sketch.	**[10]**	**1**	**2**
Q. 2.	a) Draw the 2D workspace (top view and side view) of a RRP Coordinate system-based manipulator.	**[5]**	**1**	**3**
	b) Find the degree of freedom (DOF) for the robot mechanism as shown in Figure 1 using Grubler's formula.  Figure 1	**[5]**		
Q. 3.	a) Discuss the construction and operation of a Brushed DC motor with a neat diagram.	**[8]**	**2**	**1**
	b) Find the step size of rotation in a variable reluctance stepper motor if number of stator poles and rotors poles are 8 and 6 respectively.	**[2]**		
Q. 4.	a) Refer to the following design parameters of the rotary hydraulic actuator shown in Figure 2. Outer radius of the vane, $R = 300\ mm$ Inner radius of the vane, $r = 50\ mm$ Thickness of the vane, h = 30 mm, Fluid flow rate, f(t) = $0.01\ m^3/s$. Diameter of the piston, $d = 40\ mm$, Load on the piston, $F = 5000\ N$. Obtain the angular velocity and torque developed for a robotic manipulator.  Figure 2	**[10]**	**2**	**3**
Q. 5.	Enlist the characteristics of sensors used in robots. Discuss a sensor that would enhance oscillations in presence of metallic objects. Give the principle of operation and construction with a neat sketch.	**[10]**	**3**	**1**

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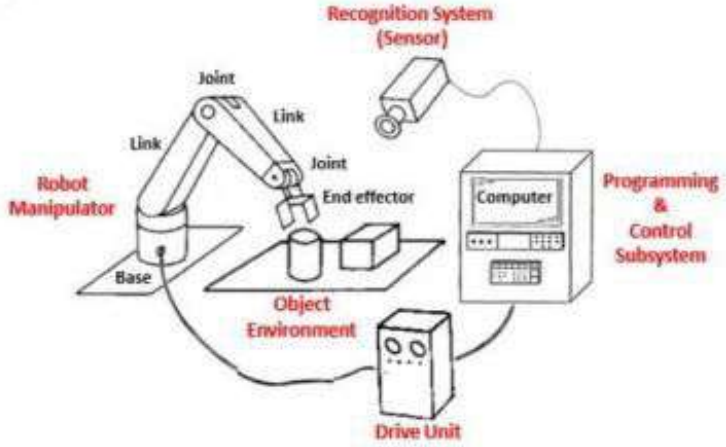
Q 1 [10]



Key Components:

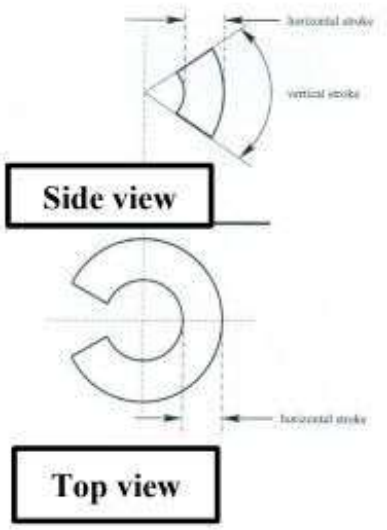
1. **Arm or Manipulator** - The mechanical structure consisting of links and joints that performs the actual work of the robot with actuators.
2. **Feedback devices** – Sensors and transducers that sense the position of various linkages and/or joints that transmit this information to the controller.
3. **Controller** - Computer used to generate signals for the drive system in order to reduce response error in positioning and applying force during robot assignments.
4. **Power/ Drive Unit** - Electric, pneumatic, and hydraulic power systems used to provide and regulate the energy needed for the manipulator's actuators.

Note: Explanation of individual blocks in precise manner.

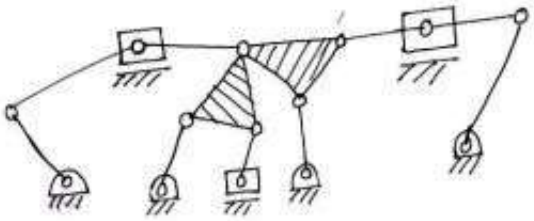
Q 2 [5]

a)

Workspace of Spherical Coordinate Robot (RRP)



b) [5]



- ✓ No of binary rotary joints = 11
- ✓ No of ternary rotary joints = 3
- ✓ No of sliding joints=3
- ✓ **Total No of binary joints = *l* = 11+ (3 x 2) + 3= 20**
- ✓ No of rigid links = n =15
- ✓ DoF = **3(n-1) - 2l – h**
  = 3(15-1)-2×20=2

