KOM COURSE FILE
### GEETHANJALI COLLEGE OF ENGINEERING AND TECHNOLOGY

#### DEPARTMENT OF Mechanical Engineering

*(Name of the Subject / Lab Course)*: kinematics of Machinery

*(JNTU CODE)*: 54014  
*(Programme)*: UG

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Classification status (Unrestricted / Restricted):

Distribution List:

**Prepared by:**

1) Name: k Raju  
2) Sign:  
3) Design: Assistant professor  
4) Date: 07/12/2015

**Verified by:**

1) Name:  
2) Sign:  
3) Design:  
4) Date:  

*For Q.C Only*

1) Name:  
2) Sign:  
3) Design:  
4) Date:  

**Approved by:** (HOD)

1) Name: T.Siva Prasad  
2) Sign:  
3) Date:  

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JAWAHARLAL NEHRU TECHNOLOGIVAL UNIVERSITY HYDERABAD

III Year B.Tech. MECH - I Sem

L T P D C
4 4 4

KINEMATICS OF MACHINERY

UNIT–I

Mechanisms: Definition of link, element, pair, kinematic chain, mechanism and machine, Grubler’s criterion, single and double slider chains, inversions of quadratic cycle chain, inversions of single and double slider crank chains. mechanism with lower pairs and straight line motion mechanism- Pantograph, Peaucerlier and Hart, Tchebicheff’s mechanism.

UNIT–II:

Straight line motion mechanisms: Graphical methods to find velocities of mechanisms, instantaneous centre, body centre and space centre, Kennedy’s theorem, graphical determination of acceleration of different mechanisms including Coriolis component of acceleration, analytical method to find the velocity and acceleration, analysis of four bar mechanism with turning pairs.

UNIT–III

KINEMATICS: Velocity and acceleration – Motion of link in machine – Determination of Velocity and acceleration diagrams – Graphical method – Application of relative velocity method four bar chain.

Analysis of Mechanisms: Analysis of slider crank chain for displacement, velocity and acceleration of slider – Acceleration diagram for a given mechanism, Klein’s construction, Coriolis acceleration, determination of Coriolis component of acceleration.

Plane motion of body: Instantaneous center of rotation, centroids and axodes – relative motion between two bodies – Three centers in line theorem – Graphical determination of instantaneous centre, diagrams for simple mechanisms and determination of angular velocity of points and links

UNIT–IV

Cams: Types of cams and followers, displacement diagrams for followers, uniform motion, parabolic motion, simple harmonic motion, cycloidal motion, drawing cam profile with
knife–edge follower, translating roller follower and translating flat follower, cams of specified contour, tangent cam with roller follower, circular arc (convex) cam with roller follower.

**UNIT–V**

**Gears:** Classification of gears, spur gears, nomenclature, law of gear tooth action, involute as gear tooth profile, interference of involute gears, minimum number of teeth to avoid interference, contact ratio, cycloidal tooth profile, comparision of involute and cycliodal tooth profile.

Helical Gears: Helical gear tooth relations, contact of helical gear teeth, gear trains–simple and compound, reverted and epicyclic gear trains.

**Text Books:**


Suggested Reading:


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**3. Vision of the Department**

To become a Regionally and Nationally recognized Department in providing high Quality Education in Mechanical Engineering, leading to well qualified, innovative and successful engineers.

**4. Mission of the Department**

- To prepare professionally competent Mechanical Engineers by developing analytical and research abilities.
• Prepare its graduates to pursue life-long learning, serve the profession and meet intellectual, ethical and career challenges.
• To develop linkages with R&D organizations and Educational Institutions in India and abroad for excellence in teaching, research and consultancy practices.

5. PEOs and POs

The Program Educational Objectives of Mechanical Engineering Program are developed to provide guidance to Graduating Mechanical Engineers, so that they can contribute effectively to the advancement of needs of Mechanical Engineering Profession.

