Unit - I

Chapter 1 : Fundamentals of Mechanisms 1-1 to 1-48

Kinematic link, Types of links, Kinematic pair, Types of constrained motions, Types of Kinematic pairs, Kinematic chain, Types of joints, Mechanism, Machine, Degree of freedom, Mobility of Mechanism, Inversion, Grashoff's law, Four-Bar Chain and its Inversions, Slider crank Chain and its Inversions, Double slider crank Chain and its Conversions, Mechanisms with Higher pairs, Equivalent Linkages and its Cases - Sliding Pairs in Place of Turning Pairs, Spring in Place of Turning Pairs, Cam Pair in Place of Turning Pairs

1.1 Introduction 1-2

1.2 Kinematic Link or Element 1-2

1.2.1 Types of Links 1-2

1.2.2 Types of Rigid Links 1-3

1.3 Machine 1-4

1.4 Structure 1-4

1.4.1 Difference between a Structure and Machine 1-5

1.5 Types of Constrained Motions 1-5

1.6 Kinematic Pair 1-6

1.6.1 Types of Kinematic Pairs 1-6

1.6.2 Classification According to the Nature of Relative Motion between the Links 1-6

1.6.3 Classification According to the Nature of Contact between the Links 1-7

1.6.4 Classification According to the Mechanical Arrangement: 1-8

1.7 Kinematic Chain 1-8

1.8 Types of Joints in a Kinematic Chain 1-9

1.8.1 Difference between Binary Link and Binary Joint 1-10

1.9 Types of Kinematic Chain 1-12

1.10 Mechanism 1-13

1.10.1 Difference between Mechanism and a Machine 1-13

1.11 Inversion of a Kinematic Chain 1-13

1.11.1 Inversions of Four Bar Kinematic Chain 1-14

1.11.2 Inversions of Single Slider Kinematic Chain 1-16

1.11.3 Inversions of Double Slider Kinematic Chain 1-20

1.12 Grashof's Law 1-25

1.12.1 Class - I Four Bar Linkage ($s + l < p + q$) 1-25

1.12.2 Class - II Four Bar Linkage ($s + l > p + q$) 1-26

1.12.3 Special Cases of Four Bar Linkage ($s + l = p + q$) 1-27

1.13 Degree of Freedom (DOF) 1-29

1.14 Mobility and Degree of Freedom (DOF) 1-30

1.15 Kutzbach Criterion 1-31

1.16 Grubler's Criterion 1-31

1.16.1 Application of Grubler's Criterion 1-33

1.16.2 Minimum Number of Links in Planar Mechanism 1-35

1.16.3 Important Conclusion from Grubler's Criteria 1-35

1.16.4 Limitations of Grubler's Criteria 1-36

1.17 Mechanisms with Higher Pairs 1-45

1.17.1 Ratchet and Escapement Mechanism 1-45

1.17.2 Indexing Mechanism 1-46

1.18 Equivalent Linkage of Mechanism 1-46

1.18.1 Turning Pair in Place of Sliding Pair 1-47

1.18.2 Turning Pair in Place of Higher (Cam) Pair 1-47

1.18.3 Turning Pair in Place of Spring 1-47

Unit - II

Chapter 2 : Kinematic Analysis of Mechanisms (Analytical Methods) 2-1 to 2-52

Analytical methods for displacement, velocity and acceleration analysis of slider crank Mechanism, Velocity and acceleration analysis of Four-Bar and Slider crank mechanisms using Vector and Complex Algebra Methods. Computer-aided Kinematic Analysis of Mechanism like Slider crank and Four-Bar mechanism, Analysis of Single and Double Hook's joint

