

**Module 1****Chapter 1 : Kinetics of Rigid Bodies and Basic Kinematics 1-1 to 1-84**

1.1 Kinetics of Rigid Bodies : Concept of mass moment of inertia and its application to standard objects.

Kinetics of rigid bodies : Work and energy

Kinetic energy in translating motion, Rotation about fixed axis and in general plane motion, Work energy principle and Conservation of energy

1.2 Basic Kinematics : Structure, Machine, Mechanism, Kinematic link & its types, Kinematic pairs, Types of constrained motions, Types of Kinematic pairs, Kinematic chains, Types of joints, Degree of freedom (mobility), Kutzbach mobility criterion, Grubler's criterion & its limitations

Four bar chain and its inversions, Grashoff's law, Slider crank chain and its inversions, Double slider crank chain and its inversions

1.1	Simple Harmonic Motion (S.H.M.)	1-2
1.1.1	Period of Oscillation	1-2
1.2	Some Important Definitions in S.H.M.	1-2
1.2.1	Amplitude of Oscillation	1-2
1.2.2	Time Period	1-2
1.2.3	Frequency	1-2
1.3	Pendulum Motion	1-2
1.3.1	Simple Pendulum	1-2
1.3.2	Compound Pendulum	1-3
1.3.3	Torsional Pendulum	1-4
1.4	Mass Moment of Inertia	1-4
1.5	Mass M.I. w.r.t. Co-ordinate Axis	1-4
1.6	Parallel Axis Theorem	1-5
1.7	Mass Moment of Inertia of Some Bodies	1-5
1.7.1	Mass M.I. of Uniform Rod of Mass M and Length L	1-5
1.7.2	Mass M.I. of a Rectangular Lamina of Mass M	1-5
1.7.3	Mass M.I. of a Circular Ring	1-6
1.7.4	Mass M.I. of Circular Lamina	1-6
1.7.5	M.I. of a Solid Cylinder	1-6
1.7.6	M.I. of a Homogeneous Hollow Right Circular Cylinder (Hoop)	1-6

1.7.7	M.I. of a Solid Sphere	1-7
1.8	Equations of Plane Motion :	
	D'Alembert's Principle	1-12
1.9	Applications to Different Types of Motion	1-13
1.9.1	Motion of Translation	1-13
1.9.2	Centroidal Rotation	1-13
1.9.3	Non Centroidal Rotation	1-13
1.10	Motion of Rolling Bodies	1-13
1.10.1	A Wheel Rolls without Slipping	1-13
1.10.2	Slipping of Roller	1-13
1.11	Application of D'Alembert's Principle for Bars, Cylinders and Spheres	1-13
1.12	Work Done	1-27
1.12.1	W.D. by Constant External Force = $F \times s$	1-27
1.12.2	W.D. by Gravitational Force = mgh	1-27
1.12.3	W.D. by Frictional Force	1-27
1.12.4	W.D. by Spring Force	1-27
1.12.5	W.D. by a Couple or Moment	1-27
1.13	Kinetic Energy	1-27
1.13.1	K.E. of Translation	1-27
1.13.2	K.E. of Rotation	1-27
1.14	Work Energy Principle	1-28
1.15	Principle of Conservation of Energy	1-28
1.16	Introduction to Theory of Machine	1-36
1.17	Kinematic Link or Element	1-37
1.17.1	Types of Links	1-37
1.17.2	Types of Rigid Links	1-38
1.18	Machine	1-38
1.19	Structure	1-39
1.19.1	Difference between a Structure and Machine	1-39
1.20	Constrained Motions	1-39
1.21	Kinematic Pair	1-40
1.22	Kinematic Chain	1-43
1.23	Types of Joints in a Kinematic Chain	1-44
1.23.1	Difference between Binary Link and Binary Joint	1-45
1.24	Closed and Open Kinematic Chain	1-46
1.25	Mechanism	1-47
1.25.1	Difference between Mechanism and a Machine	1-47
1.26	Inversion of a Kinematic Chain	1-47



1.26.1	Inversions of Four Bar Kinematic Chain	1-48
1.26.2	Inversions of Single Slider Kinematic Chain	1-51
1.26.3	Inversions of Double Slider Kinematic Chain	1-54
1.27	Grashoff's Law	1-59
1.27.1	Class - I four bar linkage ($s + l < p + q$)	1-59
1.27.2	Class - II Four Bar Linkage ($s + l > p + q$)	1-60
1.27.3	Special Cases of Four Bar Linkage ($s + l = p + q$)	1-61
1.28	Degree of Freedom (DOF)	1-63
1.29	Mobility and Degree of Freedom (DOF)	1-64
1.30	Kutzbach Criterion	1-65
1.31	Grubler's Criterion	1-65
1.31.1	Application of Grubler's Criterion	1-67
1.31.2	Minimum Number of Links in Planar Mechanism	1-69
1.31.3	Important Conclusion from Grubler's Criteria	1-70
1.31.4	Limitations of Grubler's Criteria	1-70