The graduates from Mechanical Engineering program are expected to demonstrate within three to five years of graduation that

1. They practice Mechanical Engineering in all areas of Design, Thermal and Manufacturing Engineering in all types of industrial sectors.
2. They apply technical knowledge and skills to real life technical challenges in various fields of Mechanical Engineering.
3. They are competent in advanced Research and Development and creative efforts in Mechanical Engineering and allied areas of Science and Technology.
4. They practice Mechanical Engineering in a professional, responsible and ethical manner for the benefit of the industry and society.

The Program Outcomes of the Department of Mechanical Engineering are to educate graduates, who by the time of graduation will be able to demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design a system, component, or process to meet desired needs.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulates, and solves engineering problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively.
- An ability to apply their broad education toward the understanding of the impact of engineering solutions in a global and societal context.
- Recognition of the need for, and the ability to engage in life-long learning.
- Knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
6. Course Objectives and Outcomes

Course Objectives: Student will acquire acknowledge in
1. Analysis of mechanisms,
2. Drawing displacement diagrams for followers with various types of motions,
3. Cam profile drawing for various followers,
4. Estimation of transmission of power by belts and application of various gears and gear trains.

Course Outcomes:
Student will demonstrate knowledge in
1. Designing a suitable mechanism depending on application
2. Drawing displacement diagrams and cam profile diagram for followers executing different types of motions and various configurations of followers,
3. Drawing velocity and acceleration diagrams for different mechanisms,
4. Selecting gear and gear train depending on application.

7. Brief Importance of the Course and how it fits into the curriculum

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 addition, Newton established the fundamental physical laws which govern dynamics in physics. By studying his system of mechanics, dynamics can be understood. 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.

8. Prerequisites if any

1. Introductory geometric synthesis of linkages
2. Mobility analysis of mechanisms
3. Kinematics of machines
4. Design of cam-follower mechanisms
5. Analysis and synthesis of gear trains
6. Calculus and vector algebra

9. Instructional Learning Outcomes

Learning outcomes are the key abilities and knowledge that will be assessed

UNIT-I: Mechanisms

First unit deals with the degree of freedom of a mechanism and identify the mobility of a four bar mechanism. Analysis the extremes of the transmission angle in a crank and rocker mechanism. Calculation of the displacements of a planar mechanism Apply Freudenstein’s Equation in the analysis of a four Synthesize a four bar mechanism motion generator for two or three positions of a moving plane Synthesize a four bar mechanism function generator for three precision.

UNIT–II: Straight line motion mechanisms

Unit-II deals with the velocities of planar mechanism and the accelerations of planar mechanism Recognize friction and its effects in mechanical components. Analyze planar mechanism for displacement, velocity and acceleration graphically.

UNIT–III: Kinematics

Unit-III deals with Velocity and acceleration Motion of link in machine Determination of Velocity and acceleration diagrams and Graphical method, Application of relative velocity method four bar chain. Analyses of slider crank chain for displacement, velocity and acceleration.

UNIT–IV: Cams

Unit-IV deals with the Types of cams and followers, displacement diagrams for followers, uniform motion, parabolic motion, simple harmonic motion, cycloidal motion, drawing cam profile with knife–edge follower. Analyze various motion transmission elements like gears, gear trains, cams, belt drive and rope drive.
UNIT-V: Gears

Unit-V deals with the Utilize analytical, mathematical and graphical aspects of kinematics of machines for effective design. Perform the kinematic analysis of a given mechanism. Analysis interference of involutes gears, minimum number of teeth to avoid interference, contact ratio, cycloidal tooth profile, comparison of involute and cycloidal tooth profile.

10. Course mapping with PEOs and POs

Mapping of Course with Programme Educational Objectives:

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Mapping of Course outcomes with Programme outcomes:

*When the course outcome weightage is < 40%, it will be given as moderately correlated (1).
*When the course outcome weightage is >40%, it will be given as strongly correlated (2).