2.1 Introduction 2-2

2.2 Linear and Angular Velocity 2-2

2.3 Linear and Angular Acceleration 2-2

2.4 Motion of a Particle Moving in a Circular Path 2-3

2.4.1 Tangential Acceleration, f^t 2-3

2.4.2 Centripetal Acceleration, f^c 2-4

2.4.3 Total Acceleration, f 2-4

2.5 Analytical Method 2-4

2.6 Position Analysis of Links with Complex Algebra Method 2-15

2.6.1 Velocity and Acceleration Analysis by Complex Algebra Method 2-15

2.6.2 Loop-Closure Equation 2-16

2.7 Positions Analysis of Links With Vector Algebra Methods 2-22

2.7.1 Chace Solution 2-22

2.7.2 Velocity and Acceleration Analysis by Vector Algebra Method 2-25

2.8 Hooke's Joint or Universal Coupling 2-29

2.8.1 Single Hooke's Joint Analysis 2-30

2.8.2 Maximum and Minimum Speeds of the Driven Shaft 2-31

2.8.3 For Equal Speeds of Driving and Driven Shafts 2-31

2.8.4 Polar Diagram 2-31

2.8.5 Maximum Fluctuation of Speed of Driven Shaft 2-32

2.8.6 Angular Acceleration of Driven Shaft 2-32

2.8.7 Double Hooke's Joint Analysis 2-32

2.8.8 Comparison of Single Hook's Joint with Double Hook's Joint 2-33

2.9 Computer-aided Kinematic Analysis of Mechanism like Slider crank and Four-Bar mechanism 2-38

2.9.1 Computer-aided Kinematic Analysis of Slider crank mechanism to determine Velocity and acceleration 2-38

2.9.2 Computer-aided Kinematic Analysis of Four Bar Mechanism to Determine Velocity and Acceleration 2-43

2.9.3 Computer-aided Kinematic Analysis of four bar chain mechanism using Freudenstein's Equation 2-49

2.9.4 Computer-aided Kinematic Analysis of Hooke's joint Mechanism using Analytical Method 2-51

➢ **Model Question Paper (In sem) ..... M-1 to M-2**

Unit - III

Chapter 3 : Kinematic Analysis of Mechanisms : Graphical Method 3-1 to 3-65

Displacement, velocity and acceleration analysis mechanisms by Relative Velocity Method (Mechanisms up to 6 Links), Instantaneous Centre of Velocity, Kennedy's Theorem, Angular Velocity ratio Theorem, Analysis of mechanism by ICR method (Mechanisms up to 6 Links), Coriolis component of Acceleration (Theoretical treatment only)

3.1 Introduction 3-2

3.2 Linear and Angular Velocity 3-2

3.3 Representation of Velocity by Vectors 3-2

3.4 Velocity Analysis by Relative Velocity Method 3-3

3.4.1 Relative Velocity of Two Bodies having their Absolute Motions 3-3

3.4.2 Velocity Diagram of a Rigid Link 3-4

3.5 Rubbing Velocity at a Pin Joint 3-5

3.6 Mechanical Advantage 3-5

3.7 Applications of the Relative Velocity Method 3-5

3.8 Acceleration Analysis by Relative Velocity Method 3-13

3.9 Linear and Angular Acceleration 3-13

3.10 Motion of a Particle Moving in a Circular Path 3-14

3.10.1 Tangential Acceleration, f^t 3-14

3.10.2 Centripetal Acceleration, f^c 3-14

3.10.3 Total Acceleration, f 3-14

3.11 Acceleration Diagram of a Link by Relative Acceleration Method 3-15

3.12 Outline Procedure of Drawing the Acceleration Diagram of a Mechanism 3-16

3.13 Velocity Analysis by Instantaneous Centre Method's 3-36

3.13.1 Velocity of a Point on a Link by Instantaneous Centre Method 3-36

3.13.2 Number of Instantaneous Centres in a Mechanism 3-37

3.13.3 Location of Instantaneous Centres by Inspection 3-37

3.13.4 Types of Instantaneous Centres 3-37

3.13.5 Properties of the Instantaneous Centre 3-38

3.13.6 Centrodes 3-38

3.14 Three Centres in Line Theorem (Aronhold - Kennedy's Theorem) 3-39

3.15 Steps to Locate Instantaneous Centres 3-39

3.16 Angular Velocity Ratio Theorem 3-41

3.17 Freudenstein's Theorem 3-41

3.18 Coriolis Component of Acceleration 3-60

3.18.1 Magnitude of Coriolis Component of Acceleration 3-60

3.18.2 Method of Finding the Direction of Coriolis Component 3-61

Unit - IV

Chapter 4 : Synthesis of Mechanisms 4-1 to 4-34

Steps in Synthesis : Type synthesis, Number Synthesis, Dimensional synthesis, Tasks of Kinematic synthesis - Path, function and motion generation (Body guidance), Precision Positions, Chebychev spacing, Mechanical and structural errors, **Graphical Synthesis :** Inversion and relative pole method for three position synthesis of Four-Bar and Single Slider Crank Mechanisms **Analytical Synthesis :** Three position synthesis of Four-Bar mechanism using Freudenstein's equation, Blotch synthesis

