

KINEMATICS OF MACHINERY

Subject code: ME302ES
Regulations: R16-JNTUH
Class: II Year B. Tech MECH I Sem



Department of Mechanical Engineering
BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY
Ibrahimpattam - 501 510, Hyderabad

KINEMATICS OF MACHINERY (ME302ES)

COURSE PLANNER

I. COURSE OBJECTIVE AND RELEVANCE:

1. To understand the basic components and layout of linkages in the assembly of a system/machine.
2. To understand the principles involved in the displacement, velocity and acceleration at any point in a link of a mechanism.
3. To understand the motion resulting from a specified set of linkages.
4. To understand and to design few linkage mechanisms and cam mechanisms for specified output motions.
5. To understand the basic concepts of toothed gearing and kinematics of gear trains.

II. PRE REQUISITES:

Knowledge of engineering mechanics is required.

III. COURSE PURPOSE

This course introduces students to involve in kinematics study how a physical system might develop or alter over time and study the causes of those changes. In particular, kinematics is mostly related to Newton's second law of motion. However, all three laws of motion are taken into consideration, because these are interrelated in any given observation or experiment. Kinematics of machine deals with the relative motion of machine parts. Kinematic schemes of a machine can be investigated without considering the forces.

IV. COURSE OUTCOME:

S.NO	Description	Bloom's Taxonomy Level
1	Classify different types of links and mechanisms used for different purposes in different machines.	Knowledge, Understand, (Level1, Level2,)
2	Solve the forces, velocities and accelerations in different mechanisms and machines components	Understand, Apply (Level2,Level 3)
3	List, Predict and Design different type of links applied to get the required motion of different types of the parts of machines	Understand, Apply (Level2,Level 3)

V. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes		Level	Proficiency assessed by
PO1:	Engineering knowledge: Graduates will demonstrate the ability to use basic knowledge in mathematics, science and engineering and apply them to solve problems specific to mechanical engineering.	2	Assignments, Midterm and University examinations, Practicals
PO2:	Problem analysis: Graduates will demonstrate the ability to design and conduct experiments, interpret and analyze data, and report results.	2	Assignments, Midterm and University examinations, Practicals
PO3:	PO3 Design/development of solutions: Graduates will demonstrate the ability to design any mechanical system or thermal that meets desired specifications and requirements.	2	Assignments, Midterm and University examinations, Practicals
PO4:	Conduct investigations of complex problems: Graduates will demonstrate the ability to identify, formulate and solve mechanical engineering problems of a complex kind.	2	Assignments, Midterm and University examinations, Practicals
PO5:	Modern tool usage: Graduates will be familiar with applying software methods and modern computer tools to analyze mechanical engineering problems.	3	Assignments, Midterm and University examinations, Practicals
PO6:	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	2	Assignments, Midterm and University examinations, Practicals
PO7:	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	1	Assignments, Midterm and University examinations, Practicals
PO8:	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	--	--
PO9:	Individual and teamwork: Graduates will demonstrate the ability to function as a coherent unit in multidisciplinary design teams, and deliver results through collaborative research	--	--
PO10:	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	2	Assignments, Midterm and University examinations, Practicals
PO11:	Project management and finance: Graduate will be able to design a system to meet desired needs within environmental, economic, political, ethical health and safety, manufacturability and management knowledge and techniques to estimate time, resources to complete project.	2	Assignments, Midterm and University examinations, Practicals
PO12:	Life-long learning: Graduates should be capable of self-education and clearly understand the value of life-long learning	3	Assignments, Midterm and University examinations, Practicals

VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes		Level	Proficiency assessed by
PSO1:	The student will be able to apply the knowledge of Mathematics, Sciences and engineering fundamentals to formulate, analyse and provide solutions the problems related to Mechanical engineering and communicate them effectively to the concerned.	2	Assignments, Midterm and University examinations,Practicals
PSO2:	Design mechanical systems in various fields such as machine elements, thermal, manufacturing, industrial and inter-disciplinary fields by using various engineering/technological tools to meet the mercurial needs of the industry and society at large.	2	Assignments, Midterm and University examinations,Practicals
PSO3:	The ability to grasp the latest development, methodologies of mechanical engineering and posses competent knowledge of design process,practicalprofecencies,skills and knowledge of programme and developing ideas towards research	2	Assignments, Midterm and University examinations,Practicals

VII. SYLLABUS

UNIT-I

Mechanisms: Elements or Links – Classification – Rigid Link, flexible and fluid link – Types of kinematics pairs – sliding, turning, rolling, screw and spherical pairs – lower and higher pairs – closed and open pairs – constrained motion – completely, partially or successfully and incompletely constrained .

Mechanism and Machines – Mobility of Mechanisms: Grubler’s criterion, classification of machines – kinematics chain – inversions of mechanism – inversions of quadric cycle chain, single and double slider crank chains, Mechanical Advantage.

UNIT-II

Kinematics: Velocity and acceleration – Motion of link in machine – Determination of Velocity and acceleration – Graphical method – Application of relative velocity method.

Plane motion of body: Instantaneous center of rotation- centrodes and axodes – Three centers in line theorem – Graphical determination of instantaneous center, determination of angular velocity of points and links by instantaneous center method.

Kliens construction - Coriolis acceleration - determination of Coriolis component of acceleration

Analysis of Mechanisms: Analysis of slider crank chain for displacement- velocity and acceleration of slider – Acceleration diagram for a given mechanism.