Q 3. **[8]**

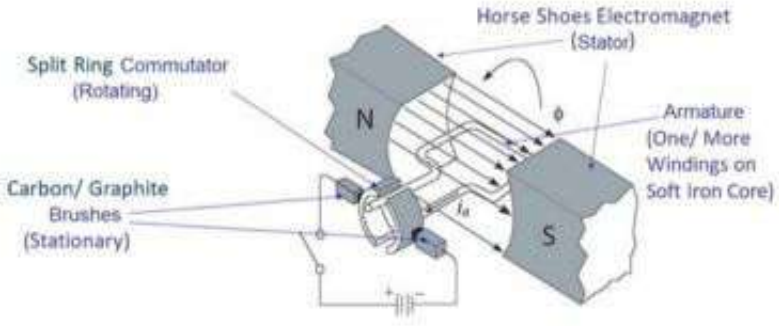
a)

Brushed DC Motor:

A device that converts direct current into rotation of an element.

Electrical Energy → **DC Motor** → Mechanical Energy

Construction of a Brushed DC Motor:



Basic elements:

- ❑ **Horse Shoes Electromagnet/ Permanent Magnet:** North and south poles of the magnet provide a strong magnetic field. Traditionally form the outer casing of the motor and collectively form the stator.
- ❑ **Armature:** Cylindrical ferrous core rotating within the stator and carries a large number of windings made from one or more conductors.
- ❑ **Commutator:** rotates with the armature and consists of copper contacts attached to the end of the windings.
- ❑ **Brushes:** are at fixed positions and in contact with the rotating commutator contacts, carry direct current to the coils, resulting in the required motion.

Working of a Brushed DC Motor:

- ✓ when the coil is powered, a magnetic field is generated around the armature.
- ✓ The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation.
- ✓ The armature continues to rotate, and when the armature becomes horizontally aligned, the commutator reverses the direction of current through the coil, reversing the magnetic field.
- ✓ The process then repeats.
- ✓ When a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by **Fleming's left-hand rule**. The magnitude of the force is given by:

$$\boxed{F = BILsin\theta}$$

where,

B is magnetic field density in $weber/m^2$
I is the current in amperes
L is the length of the conductor in meter
θ is the angle between direction of current w.r.t. magnetic flux lines.

b) **[2]**

Given: number of stator poles (Ns) and rotors poles (Nr) are 8 and 6 respectively

$$\text{Step size}(\beta) = \frac{|N_s - N_r|}{N_s \cdot N_r} \times 360^0 = 15^0$$

Q 4. **[10]**

Design Parameters are as described below:
Outer radius of the vane, $R = 300\ mm = 0.3$ m
Inner radius of the vane, $r = 50\ mm = 0.05$ m
Thickness of the vane, $h = 30\ mm = 0.03$ m
Fluid flow rate, $f(t) = 0.01\ m^3/s$
Diameter of the piston, $d = 40\ mm = 0.04$ m
Load on the piston, $F = 5000\ N$

$$\omega(t) = \frac{2f(t)}{(R^2 - r^2)h} = \frac{2 \times 0.01}{(0.3^2 - 0.05^2) \times 0.03} = 7.619\ rad/s$$

$$T(t) = \frac{1}{2}P(t)(R^2 - r^2)h = 0.5 \times \frac{5000}{\left(\pi \times \left(\frac{0.04^2}{4}\right)\right)} \times (0.3^2 - 0.05^2) \times 0.03$$
$$= 5222.27\ N - m$$

Q 5. **[10]**

Characteristics of Sensors

- Range: Difference between the maximum and minimum values of the input that can be measured.
- Response: should be capable of responding to the changes in minimum time.
- Accuracy: deviation from exact quantity

- Sensitivity = change in output/ change in input
- Linearity: constant sensitivity
- Repeatability: Deviation from reading to reading, when these are taken for a number of times under identical conditions.
- Resolution: Minimum difference between two values

Capacitive Proximity Sensor:

- Capacitive proximity sensors are similar to inductive proximity sensors.
- The main difference between the two types is that capacitive proximity sensors produce an electrostatic field instead of an electromagnetic field.
- Capacitive proximity switches will sense metal as well as non-metallic materials such as paper, glass, liquids, and cloth.

Principle of Operation:

- The sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor.
- When an object nears the sensing, surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit.
- As a result, the oscillator begins oscillating.
- The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes.
- As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state.