4.1 Introduction 4-2

4.1.1 Type Synthesis 4-2

4.1.2 Number Synthesis 4-2

4.1.3 Dimensional Synthesis 4-2

4.2 Classification of Synthesis Problems (Tasks of Kinematic Synthesis) 4-2

4.2.1 Function Generation 4-2

4.2.2 Path Generation 4-3

4.2.3 Body Guidance (Motion Generation) 4-3

4.3 Dimensional Synthesis 4-3

4.3.1 Dimensional Synthesis by Inversion Method 4-3

4.3.1.1 Two-position Synthesis of Four Bar Chain Mechanism by Inversion Method 4-3

4.3.1.2 Three-position Synthesis for Four Bar Chain Mechanism by Inversion Method 4-4

4.3.1.3 Four Position Synthesis for Four Bar Chain Mechanism by Inversion Method 4-6

4.3.1.4 Two-position Synthesis for Slider Crank Mechanism by Inversion Method 4-7

4.3.1.5 Three-position Synthesis for Slider Crank Mechanism by Inversion Method 4-7

4.3.2 Dimensional Synthesis by Relative Pole Method 4-8

4.3.2.1 Two Position Synthesis of Four Bar Chain Mechanism by Relative Pole Method 4-9

4.3.2.2 Three Position Synthesis of Four Bar Chain Mechanism by Relative Pole Method 4-10

4.3.2.3 Two Position Synthesis of Slider Crank Mechanism by Relative Pole Method 4-10

4.3.2.4 Three Position Synthesis of Slider Crank Mechanism by Relative Pole Method 4-11

4.4 Analytical Method for Dimensional Synthesis of Four Bar Chain Mechanism (Freudenstein's Equation) 4-12

4.5 Synthesis of a Function Generation 4-13

4.5.1 Types of Errors in Synthesis of Mechanisms 4-13

4.5.2 Chebyshev Spacing Method 4-13

4.6 Three Position Motion Synthesis of Four Bar Chain Mechanism (Body Guidance) 4-30

4.7 Bloch's Synthesis 4-32

Unit - V

Chapter 5 : Kinematics of Gears 5-1 to 5-57

Gear : Classification, **Spur Gear:** Terminology, law of gearing, Involute and cycloidal tooth profile, path of contact, arc of contact, sliding velocity, Interference and undercutting, Minimum number of teeth to avoid interference, Force Analysis (theoretical treatment only), **Helical and Spiral Gears :** Terminology, Geometrical Relationships, virtual number of teeth for helical gears, **Bevel Gear & Worm and Worm Wheel :** Terminology, Geometrical Relationships

5.1 Introduction to Gears 5-2

5.2 History of Gears 5-2

5.3 Advantages and Disadvantages of Gear Drive 5-3

5.4 Classification of Gears 5-3

5.4.1 Spur Gears 5-3

5.4.2 Helical Gears 5-4

5.4.3 Rack and Pinion 5-5

5.4.4 Bevel Gears 5-5

5.4.5 Spiral Gears 5-7

5.4.6 Worm and Worm Wheel 5-7

5.5 Comparison of Gears 5-8

5.6 Gear Tooth Terminology and Geometrical Relationships 5-9

5.7 Law of Gearing (Condition for Constant Velocity Ratio) 5-10

5.8 Velocity of Sliding of Teeth 5-11

5.9 Conjugate Profile 5-12

5.10 Forms of Gear Tooth Profile 5-12

5.10.1 Cycloidal Profile 5-12

5.10.2 Involute Profile 5-13

5.11 Comparison of Cycloidal and Involute Tooth Gears 5-14

5.12 Standard Tooth Profiles or Systems 5-14

5.13 Length of Path of Contact 5-15

5.14 Length of Arc of Contact 5-16

5.15 Contact Ratio or Number of Pairs of Teeth in Contact 5-17

5.16 Interference in Involute Gears 5-22

5.17 Undercutting 5-23

5.18 Critical or Minimum Number of Teeth to Avoid Interference 5-23

5.18.1 Minimum Number of Teeth on Pinion o Avoid Interference with Wheel 5-23

5.18.2 Minimum Number of Teeth on Pinion to Avoid Interference with Rack 5-25

5.19 Methods to Avoid Interference 5-25

5.19.1 Modified Profile of Tooth 5-25

5.19.2 Modified Addendum of Pinion and Wheel 5-26

5.19.3 Modified Center Distance between Pinion and Wheel 5-27

5.20 Effect of Center Distance Variation on Velocity Ratio 5-27

5.21 Rack Shift 5-28

5.22 Fouling (Interference in Internal Gears) 5-28

5.23 Static Force Analysis of Spur Gears 5-37

5.24 Introduction to Helical Gears 5-38

5.25 Terminology of Helical Gear 5-39

5.26 Virtual Number of Teeth or Number of Teeth on Equivalent Spur Gear 5-39

5.27 Velocity Ratio of Helical Gears 5-40

5.28 Centre Distance of Helical Gears 5-41

5.29 Introduction to Spiral Gears 5-43

5.30 Shaft Angle of Spiral Gears 5-43

5.31 Velocity of Sliding between Spiral Gears 5-44

5.32 Center Distance between Two Spiral Gears 5-44

5.33 Introduction to Bevel Gears 5-48

5.34 Terminology of Bevel Gear 5-49

5.35 Pitch Cone Angles and its Geometrical Relationship 5-49

5.36 Introduction to Worm and Worm Gears 5-51

5.37 Terminology of Worm 5-52

5.38 Velocity Ratio and Center Distance between Worm Gears 5-53

Unit - V

Chapter 6 : Gear Trains 6-1 to 6-26

Types, Analysis of Epicyclic gear Trains, Holding torque - simple, compound and Epicyclic gear Trains, Torque on Sun and Planetary gear Train, compound Epicyclic gear Train