UNIT-III

Straight-line motion mechanisms: Exact and approximate copied and generated types – Peaucellier - Hart - Scott Russel – Grasshopper – Watt -Tchebicheff’s and Robert Mechanism- Pantographs

Steering gears: Conditions for correct steering – Davis Steering gear, Ackerman’s steering

Hooke’s Joint: Single and double Hooke’s joint –velocity ratio – application – problems.

UNIT-IV

Cams: Definitions of cam and followers – their uses – Types of followers and cams – Terminology – Types of follower motion - Uniform velocity, Simple harmonic motion and uniform acceleration and retardation. Maximum velocity and maximum acceleration during outward and return strokes in the above 3 cases.

Analysis of motion of followers: Tangent cam with Roller follower – circular arc cam with straight, concave and convex flanks.

UNIT-V

Higher pair: Friction wheels and toothed gears – types – law of gearing, condition for constant velocity ratio for transmission of motion – velocity of sliding

Forms of teeth, cycloidal and involutes profiles – phenomena of interferences – Methods of interference. Condition for minimum number of teeth to avoid interference – expressions for arc of contact and path of contact of Pinion & Gear and Pinion & Rack Arrangements– Introduction to Helical – Bevel and worm gearing

Gear Trains: Introduction – Types – Simple – compound and reverted gear trains – Epicyclic gear train. Methods of finding train value or velocity ratio of Epicyclic gear trains. Selection of gear box - Differential gear for an automobile

SUGGESTED BOOKS:

TEXT BOOK:

1. Theory of Machines and Mechanisms/JOSEPH E. SHIGLEY/ Oxford
2. Theory of Machines / S.S.Rattan / Mc Graw Hill Publishers.

REFERENCES:

1. Theory of Machines / Sadhu Singh / Pearson.
2. Theory of Machines / Thomas Bevan/CBS.

NPTEL WEB COURSE:

- <http://nptel.ac.in/courses/112104121/>
- <http://nptel.ac.in/courses/112104121/1>
- <http://nptel.ac.in/courses/112104121/2>
- <http://nptel.ac.in/courses/112104121/3>
- <http://nptel.ac.in/courses/112104121/4>
- <http://nptel.ac.in/courses/112104121/5>
- <http://nptel.ac.in/courses/112104121/6>

NPTEL VIDEO COURSE:

- <https://youtu.be/MJeRFzs4oRU>
- <https://youtu.be/EVqBzOGQlkI>
- <https://youtu.be/GF5C8dH4f5o>

GATE SYLLABUS:

Theory of Machines: Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of slider-crank mechanism; gear trains.

IES SYLLABUS:

Kinematic and dynamic analysis of planer mechanisms, cams and gear trains.

VIII. COURSE PLAN (WEEK WISE):

Lecture No.	Week No.	TOPIC	Course Learning Outcomes	Reference
UNIT - 1				
1.	1	Elements or Links – Classification – Joints	To understand Kinematic link and Joint	Book No. 1
2.		Types of kinematic pairs – sliding, turning, rolling, screw and spherical pairs.	To understand different types	

			of Kinematic pairs	
3.		Lower and higher pairs – closed and open pairs.	To understand different types of Kinematic pairs	
4.		Constrained motion – completely, Partially or successfully constrained and incompletely constrained.	To understand different types motion	
5.		MACHINES : Mobility of Mechanism, Grubler's criteria, Kinematic chain, Inversions	To understand d.o.f. Kinematic chain, Mechanism, Machine and inversion	
6.	2	Mechanism and machines, kinematic chain-inversion of mechanism.	To differentiate mechanism and machine	
7.		Inversions of quadric cycle chain.	To understand inversions of kinematic chain	
8.		Inversions of Single and double slider crank chains.	To understand inversions of kinematic chain	
9.		Mechanical advantage	To understand iMechanical advantage of a mechanism	
UNIT – 2				
10.	3	Kinematics: Velocity and acceleration, Motion of link in machine	To determine magnitude and direction of velocity and acceleration of a point on a link	Book No. 1, 3
11.		Plane motion of body : Determination of Velocity and acceleration diagrams, Graphical method, Application of relative velocity method four bar chain.	To perform velocity analysis of a four bar mechanism.	
12.		Analysis of slider crank chain for	To perform	

		displacement, Velocity and acceleration of slider.	velocity analysis of a slider crank chain mechanism.	
13.		Mock Test – I		
14.	4	Acceleration diagram for a given mechanism.	To perform acceleration analysis of a mechanism.	
15.		Instantaneous center of rotation.	To understand I-Center and its location	
16.		Centroids and axodes – Relative motion between two bodies, Three centres in line theorem – Graphical determination of instantaneous centre.	To perform velocity analysis using I-centre method.	
17.		Determination of angular velocity of points and links by instantaneous centre method.		
		Tutorial / Bridge Class # 1		
18.	5	Determination of angular velocity of points and links by instantaneous centre method.	To perform velocity analysis using I-centre method.	
UNIT – 3				
19.	5	Klein's construction, Coriolis acceleration	To perform the acceleration analysis of a mechanism.	Book No. 1
20.		Determination of Coriolis component of acceleration.		
21.		Determination of Coriolis component of acceleration.		
	Tutorial / Bridge Class # 2			
22.	6	Straight-line motion Mechanism: Exact and approximate copied and generated types.	To study the geometry and working of straight line motion mechanisms.	
23.		Peaucellier-Hart-Scott Russel Mechanisms.		
24.		Grasshopper, Watt T. Chebicheff , Robert Mechanisms.	To study the copying mechanism	
25.		Pantographs.		
		Tutorial / Bridge Class # 3		
26.	7	Steering Gears: Conditions for correct steering	To derive a mathematical relation for correct	