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1. a) Explain the ability to synthesis, both graphically and analytically, multilink mechanisms.
   b) Designing a suitable mechanism depending on application
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### 1.9. Micro Plan:-

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Higher pairs, friction wheels and toothed gears.
Types – law of gearing.
Condition for constant velocity ratio for transmission of motion.
Form of teeth: cycloidal and involute profiles.
Velocity of sliding – phenomena of interferences –
Methods of interference. Condition for minimum number of teeth to avoid interference.
Expressions for arc of contact and path of contact
Introduction to Helical, Bevel and worm gearing.
Tutorial Class-6
Belt Rope and Chain Drives: Introduction, Belt and rope drives, selection of belt drive
Types of belt drives, V-belts, Materials used for belt and rope drives, velocity ratio of belt drives,
Slip of belt, creep of belt, Tensions for flat belt drive,
Angle of contact, centrifugal tension, Maximum tension of belt, Chains- length,
Angular speed ratio, classification of chains.
Methods of finding train value or velocity ratio – Epicyclic gear trains.
Selection of gear box, Differential gear for an automobile.
Solving University papers, Assignment test-2
Mid Test-II

1.7. Subject Contents
1.7.1. Synopsis page for each period (62 pages)
1.7.2. Detailed Lecture notes containing:
1. Ppts
2. Ohp slides
3. Subjective type questions (approximately 5 to 8 in no)
4. Objective type questions (approximately 20 to 30 in no)
5. Any simulations

1.8. Course Review (By the concerned Faculty):
    (i) Aims   (ii) Sample check   (iii) End of the course report by the concerned faculty

GUIDELINES:
Distribution of periods:
No. of classes required to cover JNTU syllabus : 54
No. of classes required to cover Additional topics : Nil
No. of classes required to cover Assignment tests (for every 2 units 1 test) : 4
No. of classes required to cover tutorials : 2
No. of classes required to cover Mid tests : 2
No of classes required to solve University Question papers : 2

Total periods : 64
DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAMME : B.TECH. (MECHANICAL ENGINEERING)

SEMESTER: II Year II- SEMESTER-MECH-A

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<td>k.Raju</td>
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NOTE: "*" Represents Tutorial Classe
# SEMESTER: II Year II- SEMESTER-MECH-B

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**FRI** - PT LAB/FHM LAB
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## DEPARTMENT OF MECHANICAL ENGINEERING
### INDIVIDUAL TIME TABLE

**COURSE:** II B.TECH  
**NAME OF THE FACULTY:** K RAJA  
**SUB:** KOM, ED  
**II YR, ME-A,B**

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### SCOPE:

1. To provide in-depth knowledge in basic mechanisms  
2. To learn the systematic way of solving problems  
3. To understand the different methods of obtaining a mechanism  
4. To efficiently implement the solutions for practical problems

### EVALUATION SCHEME:

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**TEACHER’S ASSESSMENT(TA)**

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<th>MARKS</th>
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*TA will be based on the Assignments given, Unit test Performances and Attendance in the class for a particular student.
UNIT-I: MECHANISMS AND MACHINES

1. Two shafts have their axes parallel and 2.5 cm apart. One of the shafts drives the other through an Oldham coupling. Sketch the arrangement and prove that the angular velocity ratio is unity. If the speed of the shaft is 100 rpm, what is the maximum velocity of sliding in cm per minute of the intermediate disc on either of the side discs?

2. What is meant by inversion of a mechanism? Describe with the help of suitable sketches the inversion of (a) Slider crank chain and (b) double slider chain. What are the different forms of quadric cycle chain?

3. (a) What is a Kinematic pair? State different methods of classifying them and state the salient features of each method of classification.

(b) What is the difference between quick return motion of crank and slotted lever type and that of Whitworth type? What is the ratio of time taken on cutting and return strokes?

4. (a) What are resistant bodies? Is it necessary that the resistant bodies be rigid? Give reasons for your answer.

(b) Describe elliptical trammels. How does it enable you to describe a true ellipse?