6.1 Introduction 6-2

6.2 Simple Gear Train 6-2

6.3 Compound Gear Train 6-3

6.4 Reverted Gear Train 6-4

6.5 Design of Spur Gear Trains 6-4

6.6 Epicyclic Gear Train 6-9

6.7 Method of Finding Velocity Ratio of an Epicyclic Gear Train 6-9

6.8 Epicyclic Gear Train with Bevel Gears 6-11

6.9 Torque and Tooth Load in Epicyclic Gear Train 6-20

Unit - VI

Chapter 7 : Cams and Followers 7-1 to 7-37

Introduction, Classification of Followers and Cams, Terminology of Cam Displacement diagram for the Motion of follower as Uniform velocity, Simple Harmonic Motion (SHM), Uniform Acceleration and Retardation Motion (UARM), Cycloid motion, Cam Profile construction for Knife-edge Follower and Roller Follower, Cam jump Phenomenon

7.1 Introduction 7-2

7.2 Classification of Followers 7-2

7.3 Classification of Cams 7-3

7.3.1 Classification of Cam According to Types of Shape 7-4

7.3.2 Classification of Cam According to Type of Follower Movement 7-6

7.3.3 Classification of Cam According to Type of Constraint of the Follower 7-6

7.4 Terminology and Definitions 7-7

7.5 Types of Motions of the Follower 7-8

7.6 Motion of Follower with Uniform Velocity 7-8

7.6.1 Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Uniform Velocity 7-9

7.7 Motion of Follower with Simple Harmonic Motion 7-10

7.7.1 Method of Drawing the Displacement Diagram 7-10

7.7.2 Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Simple Harmonic Motion..... 7-11

7.8 Motion of Follower with Uniform Acceleration and Retardation..... 7-13

7.8.1 Method of Drawing the Displacement Diagram... 7-13

7.8.2 Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Uniform Acceleration and Retardation..... 7-13

7.9 Motion of Follower with Cycloidal Motion..... 7-15

7.9.1 Method of Drawing the Displacement Diagram... 7-15

7.9.2 Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Cycloidal Motion..... 7-15

7.10 Determination of Cam Profile for a given Follower Motions..... 7-18

7.11 Eccentric Cam with Flat-faced Follower..... 7-33

7.12 Jump Phenomenon..... 7-34

Unit - VI

Chapter 8 : Automation Systems 8-1 to 8-17

Automation : Introductions, Types of Automation

Method of Work Part Transport : Continuous transfer, Intermittent or Synchronous Transfer, Asynchronous transfer, Different type of transfer mechanisms - Linear transfer mechanisms and Rotary transfer mechanisms

Automated Assembly-Line : Types, Assembly line balancing Buffer Storages, Automated assembly line for car manufacturing, Artificial intelligence in automation

8.1 Introduction to Automation 8-2

8.1.1 Need for Automation..... 8-2

8.2 Types of Automation..... 8-2

8.2.1 Comparison of Types of Automation Systems 8-3

8.3 Advantages and Limitations of Automation..... 8-4

8.3.1 Advantages of Automation..... 8-4

8.3.2 Limitations of Automation..... 8-4

8.4 Work Part Transport..... 8-4

8.5 Methods of Work Part Transport..... 8-5

8.6 Types of Transfer Mechanisms..... 8-6

8.6.1 Linear transfer mechanism..... 8-6

8.6.2 Rotary Transfer mechanism..... 8-8

8.7 Advantages and Disadvantages of Work Part Transport Mechanisms..... 8-9

8.8 Automated Assembly-Line..... 8-9

8.9 Types of Automated Assembly Systems.....8-10

8.9.1 Dial-type Assembly System 8-10

8.9.2 In-line assembly system.....8-10

8.9.3 Carousel Assembly System.....8-11

8.9.4 Single-station Assembly System.....8-11

8.10 Assembly Line Balancing.....8-11

8.11 Buffer Storages.....8-12

8.12 Automated Assembly Line For Car Manufacturing 8-13

8.13 Artificial Intelligence in Automation 8-15

8.13.1 Major Components of AI in Automation 8-16

8.13.2 Advantages and Disadvantages of AI in Automation 8-16

➢ **Model Question Paper (End sem) ..... M-1 to M-4**

❑❑❑