			steering.	
27.		Davis Steering gear	To study the steering gear mechanisms	
28.		Ackerman's steering gear		
		I Mid Examinations		
29.		HOOKE'S JOINT: Single	To study the geometry and working of Hooke's joint and evaluate its velocity ratio.	
		<i>Tutorial / Bridge Class # 4</i>		
30.	8	Double Hooke's joint	To study the geometry and working of Hooke's joint and evaluate its velocity ratio.	
31.		velocity ratio - Universal coupling		
32.		Application – problems		
33.		Revision		
		<i>Tutorial / Bridge Class # 5</i>		
UNIT – 4				
34.	9	Cams: Definitions of cam and followers – their uses – Terminology	To understand the roller-follower mechanism and purpose	Book No. 1
35.		Types of followers	To study the various types of followers	
36.		Types of cams	To study the various types of cams	
37.	Types of follower motion - Uniform velocity (Max. & Min Acc)			
	<i>Tutorial / Bridge Class # 6</i>			
38.	10	Types of follower motion – Simple harmonic motion (Max. & Min Acc)	To draw the cam profile for various types of follower motions	
39.		Types of follower motion – uniform acceleration and retardation (Max. & Min Acc)		
40.		To draw the cam profile		
41.		<i>Tutorial / Bridge Class # 7</i>		
		Analysis of motion of followers: Roller follower flanks	To analyze the motion of	

42.	11	Analysis of motion of followers: Tangent cam with Roller follower	follower for various types of cams.	
43.		Circular cam with straight flank		
44.		Circular cam with straight flanks		
45.		Circular cam with concave and convex flanks		
Mock Test - II				
UNIT – 5				
46.	12	Higher pairs: Friction wheels and toothed gears	To understand the friction wheels and gears	
47.		Gears– types	To understand the classification of gears	
48.		Condition for constant velocity ratio for transmission of motion. Velocity of sliding	To understand and derive law of gearing.	
49.		Forms of teeth: cycloid and involute profiles	To study the different forms of tooth profiles.	
Tutorial / Bridge Class # 8				
50.	13	Phenomena of interferences, Methods of interference	To understand the interference and methods to avoid interference	
51.		Phenomena of interferences, Methods of interference		
52.		Condition for minimum number of teeth to avoid interference		
53.		Condition for minimum number of teeth to avoid interference		
Tutorial / Bridge Class # 9				
54.	14	Expressions for arc of contact and path of contact of pinion and gear arrangement	To understand length of path of contact.	
55.		Expressions for arc of contact and path of contact of pinion and rack arrangements.	To understand length of arc of contact	
56.		Introduction to Helical, Bevel and worm gearing	To understand Helical, Bevel and worm bearing.	
57.		Helical, Bevel and worm gearing		
Tutorial / Bridge Class # 10				
58.	15	Introduction, Train value – Types of gear trains	To understand gear trains and Velocity ratio.	

Book No. 4

59.		Gear Trains: Simple – compound and reverted wheel train – Epicyclic gear train	To analyze different types of gear trains.
60.		Methods of finding train value or velocity ratio of Epicyclic gear trains	To determine train value of Epicyclic gear train
61.		Methods of finding train value or velocity ratio – Epicyclic gear trains	
		Tutorial / Bridge Class # 11	
61.	16	Differential gear for an automobile	To study differential of an automobile and find its train value.
62.		Differential gear for an automobile	
63.		Revision	
64.		Revision	
		Tutorial / Bridge Class # 12	
II Mid Examinations			

IX. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF TSHE PROGRAM OUTCOMES:

CO's	Program Outcomes (PO's)												Program Specific Outcomes (POS's)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	2	3	2	1	--	--	2	3	3	2	2	2
CO2	2	1	--	2	--		--	--	--	3	--	3	2	2	2
CO3	2	2	2	2	--	2	1	--	--	2	3	3	1	1	3

X. QUESTION BANK: (JNTUH)

DESCRIPTIVE QUESTIONS:

UNIT-I Short Answer Questions-

S. No	Question	Blooms Taxonomy Level	Course Outcome
UNIT-I MECHANISMS			
1	a) Define link and kinematic pair. b) Enumerate the inversions of double slider crank chain mechanism.	Knowledge, Application	1, 3
2	a) Define machine and mechanism. b) Enumerate the inversions of single slider crank chain mechanism	Knowledge, Application	1,3