UNIT-II: STRAIGHT LINE MOTION MECHANISMS

1.(a) Prove that the tracing point, giving the horizontal straight line motion in Tchebicheff mechanism, lies at the mid point of the coupler.

(b) Prove that a point on one of links of a Hart mechanism traces a straight line on the movement of its links?
2. (a) Under what conditions Scott-Russell mechanism traces out a straight line and an ellipse? State the limitations of Scott-Russell mechanism.

(b) Sketch a pantograph, explain its working and show that it can be used to reproduce to an enlarged scale a given figure.

3. (a) Show that the Peaucellier mechanism generates an exact straight line as its path.

(b) A circle has OR as its diameter and a point Q lies on its circumference. Another point P lies on the line OQ produced. If OQ turns about O as centre and the product OQ x OP remains constant, show that the point P moves along a straight line perpendicular to the diameter OR.

4. (a) Sketch a Peaucellier mechanism. Show that it can be used to trace a straight line.

(b) How can you show that a Watt mechanism traces an approximate straight line?

UNIT-III: KINEMATICS

1. (a) State and prove the Kennedy’s theorem as applicable to instantaneous centres of rotation of three bodies. How is it helpful in locating various instantaneous centres of a mechanism?

(b) In a four bar chain ABCD, AD is the fixed link 12 cm long, crank AB is 3 cm long and rotates uniformly at 100 r.p.m. clockwise while the link CD is 6 cm long and oscillates about D. Link BC is equal to link AD. Find the angular velocity of link DC when angle BAD is 60°.

2. Prove Klein’s construction for determining the acceleration of a slider in a slider-crank mechanism. Hence show that the acceleration of the piston of an engine at inner and outer dead centre positions is given by
3. Refer to Figure 1. The following dimensions are given. \( O_2A = 4 \text{ cm}, AB = 7 \text{ cm}, AO_2B = 45^\circ, \omega_2 = 25 \text{ rad/s cw} \). Determine the angular velocity of the connecting rod and velocity of piston. Also, determine the velocity of the center of gravity of the connecting rod which is at a distance of 3 cm from the crank pin A. Use the Instantaneous center method.

4. In a Whitworth quick return motion, a crank AB rotates about the fixed centre A. The end B operates a slider reciprocating in a slotted link, rotating about a fixed centre D, 5 cm vertically above A. The crank AB which is 10 cm long, rotates in a clockwise direction at a
speed of 100 r.p.m. Find the angular acceleration of the slotted link for the configuration in which AB has turned through an angle of 45 degrees past its lowest position.

   (a) An Ackermann steering gear does not satisfy the fundamental equation of steering gear at all positions. Yet it is widely used. Why?

(b) Two shafts are to be connected by a Hooke’s joint. The driving shaft rotates at a uniform speed of 500 rpm and the speed of the driven shaft must lie between 475 and 525 rpm. Determine the maximum permissible angle between the shafts.

1. (a) An Ackermann steering gear does not satisfy the fundamental equation of steering gear at all positions. Yet it is widely used. Why?

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2. (a) What conditions must be satisfied by the steering mechanism of a car in order that the wheels may have a pure rolling motion when rounding a curve? Deduce the relationship connecting the inclinations of the front stub axles to the rear axle, the distance between the pivot centres for the front axles and wheel base of the car.

(b) Give salient features of the speed of driven shaft of a Hooke’s joint by drawing a polar diagram.

3. (a) Derive an expression for the ratio of angular velocities of the shafts of a Hooke’s joint.

(b) Using Davis steering gear, find the inclination of the track arms to the longitudinal axis of the car if the length of car between axles is 2.3 m, and the steering pivots are 1.3 m apart. The car is moving in a straight path.

**UNIT-IV: CAMS**

1. (a) Explain the procedure to layout the cam profile for a reciprocating follower.

(b) Derive relations for velocity and acceleration for a convex cam with a flat faced follower.