Module 2

Chapter 2 : Special Mechanisms 2-1 to 2-29

2.1 Straight line generating mechanisms :

Introduction to Exact straight line generating mechanisms – Peaucillier's and Hart's Mechanisms, Introduction to Approximate Straight line generating mechanisms – Watt's, Grasshopper mechanism, Tchebicheff's mechanisms

2.2 Offset slider crank mechanisms : Pantograph, Hook-joint (single and double).

2.3 Steering Gear Mechanisms : Ackerman, Davis steering gears

2.1	Pantograph	2-2
2.2	Straight Line Generating Mechanisms	2-3
2.2.1	Exact Straight Line Generating Mechanisms	2-3
2.2.2	Approximate Straight Line Generating Mechanisms	2-5
2.3	Automobile Steering Gear Mechanism	2-8
2.3.1	Davis Steering Gear Mechanism	2-9
2.3.2	Ackermann Steering Gear Mechanism	2-11
2.3.3	Differentiate between 'Davis Steering Gear Mechanism' and 'Ackermann Steering Gear Mechanism'	2-12

2.4	Hooke's Joint or Universal Coupling	2-13
2.4.1	Hooke's Joint Analysis	2-14
2.4.2	Maximum and Minimum Speeds of the Driven Shaft	2-15
2.4.3	For Equal Speeds of Driving and Driven Shafts	2-15
2.4.4	Maximum Fluctuation of Speed of Driven Shaft	2-16
2.4.5	Polar Diagram	2-16
2.4.6	Angular Acceleration of Driven Shaft	2-16
2.4.7	Double Hooke's Joint	2-16
2.5	Offset Slider Crank Mechanism	2-26

Module 3

Chapter 3 : Velocity and Acceleration Analysis of Mechanisms 3-1 to 3-89

3.1 Velocity Analysis of Mechanisms (mechanisms up to 6 links)

Velocity analysis by instantaneous centre of rotation method (Graphical approach), Velocity analysis by relative velocity method (Graphical approach)

3.2 Acceleration Analysis of Mechanisms

(mechanisms up to 6 links) Acceleration analysis by relative method including pairs involving Coriolis acceleration (Graphical approach)

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	Velocity Analysis by Instantaneous Centre Method	3-16
3.8.1	Velocity of a Point on a Link by Instantaneous Centre Method	3-16



3.8.2	Number of Instantaneous Centres in a Mechanism.....	3-17	4.1	Introduction	4-2
3.8.3	Location of Instantaneous Centres by Inspection	3-17	4.2	Classification of Followers	4-2
3.8.4	Types of Instantaneous Centres.....	3-17	4.3	Classification of Cams	4-3
3.8.5	Properties of the Instantaneous Centre.....	3-18	4.3.1	Classification of Cam According to Types of Shape.....	4-3
3.8.6	Centrodes	3-18	4.3.2	Classification of Cam According to Type of Follower Movement.....	4-4
3.9	Three Centres in Line Theorem (Aronhold - Kennedy's Theorem)	3-18	4.3.3	Classification of Cam According to Type of Constraint of the Follower.....	4-5
3.10	Steps to Locate Instantaneous Centres	3-19	4.4	Terminology and Definitions.....	4-6
3.11	Angular Velocity Ratio Theorem	3-20	4.5	Types of Motions of the Follower	4-6
3.12	Freudenstein's Theorem.....	3-20	4.6	Motion of Follower with Uniform Velocity	4-7
3.13	Acceleration Analysis by Relative Velocity Method.....	3-42	4.6.1	Analytical Solution for Calculation of Displacement Velocity, Acceleration and Jerk of Follower having Uniform Velocity.....	4-7
3.14	Linear and Angular Acceleration.....	3-42	4.7	Motion of Follower with Simple Harmonic Motion.....	4-8
3.15	Motion of a Particle Moving in a Circular Path.....	3-42	4.7.1	Method of Drawing the Displacement Diagram.....	4-8
3.15.1	Tangential Acceleration, f^t	3-43	4.7.2	Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Simple Harmonic Motion.....	4-9
3.15.2	Centripetal Acceleration, f^c	3-43	4.8	Motion of Follower with Uniform Acceleration and Retardation	4-10
3.15.3	Total Acceleration, f	3-43	4.8.1	Method of Drawing the Displacement Diagram	4-11
3.16	Acceleration Diagram of a Link by Relative Acceleration Method	3-43	4.8.2	Analytical Solution for Calculation of Displacement Velocity, Acceleration and Jerk of Follower having Uniform Acceleration and Retardation	4-11
3.17	Outline Procedure of Drawing the Acceleration Diagram of a Mechanism	3-44	4.9	Motion of Follower with Cycloidal Motion.....	4-12
3.18	Coriolis Component of Acceleration.....	3-64	4.9.1	Method of Drawing the Displacement Diagram...4-12	
3.18.1	Magnitude of Coriolis Component of Acceleration.....	3-65	4.9.2	Analytical Solution for Calculation of Displacement, Velocity, Acceleration and Jerk of Follower having Cycloidal Motion	4-12
3.18.2	Method of Finding the Direction of Coriolis Component.....	3-65	4.10	Determination of Cam Profile for a given Follower Motions.....	4-15

