B.E. MECHANICAL ENGINEERING SECOND YEAR SECOND SEMESTER (Old) – 2018

Subject: ADVANCED KINEMATICS AND ROBOTICS

Time 3 hours Full Marks 100

Answer any five questions

1. (i) What is Chebyshev spacing? If a function varies from 10 to 20, find the Chebyshev spacing for 2, 3, 4 and 6 precision positions. (2+4)

(ii) What are type, number and dimensional synthesis of linkages? (3x2)

(iii) State and explain Gruebler's criterion in connection with number synthesis. 8

2. (i) Deduce the Freudenstein position equation for a 4R linkage. 5

(ii) By this equation synthesize a 4R linkage for coordinating the following input and output positions: 15

$$\theta_1 = 30^0, \theta_2 = 40^0, \theta_3 = 50^0$$
$$\psi_1 = 45^0, \psi_2 = 60^0, \psi_3 = 75^0$$

3. Design a 4R linkage graphically using relative pole method to generate the following pairs of movements: $(\theta_2^{12} = 50^0, \theta_4^{12} = 25^0)$ and $(\theta_2^{13} = 80^0, \theta_4^{13} = 55^0)$. For a minimum link length of 20 find the lengths of other links. Select suitable scale of drawing. 20

4. Synthesize an offset slider-crank mechanism for 3 accuracy points so that the displacement of the slider is proportional to the square of the crank rotation in the interval of $60^0 \le \theta_2 \le 150^0$. The distance of the slider from the crank-shaft, s, should be 20 for $\theta_2 = 60^0$ and 10 for $\theta_2 = 150^0$. 20

5. Table Q5 shows the D-H parameters of a 3-DOF robotic manipulator. Apply D-H algorithm to draw the link coordinate frames. Also compute the overall transformation matrix. Given: $\theta_1 = \frac{\pi}{4}\,rad, \theta_2 = \frac{\pi}{4}\,rad, \theta_3 = \frac{\pi}{3}\,rad$. 20

Table Q5

Axis	a	α	d	θ
1	10	0	10	θ_1
2	30	$\pi/2$	20	θ_2
3	10	0	0	θ_3

6. Design a 4R linkage, which will move a line AP on its coupler APB such that a point P on that line will be first at P_1 and then at P_2 (Fig. Q6). The line will also rotate through an angle α between these two precision positions. δ and P_{21} define the positions of P_1 and P_2 with respect to a frame x-iy. For $\delta = 210^0$, $\alpha = 20^0$ and $P_{21} = 50$, find the lengths and angles of the four links and the coupler link dimensions A_1P_1 and B_1P_1. 20

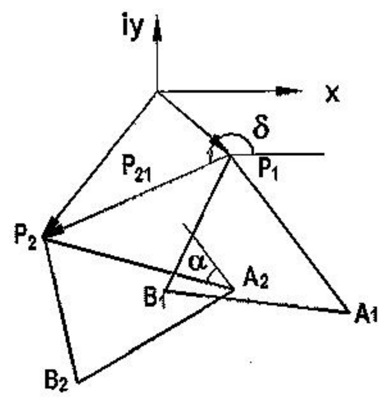

Fig.Q6

7. An offset slider crank mechanism is shown in Fig.Q7. If an external force F_P acts on the slider link 4, establish the matrix equation for determining the forces at the joints. Also find the driving torque needed on the crank 2 to obtain the specified acceleration. Assume μ as the coefficient of friction at sliding. 20

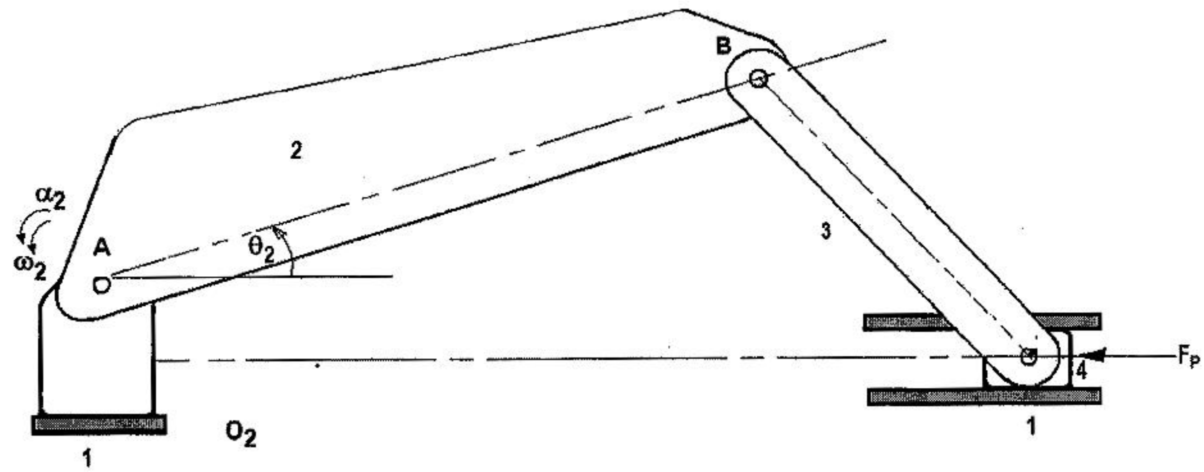

Fig.Q7

8. Transformation matrices corresponding to each joint of a 4-DOF robot are given by:

$$T_1^0(\theta_1)=\begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, T_2^1(d_2)=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, T_3^2(d_3)=\begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}, T_4^3(\theta_1)=\begin{bmatrix} C_4 & -S_4 & 0 & 0 \\ S_4 & C_4 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The position and orientation of tool at a given instant is given by the matrix

$$T_{Tool}^{Base}=\begin{bmatrix} -0.250 & 0.433 & -0.866 & -89.10 \\ 0.433 & -0.750 & -0.500 & -45.67 \\ -0.866 & -0.500 & 0.000 & 50.00 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

By the close-form approach of inverse kinematics find the magnitude of all joint variables.

9. Write notes on (any four): (4x5)

(i) Drive systems of robot;

(ii) Redundant degrees of freedom;

(iii) Errors in kinematic synthesis;

(iv) Shape-memory-effect actuators;

(v) Touch and tactile sensors.