2. Draw a cam profile which would impart motion to a flat faced follower in the following desired way. The stroke of the follower being 5 cm. (i) The follower to move with uniform acceleration upward for 90°, dwell for next 90°, (ii) The follower to return downward with uniform retardation for 120° and dwell for next 60°. The minimum radius of the cam being 3 cm.

3. (a) Compare the performance of Knife–edge, roller and mushroom followers.

(b) A knife edged follower for the fuel valve of a four stroke diesel engine has its centre line coincident with the vertical centre line of the cam. It rises 2.5 cm with SHM during 60° rotation of cam, then dwells for 20° rotation of cam and finally descends with uniform acceleration and deceleration during 45° rotation of cam, the deceleration period being
half the acceleration period. The least radius of the cam is 5 cm. Draw the profile of the cam to full size.

4. A cam profile consists of two circular arcs of radii 24 mm and 12 mm joined by straight lines giving the follower a lift of 12 mm. The follower is a roller of 24 mm radius and its line of action is a straight line passing through the cam shaft axis. When the cam shaft has a uniform speed of 500 r.p.m., find the maximum velocity and acceleration of the follower while in contact with the straight flank of the cam.

UNIT-V: GEARING

1. (a) Make a comparison of cycloidal and involute tooth forms.
   (b) Two 20° pressure angle involute gears in mesh have a module of 10mm. Addendum is 1 module. Large gear has 50 teeth and the pinion has 13 teeth. Does interference occur? If it occurs, to what value should the pressure angle be changed to eliminate interference?

2. (a) Sketch two teeth of a gear and show the following: face, flank, top land, bottom land, addendum, dedendum, tooth thickness, space width, face width and circular pitch.
   (b) Derive a relation for minimum number of teeth on the gear wheel and the pinion to avoid interference.

3. Two gears in mesh have a module of 10 mm and a pressure angle of 25°. The pinion has 20 teeth and the gear has 52. The addendum on both the gears is equal to one module. Determine (i) The number of pairs of teeth in contact (ii) The angles of action of the pinion and the wheel (iii) The ratio of the sliding velocity to the rolling velocity at the pitch point and at the beginning and end of engagement.

4. (a) What is a worm and worm wheel? Where is it used?
   (b) Two 20° involute spur gears mesh externally and give a velocity ratio of 3. Module is 3 mm and the addendum is equal to 1.1 module. If the pinton rotates at 120 r.p.m. find: (i) The minimum number of teeth on each wheel to avoid interference. (ii) The number of pairs of teeth in contact.

Objective type questions:

1) In a structure the degree of freedom is
   a) 1           b) 2           c) ∞           d) 0

2) In a mechanism which one is true
   a) All links fixed b) one link fixed c) All links free d) None.

3) In a slider crank mechanism there are
4) The links of a structure transmit
   a) Forces only  b) Motion only  c) Both  d) None
5) The links of a machine may transmit
   a) Force only  b) Motion only  c) Power & Motion  d) None
6) Hydraulic press is
   a) Rigid link  b) Flexible link  c) Fluid link  d) None
7) For a kinematic chain which relation is true
   a) \( l = 2p - 4 \)  b) \( l = 2f + 4 \)  c) \( l = p - 4 \)  d) \( l = p + 4 \)
   Where \( l \) = No. Of links & \( p \) = No. Of pairs
8) In a reciprocating steam engine, which of the following form a kinematic link
   a) Crank shaft & flywheel  b) Cylinder & Piston
   c) Piston & connecting rod  d) Flywheel & engine frame
9) The Grueblen’s criterion for determining the degree of freedom of a mechanism having \( n \) links and \( p \) pair is given by
   a) \( F = 3(n-1) - 2p \)  b) \( F = 6(n-1) - 2p \)
   c) \( F = 5n - 2p \)  d) \( F = 3(n+1) - 2p \)
10) Which of the following is the inversion of double slider crank chain
    a) Beam engine  b) Elliptical trammel
    c) Watts indicator mechanism  d) Quick return motion mechanism
11) Kinematic pairs are those which have
    a) Two elements that permit relative motion.
    b) Pair of elements held together mathematically
    c) Pair of elements having line contact
    d) Pair of elements having surface contact
12) A 6-bar chain can be formulated to give constrained motion by using
    a) 5 turning pairs.  b) 6 turning pairs.
    c) 7 turning pairs.  d) 8 turning pairs.
13) In a six bar chain for constrained motion there will be
    a) 6 binary links.
    b) 4 binary & 2 ternary links.
    c) 5 binary & 1 ternary links.
    d) 3 binary & 3 ternary links.
14) Which of the following mechanism is used to enlarge or reduce the size of a drawing
    a) Pantograph
b) Graphometer
c) Oacillograph
d) Clinograp