Module 4

Chapter 4 : CAM Mechanisms 4-1 to 4-38

4.1 Cam and its Classification based on shape, follower movement, and manner of constraint of follower; Followers and its Classification based on shape, movement, and location of line of movement; Cam and follower terminology

4.2 Motions of the follower : SHM, Constant acceleration and deceleration (parabolic), Constant velocity, Cycloidal; Introduction to cam profiles (No problems on this point)

**Module 5****Chapter 5 : Belts, Chains and Breaks 5-1 to 5-54**

5.1 Belts : Introduction, Types and all other fundamentals of belting, Dynamic analysis –belt tensions, condition of maximum power transmission

5.2 Chains (No problems) : types of chains, chordal action, variation in velocity ratio, length of chain (No problems)

5.3 Brakes (No problems) : Introduction, types and working principles, Introduction to braking of vehicles

5.1	Introduction to Belt and Rope Drive	5-2
5.2	Types of Belts	5-2
5.2.1	Materials used for Belt and Rope Drives	5-2
5.2.2	Selection of Belt Drive.....	5-3
5.3	Types of Belt Drives	5-3
5.4	Crowning of Pulley	5-4
5.5	Law of Belting.....	5-5
5.6	Velocity Ratio of Belt Drive.....	5-5
5.6.1	Velocity Ratio of Open Belt Drive	5-5
5.6.2	Velocity Ratio of Compound Belt Drive.....	5-6
5.7	Slip of Belt.....	5-6
5.8	Creep of Belt	5-7
5.9	Length of Belt	5-9
5.9.1	Length of an Open Belt Drive	5-9
5.9.2	Length of Cross Belt Drive	5-10
5.10	Angle of Contact or Angle of Lap	5-11
5.11	Limiting Tension Ratio	5-11
5.12	Limiting Tension Ratio in V-belt or Rope	5-12
5.13	Centrifugal Tension in Belt	5-15
5.14	Stress Induced in Belt.....	5-15
5.15	Power Transmitted by Belt.....	5-16
5.16	Maximum Power Transmitted by Belt.....	5-19
5.17	Initial Tension in the Belt.....	5-23
5.18	Rope Drive.....	5-31
5.18.1	Types of Rope Drives.....	5-31
5.18.2	Advantages and Limitations of Rope Drives over Other Drives.....	5-31
5.19	Chain Drive	5-33
5.20	Advantages and Disadvantages of Chain Drive over Belt or Rope Drive	5-33
5.21	Classification of Chains.....	5-34
5.22	Terms used in Chain Drive	5-35
5.23	Relation between Pitch and Pitch Circle Diameter	5-35
5.24	Relation between Chain Speed and Angular Velocity of Sprocket	5-35
5.25	Chordal Action.....	5-36
5.26	Length of Chain.....	5-37
5.27	Introduction to Brakes.....	5-37
5.27.1	General Requirements of a Good Braking System	5-38
5.27.2	General Requirements of a Good Brake Lining Material	5-38
5.28	Classification of Brakes.....	5-38
5.29	Block or Shoe Brakes	5-38
5.29.1	Single Block or Shoe Brake.....	5-39
5.29.1.1	Self Locking and Self Energizing of Brakes.....	5-41
5.29.2	Pivoted Block Brake ($2\theta > 60^\circ$).....	5-41
5.29.3	Double Block or Shoe Brake	5-41
5.30	Band Brakes	5-42
5.30.1	Simple Band Brake	5-42
5.30.2	Differential Band Brake	5-43
5.30.2.1	Self Locking and Self Energizing of Differential Band Brake	5-44
5.31	Band and Block Brake	5-44
5.32	Internal Expanding Shoe Brake	5-45
5.32.1	Braking Torque of an Internal Expanding Shoe Brake	5-46
5.33	Braking of a Vehicles.....	5-47
5.34	Hydraulic Brakes.....	5-49
5.34.1	Construction	5-49
5.34.2	Working Principle.....	5-50
5.34.3	Advantages of Hydraulic Brake System	5-50
5.34.4	Disadvantages of Hydraulic Brake System	5-50
5.35	Disc Brakes	5-50
5.36	Pneumatic (Air) Brakes	5-51