3	a) Explain the quick return motion mechanism of crank and slotted lever. b) The length of the fixed link in a crank and slotted lever quick return mechanism is 300 mm and crank is 110 mm. Determine the inclination of the slotted lever with the vertical in the extreme position.	Comprehension, Application	1, 3
4	a) Identify the difference between a machine and a structure. b) Classify kinematic pairs.	Knowledge, Application	1,3
5	a) Explain the Whitworth quick return motion mechanism . b) In a Whitworth quick return motion mechanism, the distance between the fixed centers is 50 mm and the length of the driving crank is 75 mm. The length of the slotted lever is 150 mm and the length of the connecting rod is 135 mm. Find the ratio of time of cutting and return strokes and also the effective stroke.	Knowledge, Application	1,3
6	a) Define machine and structure. b) Explain different types of constrained motions.	Comprehension, Application	1, 3
7	a) Explain the function of Oldham's coupling. b) Prove that the elliptical trammel describes an ellipse.	Knowledge, Application	1,3
8	a) Define inversion of a mechanism? b) Explain the inversions of a quadric cycle chain?	Knowledge, Application	1, 3
9	a) Explain Grubler's criterion. b) Identify the degrees of freedom for four bar mechanism, slider crank mechanism and five bar mechanism.	Knowledge, Application	1,3
10	a) What is meant by degrees of freedom of a mechanism? b) Explain the applications of Kutzbach criterion to plane mechanisms.	Knowledge, Application	1,3
UNIT-II KINEMATICS			
1	a) Mention different types of instantaneous centres. b) Locate the instantaneous centres for crank and slotted lever quick return mechanism?	Knowledge, Application	1,3
2	a) Define Instantaneous centre b) Locate all the Instantaneous centers of slider crank mechanism with crank length of 25mm rotating clockwise at a uniform speed of 100 rpm. The crank makes 45° with IDC and the connecting rod is 400 mm long .Determine the velocity of the slider and the angular velocity of connecting rod?	Knowledge, Application	1, 3
3	a) State and explain the Kennedy's theorem.. b) In a slider crank mechanism, the crank OA makes 400 rpm in the counter clockwise direction which is 60° from IDC. The lengths of the links are OA= 60 mm, OB= 220 mm and BA= 280 mm. Determine the velocity and acceleration of the sliderB?	Comprehension, Application	1, 3
4	a) Explain Klien's construction for determining velocity and acceleration of slider crank mechanism. b) Explain the method of determining the Coriolis component of acceleration in crank and slotted lever quick return mechanism?	Comprehension, Application	1, 3

5	Determine the velocity and acceleration of the link QR and RS in a four bar mechanism in which PQRS is a four bar mechanism with fixed link PS. Crank PQ rotates uniformly and makes an angle of 60^0 with PS in anti clockwise direction.. The length of the links are PQ=62.5 mm, QR=175 mm, RS= 112.5 mm and PS= 200 mm. Crank PQ rotates at 10 radians/ second?	Knowledge, Application	1,3
6	a) Define centrode and axode. b) Derive the analytical method of determination of velocity and acceleration for a slider crank mechanism?	Knowledge, Application	1, 3
7	a) Explain how the acceleration of a point in a link is determined when the acceleration of some other point on the same link is given in magnitude and direction. b) Draw the acceleration diagram of a slider crank mechanism.	Knowledge, Application	1,3
8	a) What is acceleration image? b) Draw and explain the velocity diagram of Whitworth quick return mechanism by assuming suitable proportions.	Knowledge, Application	1,3
9	Derive an expression for the magnitude of Coriolis component of acceleration.	comprehension	1,3
10	a) What is the practical significance of evaluating velocity and acceleration of members of a mechanism? b) Assuming suitable proportions determine the velocity and acceleration of a slider in Toggle mechanism.	Knowledge, Application	1,3
UNIT-III STRAIGHT LINE MOTION MECHANISMS			
1	a) What are straight line mechanisms? b) Describe any one mechanism having all turning pairs that generate an exact straight line?	Knowledge, Application	1, 3
2	a) Explain the Peaucellier's straight line mechanism. b) Explain the principle of generation of straight line.	Knowledge, Application	1,3
3	a) What is an approximate straight line mechanism? b) Explain a mechanism which consists of a sliding pair.	Knowledge, Application	1,3
4	a) What is an exact straight line mechanism? b) Explain an exact straight line mechanism?	Knowledge, Application	1,3
5	a) Describe the Watt's parallel mechanism for straight line motion. b) Derive the condition for generating a straight line in Watt's mechanism?	Knowledge, Application	1,3
6	a) What is a Pantograph? What is its use? b) Explain Scot Russel mechanism with a neat sketch, Show that it generates a straight line?	Comprehension, Application	1, 3
7	a) Differentiate between Davi's and Ackerman steering gears. b) In a Davi's steering gear, the distance between the pivots of the front axle is 1 meter and the wheel base is 2.5 meters. Find the inclination of the track arm to the longitudinal axis of the car when it is moving along a straight path?	Comprehension, Application	1, 3

8	a) What is the condition for correct steering? b) Explain the Ackerman's steering gear mechanism.	Knowledge, Application	1,3
9	a) What is a Hooke's joint? What are its applications? b) A Hooke's joint connects two shafts whose axes intersect at 150° . The driving shaft rotates uniformly at 120 rpm. The driven shaft operates against a steady torque of 150NM. And carries a flywheel whose mass is 45 kg. and radius of gyration 150 mm. Find the maximum torque which will be exerted by the driving shaft.	Knowledge, Application	1, 3
10	a) What is a Double Hooke's joint? b) Derive an expression for the ratio of shaft velocities in a Hooke's joint.	Knowledge, Application	1,3
UNIT-IV CAMS			
1	a) Define a cam and mention the types? b) What are the various motions possible with cam and follower?	Knowledge, Application	1, 3
2	a) Define a follower and mention the types? b) Draw and explain the displacement and velocity diagrams for uniform velocity motion.	Knowledge, Application	1,3
3	a) Define the following terms as applied to cams with neat sketch: i) Base circle ii) pitch circle iii) pressure angle. b) Draw the profile of a cam with oscillating roller follower for the following motion: Follower to move outwards through an angular displacement of 20° during 120° of cam rotation, follower to dwell for 50° , follower to return to its initial position during 90° of cam rotation with UARM, follower to dwell for the remaining period.	Knowledge, Application	1,3
4	a) Write short notes on cams and followers. b) Draw a cam to raise a valve through a distance of 50 mm in $1/3$ of revolution with SHM, keep it fully raised through $1/12$ of revolution and lower it with harmonic motion in $1/6$ of revolution. The valve remains closed during the rest of the revolution. The diameter of the roller is 20 mm and the minimum radius of the cam is 25 mm. The axis of the valve rod passes through the axis of the cam shaft.	Knowledge, Application	1,3
5	a) Draw and explain the displacement and velocity diagrams for Simple Harmonic motion. b) Lay out the profile of a cam so that the follower is to move outwards through 30 mm during 160° of cam rotation with Uniform velocity and dwell for 30° of cam rotation followed by returning to initial position with Uniform acceleration and retardation during 110° of cam rotation and dwell for the remaining period. The base circle diameter of cam is 28 mm and the follower is a knife edge follower. The axis of the follower is offset by 6 mm.	Knowledge, Application	1,3