15) In a kinematic chain, if the specification of one coordinate or dimension or position of a single link is sufficient to define the position of all other links, then the chain is called a kinematic chain of
   a) 2 D.O.F
   b) 1 D.O.F
   c) 3 D.O.F
   d) None

16) A negative degree of freedom for a linkage means
   a) Constrained motion of the linkage.
   b) Un-Constrained motion of the linkage
   c) Any of the linkage
   d) Statically indeterminate structure

17) A slider crank mechanism is a special case of a
   a) 3-bar mechanism
   b) 2-bar mechanism
   c) 6-bar mechanism
   d) 4-bar mechanism

18) The study of relative motion between the parts of a machine is called
   a) Static
   b) Hydrodynamics
   c) Kinematics
   d) Kinetics

19) The elements or links which are connected together in such a way that the relative motion is completely constrained, from a
   a) Kinematic pair
   b) Machine
   c) Mechanism
   d) Kinematic chain

20) When two elements have point or line contact motion, the pair so formed is known as
   a) Higher pair
   b) Lower pair
   c) Screw pair
   d) Closed pair
21) Which one of the following is an example of completely constrained motion
   a) Rotor of a vertical shaft turbine
   b) A foot step bearing
   c) A shaft with collars at each end rotating in a round hole
   d) A circular bar moving in a round hole
22) A spherical pair allows
   a) 2 D.O.F
   b) 4 D.O.F
   c) 1 D.O.F
   d) 3 D.O.F
23) A cylindrical pair allows
   a) 2 D.O.F
   b) 3 D.O.F
   c) 4 D.O.F
   d) 1 D.O.F
24) A screw pair allows
   a) 2 D.O.F
   b) 3 D.O.F
   c) 5 D.O.F
   d) 1 D.O.F

NUMERICAL PROBLEMS:

1) The transom mechanism of the door is shown in Figure 5-a. The opening and closing mechanism is shown in Figure 5-b. calculate its degree of freedom.
2) Calculate the degrees of freedom of the mechanisms shown in Figure 7

3) Calculate the degrees of freedom of the mechanisms shown in Figure 8a and 8b.

4) Calculate the degrees of freedom for the following
5) In a crank and slotted lever quick return mechanism, the distance between the fixed centers is 240mm and the length of the driving crank is 120mm. Find the inclination of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke.

If the length of the slotted bar is 450 mm, find the length of stroke if the line of stroke passes through the extreme positions of the free end of the lever.

6) In a quick return mechanism the driving crank is 30mm long, and the time ratio of the working stroke to the return stroke is to be 1.7, length of the working stroke is 120mm, determine the length of the slotted lever.

7) In a with worth quick return motion mechanism, the distance between the fixed centers is 50mm and the length of the driving crank is 75mm, the length of the slotted lever is 150mm and the length of the connecting rod is 135mm. Find the time of cutting stroke to the time of return stroke and also the length of the stroke.