5.36.1	Working Principle	5-51
5.37	Vacuum Brakes	5-51

Module 6

Chapter 6 : Gears and Gear Trains 6-1 to 6-100

6.1 Gears : Introduction, Types, Law of gearing, Forms of teeth, Details of gear terminology, Path of contact, Arc of contact, Contact ratio, Interference in involutes gears, Minimum number of teeth for interference free motion, Methods to control interference in involutes gears, Static force analysis in gears - spur, helical, bevel, worm & worm wheel (No problems on this point)

6.2 Gear Trains : Kinematics and dynamic analysis of simple and compound gear trains, reverted gear trains, epi-cycle gear trains with spur or bevel gear combination.

6.1	Introduction	6-2
6.2	History of Gears	6-2
6.3	Advantages and Disadvantages of Gear Drive	6-2
6.4	Classification of Gears	6-3
6.4.1	Classification of Gears According to the Position of Shaft Axis	6-3
6.4.1.1	Spur Gears	6-3
6.4.1.2	Helical Gears	6-4
6.4.1.3	Rack and Pinion	6-4
6.4.1.4	Bevel Gears	6-5
6.4.1.5	Spiral Gears	6-6
6.4.1.6	Worm and Worm Wheel	6-6
6.4.2	Classification of Gears According to the Peripheral Velocity of the Gears	6-7
6.4.3	Classification of Gears According to Type of Meshing of Gears	6-7
6.5	Comparison of Gears	6-8
6.6	Gear Tooth Terminology	6-8
6.7	Law of Gearing (Condition for Constant Velocity Ratio)	6-10

6.8	Velocity of Sliding of Teeth	6-11
6.9	Conjugate Profile	6-11
6.9.1	Graphical Construction of Conjugate Profile	6-11
6.10	Forms of Gear Tooth Profile	6-13
6.10.1	Cycloidal Profile	6-13
6.10.2	Involute Profile	6-13
6.11	Comparison of Cycloidal and Involute Tooth Gears	6-14
6.12	Standard Tooth Profiles or Systems	6-15
6.13	Length of Path of Contact	6-16
6.14	Length of Arc of Contact	6-17
6.15	Contact Ratio or Number of Pairs of Teeth in Contact	6-18
6.16	Interference in Involute Gears	6-32
6.17	Undercutting	6-33
6.18	Critical or Minimum Number of Teeth to Avoid Interference	6-33
6.18.1	Minimum Number of Teeth on Pinion to Avoid Interference with Wheel	6-34
6.18.2	Minimum Number of Teeth on Pinion to Avoid Interference with Rack	6-35
6.19	Methods to Avoid Interference	6-36
6.19.1	Modified Profile of Tooth	6-36
6.19.2	Modified Addendum of Pinion and Wheel	6-36
6.19.3	Modified Center Distance between Pinion and Wheel	6-37
6.20	Effect of Center Distance Variation on Velocity Ratio	6-37
6.21	Rack Shift	6-38
6.22	Friction between Gear Teeth	6-39
6.23	Static Force Analysis of Spur Gears	6-52
6.24	Force Analysis of Helical Gears	6-57
6.24.1	Relation between Normal Pressure Angle (ϕ_n) and Transverse Pressure Angle (ϕ_t)	6-59
6.25	Static Force Analysis of Worm and Worm Gear Pair	6-60



6.25.1	Components of Force Acting on Worm.....	6-60	6.30	Simple Gear Train	6-69
6.25.2	Components of Force Acting on Worm Gear	6-61	6.31	Compound Gear Train	6-69
6.25.3	Direction of Components of Forces on Worm and Worm Gear.....	6-61	6.32	Reverted Gear Train.....	6-70
6.26	Sliding Velocity in Worm and Worm Gear Pair	6-62	6.33	Design of Spur Gear Trains	6-71
6.27	Efficiency of Worm and Worm Gear Pair.....	6-62	6.34	Epicyclic Gear Train	6-75
6.28	Static Force Analysis of Straight Bevel Gears.....	6-66	6.35	Method of Finding Velocity Ratio of an Epicyclic Gear Train	6-75
6.29	Introduction to Gear Train.....	6-68	6.36	Epicyclic Gear Train with Bevel Gears	6-77
			6.37	Torque and Tooth Load in Epicyclic Gear Train	6-89