6	<p>a) Define angle of action, angle of dwell and pressure angle in cams.</p> <p>b) Lay out the profile of a cam so that the follower is to move outwards through 30 mm during 180° of cam rotation with SHM and dwell for 20° of cam rotation followed by returning to initial position with Uniform velocity during 160° of cam rotation. The base circle diameter of cam is 28 mm and the roller diameter is 8 mm. The axis of the follower is offset by 6 mm.</p>	Comprehension, Application	1, 3
7	<p>a) Explain with the help of displacement, velocity and acceleration diagrams the UARM.</p> <p>b) A cam operating a knife edge follower has the following data: Follower moves outward through 40 mm during 60° of cam rotation with uniform velocity, follower dwells for the next 45°, follower returns to its original position during next 90° with Uniform velocity and dwells for the remaining period. Draw the cam profile.</p>	Comprehension, Application	1, 3
8	<p>a) What are the uses of cams and followers?</p> <p>b) A radial translating flat faced follower has a lift of 30 mm. The rise takes place with SHM during 180° of cam rotation. The return also takes place with SHM during the next 180° of cam rotation. Assume anti clockwise rotation of the cam. Draw the cam profile and determine the maximum velocity and acceleration values when the follower rises and the cam rotates at 50 rpm.</p>	Knowledge, Application	1, 3
9	<p>a) Why a roller follower is preferred to a knife edge follower?</p> <p>b) Derive expressions for displacement, velocity and acceleration for a tangent cam operating a radial translating roller follower when the contact is on circular nose.</p>	Knowledge, Application	1,3
10	<p>a) What is a tangent cam?</p> <p>b) Derive an expression for the tangent cam when the follower is contacting the convex flanks.</p>	Knowledge, application	1,3
UNIT-V HIGHER PAIR			
1	<p>a) Explain spur, helical and bevel gears?</p> <p>b) Derive an expression for the length of path of contact.</p>	Knowledge, Application	1, 3
2	<p>a) Explain the terms module, pressure angle and addendum in gears.</p> <p>b) Two mating gears have 29 and 40 involute teeth of module 10 mm and 20° pressure angle. If the addendum on each wheel is such that the path of contact is maximum and interference is just avoided, find the addendum for each gear wheel, path of contact, arc of contact and contact ratio.</p>	Knowledge, Application	1,3
3	<p>a) Make a comparison of cycloidal and involute profiles of gears?</p> <p>b) A pair of 20° pressure angle gears in mesh have the following data: Speed of pinion = 400 rpm, Number of teeth on pinion = 24, number of teeth on gear = 28. Determine the addendum of the gears if the path of approach and recess is half the maximum value.</p>	Comprehension, Application	1, 3

4	a) Explain the method of eliminating interference in gears. b) A pair of gears having 40 and 20 teeth respectively are rotating in mesh. The speed of the smaller is 2000 rpm. Determine the velocity of sliding at	Comprehension, Application	1, 3
---	--	----------------------------	------

S. No	Question	Blooms Taxonomy Level	Course Outcome
	the point of engagement, at the pitch point and at the point of disengagement. Assume that the gear teeth are 20° involute, addendum is 5 mm and module is 5 mm.		
5	a) Derive an expression for the length of arc of contact. b) The pitch circle diameter of the smaller of the two gears which mesh externally and have involute teeth is 100 mm. The number of teeth are 16 and 32. The pressure angle is 20° . The addendum is 0.32 of the circular pitch. Find the length of path of contact of the pair of teeth.	Knowledge, Application	1,3
6	a) Derive an expression for the minimum number of teeth on pinion to avoid interference. b) The pressure angle of two gears in mesh is 20° and have a module of 10 mm. The number of teeth on pinion are 24 and on gear 60. The addendum of pinion and gear is same and equal to one module. Determine the number of pairs of teeth in contact, the angle of action of pinion and gear, the ratio of sliding to rolling velocity at the beginning of contact, at pitch point and at the end of contact.	Comprehension, application	1,3
7	a) What is a gear train and what are its types? b) The speed ratio of a reverted gear train is 12. The module pitch of gears A and B which are in mesh is 3.125 mm and of gears C and D which are in mesh is 2.5 mm. Calculate the suitable number of teeth for the gears. No gear is to have less than 20 teeth. B-C is a compound gear.	Knowledge, Application	1, 3
8	a) Explain with a neat sketch the sun and planet wheel. b) In an epicyclic gear train, an arm carries two gears 1 and 2 having 40 and 50 teeth respectively. The arm rotates at 160 rpm counter clockwise about the centre of gear 1, which is fixed. Determine the speed of gear 2.	Knowledge, Application	1,3
9	a) What is a Differential? b) An internal wheel B with 80 teeth is keyed to a shaft F. A fixed internal wheel C with 82 teeth is concentric with B. A compound wheel D-E gears with two internal wheels. D has 28 teeth and gears with C while E gears with B. The compound wheels revolve freely on a pin which projects from a disc keyed to shaft A coaxial with F. If the wheels have the same pitch and the shaft rotates at 800 rpm what is the speed of the shaft F? Sketch the arrangement.	Knowledge, application	1,3