**UNIT –II (Straight Line Motion Mechanism)**

**Learning Objects:**

By the end of Unit –II, the student should be able to

- Write the need of straight line motion mechanisms
- List out different exact and approximate straight line motion mechanisms
- Write principle of exact straight line motion mechanisms.
- Write how straight line motion can be obtained with the help of peancellar and hart mechanisms
- Write the use of pantograph.
- Draw the sketch of pantograph and write how a given path can be copied (Either to reduce scale or to enlarge scale) with the help of pantograph.
- Draw the sketches of Scott Russell mechanism, croon hopper mechanism revert mechanism, Tihebicff”s mechanism.
**Essay Questions:**

1. What is a photograph? Show that it can produce paths exactly similar to the ones traced out by a point on a link on an enlarged or reduced scale.
2. Enumerate straight line mechanism. Why are they classified into exact and approximate straight line mechanism?
3. Sketch a Peaucellier mechanism. Show that it can be used to track a straight line.
4. Prove that a point on one of links of a Hart mechanism traces a straight line on the movement of its links.
5. What is Scott Russell mechanism? What are its limitations? How it is modified?
6. In what way Group hopper mechanism is the derivation of modified Scott Russell mechanism.
7. How can you show that Watt mechanism traces an approximate straight line?
8. How can we ensure that a Tchebylef’s traces an approximate straight line?
9. Discuss Robert mechanism.
10. What are straight line mechanisms?
11. What are the different types of exact straight line motion mechanisms and explain each of them.
12. What are the different types of approximate straight line motion mechanisms and explain each of them.
13. Explain briefly Scott Russell mechanism for tracing a straight line?
14. Write short notes on Peaucellier and Hart straight line motion mechanisms.

**Objective Questions:**

1. In 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 only?
   
   [   ]
   
   (a) Scotch Russell mechanism       (b) Peaucellier mechanism
3. Which of the following is used to enlarge or reduce site of a drawing?
   [ ]
   (a) Groan hopper mechanism  (b) Watts mechanism
   (c) Pantograph  (d) None

4. Which of the following is derivation of modified Scott Russell mechanism?
   [ ]
   (a) Groan hopper mechanism  (b) Watts mechanism
   (c) Pantograph  (d) None

5. Peancellar mechanism has got _____________ no of links.
   [ ]
   a) 2  (b) 4  (c) 6  (d) 8

6. Heart mechanism has got _____________ no of links.
   [ ]
   a) 2  (b) 4  (c) 6  (d) 8

7. Which of the following is an exact straight line motion mechanism?
   [ ]
   a) Heart mechanism  (b) Robert mechanism
   c) Modified Scott Russell mechanism  (d) None

8. Which of the following is an approximate straight line motion mechanism?
   [ ]
   a) Peancellar mechanism  (b) Hart mechanism
   c) Modified Scott Russell mechanism  (d) None

9. Which of the following is a coping mechanism
   [ ]
   a) Peancellar mechanism  (b) Hart mechanism
   c) Modified Scott Russell mechanism  (d) None

UNIT-III - Velocity and Acceleration Analysis

Learning Objects:
By the end of Unit-III, the student should be able to

- Compute Velocity, centripetal and tangential acceleration of a rotating link (Both in magnitude and direction)
- Compute Velocity and acceleration of a sliding link (Both in magnitude and direction)
- Draw the Velocity diagram of a given mechanism.
- Draw the acceleration diagram of a given mechanism.
- Compute Velocities, angular Velocities, acceleration and angular acceleration of various likes of mechanisms.
- Define instantaneous centre, types of instantaneous centers.
- State and prove Kennedy’s theorem
- Apply Kennedy's theorem to locate instantaneous centers of a given mechanism and compute Velocity from it.
- State importance of corioli’s component of acceleration.
- Compute magnitude and direction of corioli’s component of acceleration and use it in drawing acceleration diagrams.
- List out the mechanisms where corioli’s component of acceleration exists
- Draw Klein’s construction.
- Compute Velocities and accelerations of various links of a single slider crank chain from Klein’s construction.
- Derive the expression for displacement, Velocity and acceleration of slider of a single slider crank chain.