OBJECTIVE QUESTIONS:

JNTUH:

UNIT-1

- In a reciprocating steam engine, which of the following forms a kinematic link?
(a) cylinder and piston (b) piston rod and connecting rod
(c) crank shaft and flywheel (d) flywheel and engine frame
- The motion of a piston in the cylinder of a steam engine is an example of _____.
(a) completely constrained motion (b) incompletely constrained motion
(c) successfully constrained motion (d) none of these
- The motion transmitted between the teeth of gears in mesh is _____.
(a) sliding (b) rolling
(c) may be rolling or sliding depending upon the shape of teeth
(d) partly sliding and partly rolling
- The cam and follower without a spring forms a _____.
(a) lower pair (b) higher pair (c) self-closed pair (d) force closed pair
- A ball and a socket joint form a _____.
(a) turning pair (b) rolling pair (c) sliding pair (d) spherical pair
- The lead screw of a lathe with nut forms a _____.
(a) sliding pair (b) rolling pair (c) screw pair (d) turning pair
- When the elements of the pair are kept in contact by the action of external forces, the pair is said to be a _____.
(a) lower pair (b) higher pair (c) self-closed pair (d) force closed pair
- Which of the following is a turning pair?
(a) Piston and cylinder of a reciprocating steam engine
(b) Shaft with collars at both ends fitted in a circular hole
(c) Lead screw of a lathe with nut
(d) Ball and socket joint
- A combination of kinematic pairs, joined in such a way that the relative motion between the links is completely constrained, is called a _____.
(a) structure (b) mechanism (c) kinematic chain (d) inversion
- The relation between the number of pairs (p) forming a kinematic chain and the number of links (l) is _____.
(a) $l = 2p - 2$ (b) $l = 2p - 3$ (c) $l = 2p - 4$ (d) $l = 2p - 5$

UNIT-2

- When the motion of a body is confined to only one plane, the motion is said to be _____.
- The unit of linear acceleration is _____.
(a) kg-m (b) m/s (c) m/s² (d) rad/s²
- The angular velocity (in rad/s) of a body rotating at N rpm is _____.
(a) $\pi N/60$ (b) $2\pi N/60$ (c) $\pi N/120$ (d) $\pi N/180$
- The linear velocity of a body rotating at ω rad/s along a circular path of radius r is given by
(a) $\omega \cdot r$ (b) ω/r (c) $\omega^2 r$ (d) ω^2/r
- When a particle moves along a straight path, then the particle has _____.
(a) tangential acceleration only (b) centripetal acceleration only
(c) both tangential and centripetal acceleration (d) None

6. When a particle moves with a uniform velocity along a circular path, then the particle has _____.
- (a) tangential acceleration only (b) centripetal acceleration only
(c) both tangential and centripetal acceleration (d) None
7. The total number of instantaneous centres for a mechanism consisting of n links are _____.
- (a) $\frac{n}{2}$ (b) n (c) $\frac{n-1}{2}$ (d) $\frac{n(n-1)}{2}$
8. According to Aronhold Kennedy's theorem, if three bodies move relatively to each other, their instantaneous centres will lie on a _____.
- (a) straight line (b) parabolic curve (c) ellipse (d) none of these
9. In a mechanism, the fixed instantaneous centres are that centres which _____.
- (a) remain in the same place for all configurations of the mechanism
(b) vary with the configuration of the mechanism
(c) moves as the mechanism moves, but joints are of permanent nature
(d) none of the above
10. Rate of change of angular displacement with respect to time is known as _____.

UNIT-3

1. In a pantograph, all the pairs are _____.
- (a) turning pairs (b) sliding pairs (c) spherical pairs (d) self-closed pairs
2. Which of the following mechanism is made up of turning pairs?
- (a) Scott Russel's mechanism (b) Peaucellier's mechanism
(c) Hart's mechanism (d) none of these
3. Which of the following mechanism is used to enlarge or reduce the size of a drawing?
- (a) Grasshopper mechanism (b) Watt mechanism (c) Pantograph (d) none of these
4. The driving and driven shafts connected by a Hooke's joint will have equal speeds, if ____.
- (a) $\cos\theta = \sin\alpha$ (b) $\sin\theta = \sqrt{\tan\alpha}$ (c) $\tan\theta = \sqrt{\cos\alpha}$ (d) $\cot\theta = \cos\alpha$ where θ = Angle through which the driving shaft turns, and α = Angle of inclination of the driving and driven shafts.
5. The instantaneous centres which vary with the configuration of the mechanism are called _____.
- (a) permanent instantaneous centres (b) fixed instantaneous centres
(c) neither fixed nor permanent instantaneous centres (d) none of these
6. When a slider moves on a fixed link having curved surface, their instantaneous centre lies _____.
- (a) on their point of contact (b) at the centre of curvature
(c) at the centre of circle (d) at the pin joint
7. The direction of linear velocity of any point on a link with respect to another point on the same link is _____.
- (a) parallel to the link joining the points (b) perpendicular to the link joining the points
(c) at 45° to the link joining the points (d) none of these
8. If ω = Angular velocity of the link AB , then the magnitude of linear velocity of a point B on a link AB relative to point A is _____.
- (a) ωAB (b) $\omega(AB)$ (c) $\omega^2 AB$ (d) (ωAB)
9. The two links OA and OB are connected by a pin joint at O . If the link OA turns with angular velocity ω_1 rad/s in the clockwise direction and the link OB turns with angular velocity ω_2

rad/s in the anti-clockwise direction, r is the radius of the pin at O then the rubbing velocity at the pin joint O is _____.

(a) $\omega_1 \cdot \omega_2 \cdot r$ (b) $(\omega_1 - \omega_2)r$ (c) $(\omega_1 + \omega_2) r$ (d) $(\omega_1 - \omega_2)^2 r$

10. The Ackerman steering gear mechanism is preferred to the Davis steering gear mechanism, because _____.
- (a) whole of the mechanism in the Ackerman steering gear is on the back of the front wheels.
(b) the Ackerman steering gear consists of turning pairs
(c) the Ackerman steering gear is most economical
(d) both (a) and (b)

UNIT -4

- The size of a cam depends upon _____.
(a) base circle (b) pitch circle (c) prime circle (d) pitch curve
- The angle between the direction of the follower motion and a normal to the pitch curve is called _____.
(a) pitch angle (b) prime angle (c) base angle (d) pressure angle
- A circle drawn with centre as the cam centre and radius equal to the distance between the cam centre and the point on the pitch curve at which the pressure angle is maximum, is called _____.
(a) base circle (b) pitch circle (c) prime circle (d) none of these
- The cam follower generally used in automobile engines is _____.
(a) knife edge follower (b) flat faced follower
(c) spherical faced follower (d) roller follower
- The cam follower extensively used in air-craft engines is _____.
(a) knife edge follower (b) flat faced follower
(c) spherical faced follower (d) roller follower
- In a radial cam, the follower moves _____.
(a) in a direction perpendicular to the cam axis
(b) in a direction parallel to the cam axis
(c) in any direction irrespective of the cam axis
(d) along the cam axis
- A radial follower is one _____.
(a) that reciprocates in the guides
(b) that oscillates
(c) in which the follower translates along an axis passing through the cam centre of rotation.
(d) none of the above
- For high speed engines, the cam follower should move with _____.
(a) uniform velocity (b) simple harmonic motion
(c) uniform acceleration and retardation (d) cycloidal motion
- Offset is provided to a cam follower mechanism to _____.
(a) minimize the side thrust (b) accelerate
(c) avoid jerk (d) none of these
- For low and moderate speed engines, the cam follower should move with _____.
(a) uniform velocity (b) simple harmonic motion
(c) uniform acceleration and retardation (d) cycloidal motion

UNIT -5

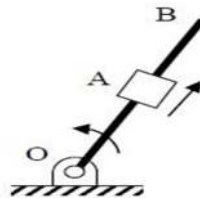
- The two parallel and coplanar shafts are connected by gears having teeth parallel to the axis of the shaft. This arrangement is called _____.
(a) spur gearing (b) helical gearing (c) bevel gearing (d) spiral gearing
- The type of gears used to connect two non-parallel non-intersecting shafts are _____.
(a) spur gears (b) helical gears (c) spiral gears (d) none of these
- An imaginary circle which by pure rolling action, gives the same motion as the actual gear, is called _____.
(a) addendum circle (b) dedendum circle
(c) pitch circle (d) clearance circle
- The size of a gear is usually specified by _____.
(a) pressure angle (b) circular pitch
(c) diametral pitch (d) pitch circle diameter
- The radial distance of a tooth from the pitch circle to the bottom of the tooth, is called _____.
(a) dedendum (b) addendum (c) clearance (d) working depth
- The product of the diametral pitch and circular pitch is equal to _____.
(a) 1 (b) $1/\pi$ (c) π (d) 2π
- The module is the reciprocal of _____.
(a) diametral pitch (b) circular pitch (c) pitch diameter (d) none of these
- Which is the incorrect relationship of gears?
(a) Circular pitch \times Diametral pitch = π (b) Module = P.C.D/No.of teeth
(c) Dedendum = 1.157 module (d) Addendum = 2.157 module
- Mitre gears are used for _____.
(a) great speed reduction (b) equal speed
(c) minimum axial thrust (d) minimum backlash
- If the module of a gear be m , the number of teeth T and pitch circle diameter D , then _____.
(a) $m = D/T$ (b) $D = T/m$ (c) $m = D/2T$ (d) none of these

GATE:

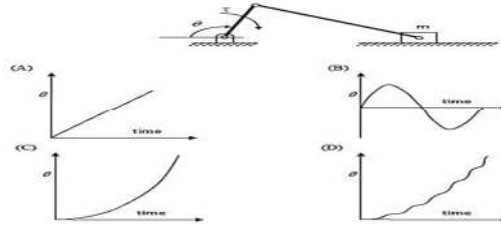
- Which of the following mechanism is used to enlarge or reduce the size of a drawing?
(a) Grasshopper mechanism (b) Watt mechanism
(c) Pantograph (d) none of these
- In a radial cam, the follower moves _____.
(a) in a direction perpendicular to the cam axis
(b) in a direction parallel to the cam axis
(c) in any direction irrespective of the cam axis
(d) along the cam axis
- A radial follower is one _____.
(a) that reciprocates in the guides
(b) that oscillates
(c) in which the follower translates along an axis passing through the cam centre of rotation.
(d) none of the above
- Two pulleys of diameters d_1 and d_2 and at distance x apart are connected by means of an open belt drive. The length of the belt is _____.

(a) $\frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 + d_2)^2}{4x}$ (b) $\frac{\pi}{2}(d_1 - d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$
 (c) $\frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$ (d) $\frac{\pi}{2}(d_1 - d_2) + 2x + \frac{(d_1 + d_2)^2}{4x}$

5. In a cone pulley, if the sum of radii of the pulleys on the driving and driven shafts is constant, then _____.
- (a) open belt drive is recommended
 (b) cross belt drive is recommended
 (c) both open belt drive and cross belt drive are recommended
 (d) the drive is recommended depending upon the torque transmitted
6. The train value of a gear train is _____.
- (a) equal to velocity ratio of a gear train
 (b) reciprocal of velocity ratio of a gear train
 (c) always greater than unity
 (d) always less than unity
7. When the axes of first and last gear are co-axial, then gear train is known as _____.
- (a) simple gear train (b) compound gear train
 (c) reverted gear train (d) epicyclic gear train
8. In a clock mechanism, the gear train used to connect minute hand to hour hand, is _____.
- (a) epicyclic gear train (b) reverted gear train
 (c) compound gear train (d) simple gear train
9. The Ackerman steering gear mechanism is preferred to the Davis steering gear mechanism, because _____.
- (a) whole of the mechanism in the Ackerman steering gear is on the back of the front wheels.
 (b) the Ackerman steering gear consists of turning pairs
 (c) the Ackerman steering gear is most economical
 (d) both (a) and (b)
10. A link OB is rotating with a constant angular velocity of 2 rad/s in counter clockwise direction and a block is sliding radially outward on it with an uniform velocity of 0.75 m/s with respect to the rod, as shown in the figure below. If OA = 1 m, the magnitude of the absolute acceleration of the block at location A in m/s² is _____.



- (a) 3 (b) 4 (c) 5 (d) 6
11. Consider a slider crank mechanism with nonzero masses and inertia. A constant torque τ is applied on the crank as shown in the figure. Which of the following plots best resembles variation of crank angle, θ versus time?



IES:

- The ratio of face width to transverse pitch of a helical gear with α as the helix angle is normally _____.
 - more than $1.15/\tan\alpha$
 - more than $1.05/\tan\alpha$
 - more than $1/\tan\alpha$
 - none of these
- The maximum efficiency for spiral gears is _____.
 - $\frac{\sin(\theta+\phi)+1}{\cos(\theta-\phi)+1}$
 - $\frac{\cos(\theta-\phi)+1}{\sin(\theta+\phi)+1}$
 - $\frac{\cos(\theta+\phi)+1}{\cos(\theta-\phi)+1}$
 - $\frac{\cos(\theta-\phi)+1}{\cos(\theta+\phi)+1}$
 where θ = Shaft angle, and ϕ = Friction angle.
- For a speed ratio of 100, smallest gear box is obtained by using _____.
 - a pair of spur gears
 - a pair of helical and a pair of spur gear compounded
 - a pair of bevel and a pair of spur gear compounded
 - a pair of helical and a pair of worm gear compounded
- When the addenda on pinion and wheel is such that the path of approach and path of recess are half of their maximum possible values, then the length of the path of contact is given by _____.
 - $\frac{(r+R)\sin\phi}{2}$
 - $\frac{(r+R)\cos\phi}{2}$
 - $\frac{(r+R)\tan\phi}{2}$
 - none of these
- The radial distance of a tooth from the pitch circle to the bottom of the tooth, is called _____.
 - dedendum
 - addendum
 - clearance
 - working depth
- The product of the diametral pitch and circular pitch is equal to _____.
 - 1
 - $1/\pi$
 - π
 - 2π
- Offset is provided to a cam follower mechanism to _____.
 - minimize the side thrust
 - accelerate
 - avoid jerk
 - none of these
- For low and moderate speed engines, the cam follower should move with _____.
 - uniform velocity
 - simple harmonic motion
 - uniform acceleration and retardation
 - cycloidal motion
- For high speed engines, the cam follower should move with _____.
 - uniform velocity
 - simple harmonic motion
 - uniform acceleration and retardation
 - cycloidal motion
- The crankshaft of reciprocating engine having a 20 cm crank and 100 cm connecting rod rotates at 210 rpm. When the crank angle is 45° , the velocity of piston is nearly _____.

(a) 1.8 m/ s

(b) 1.9 m/ s

(c) 18 m/ s

(d) 19 m/ s

XI. WEBSITES:

1. <http://nptel.ac.in/courses/112104121/1>
2. <http://nptel.ac.in/courses/112104121/2>
3. <https://www.youtube.com/watch?v=MJeRFzs4oRU>
4. <https://www.youtube.com/watch?v=MJeRFzs4oRU&list=PLBEA57F7E7560C8E8>
5. <http://freevidelectures.com/Course/2359/Kinematics-of-Machines>
6. http://ocw.metu.edu.tr/pluginfile.php/3957/mod_resource/content/0/ch4/4-2-1.htm
7. <https://www.softintegration.com/webservices/mechanism/>

XII. EXPERT DETAILS:

1. Dr. Jayaram S R, MCE, Hassan.
2. Prof. V. V. Bongale, MCE, Hassan.
3. Dr. B. Suresh, NIE, Mysore.
4. Prof. Y. M. Shashidhar, MCE, Hassan.

XIII. JOURNALS:

1. American standards of mechanical engineering (ASME)
2. Mechanism and machine theory
3. Journal of Machinery Manufacture and Reliability
4. Theory of Mechanisms and Machines

XIV. LIST OF TOPICS FOR STUDENT SEMINARS:

1. Belt Rope and Chain Drives.
2. Steering mechanisms.
3. Straight line motion mechanisms.
4. Gear trains.

XV. CASE STUDIES / SMALL PROJECTS:

1. Prepare the models of Inversions of 4 bar mechanisms.
2. Single slider crank mechanism.
3. Double slider crank mechanism.
4. Cam and follower.