**Essay Questions:**

1. What is a configuration diagram? What is it we?
2. Describe the procedure to construct velocity diagram of a four bar linkage.
3. What is velocity image? State why it is known as helpful device in velocity analysis of complicated linkage.
4. What is velocity of rubbing? How it is found?
5. What do you mean by the term coincident point?
6. What is instantaneous centre? How do you know the number of instantaneous centers of a mechanism?
7. State ad prove Kennedys theorem as applicable to instantaneous centre of rotation of three bodies. How it i) useful in locating various instantaneous centre of a mechanism.
8. What do you mean by cent rode of a body? What are its types? (or) Define space cent rode and body cent rode.
9. In a slider crank mechanism, stoke of the slider is half of length of connecting rod. Draw a diagram to give velocity of slider at any instant assuming creak shat turns unifened.
10. Show that plane motion of a rigid body relative to another rigid body is equalent to rolling motion of one cent rode or the other.
11. State and explain angular velocity ratio theorem as applicable to mechanism.

**Objective Questions:**

1. For a rotating link, the direction of velocity vector is _________  [ ]
   a. a)Parallel to link b) 90° to link c) 45° to link d) None
2. For a rotating link the direction of centripetal acceleration is _____  [ ]
   a. a)Parallel to link b) 90° to link c) 45° to link d) None
3. For a rotating link the direction of tangential acceleration is _____  [ ]
   a. a)Parallel to link b) 90° to link c) 45° to link d) None
4. For a slider the sliding velocity direction is _______  
   a. a)Parallel to sliding path b) 90° to sliding path c) 45° to sliding path d) None
5. For a slider the sliding acceleration direction is _______  [ ]
a. a) Parallel to sliding path  
   b) $\perp r$ to sliding path  
   c) 45° to sliding path  
   d) None

6. Velocity of point ‘A’ is__________________________
   a) rw  
   b) $w^2r$  
   c) $r\alpha$  
   d) None

7. Centripetal acceleration of point ‘A’ is___________
   [a)rw  
   b) $w^2r$  
   c) $r\alpha$  
   d) None

8. Tangential acceleration q point ‘A’ is__________
   [a)rw  
   b) $w^2r$  
   c) $r\alpha$  
   d) None

9. A pin of a radius ‘r’ is connecting two links that are rotating with angular velocities
   a. ‘$w_1$ and $w_2$ in opposite direction then rubbing velocity at pin is ___
   [a)($w_1- w_2$) r  
   b) ($w_1+ w_2$) r  
   c) $\frac{w_1^2}{w_2} r$  
   d) None

10. A pin of radius ‘r’ is connecting two lines that are rotating with angular velocities $w_1$ and $w_2$, in same direction then rubbing velocity at pin is ______
    [a)($w_1- w_2$) r  
    b) ($w_1+ w_2$) r  
    c) $\frac{w_1^2}{w_2} r$  
    d) None

11. If $w_A w_B$ be angular velocities of input and output links of a four bar mechanism
    a. then ‘n’ of mechanism ________________
    [   ]

12. If ‘n’ is the number of links of a mechanism then number of instantaneous center is
    [   ]
    a) $\frac{n}{2}$  
    b) $\frac{n(n+1)}{2}$  
    c) $\frac{n(n-1)}{2}$  
    d) None

13. According to Kennedy’s theorem, if three bodies move relative to each other,
    a. their instantaneous centers will lie on a______
    [   ]
    b. a) Straight line  
    b) Parabolic curve  
    c) Ellipse  
    d) None
14) The instances centre that remains in same place for all configuration of the
c. mechanism is known as ______________ [ ]
d. a) Permanent instance 
b) Fixed instances centre
e. c) Both fixed and permanent 
d) None

15. The instantaneous centre that varies with configuration of mechanism is ____ [ ]
a) Permanent 
b) Fixed centre 
c) Both fixed and Permanent 
d) None

16. When a slider is sliding along the straight path its instantaneous centre lies at __[ ]
a) At ‘∞’ parallel to path 
b) At ‘a’ L r to path 
c) At content point between slider an path 
d) None

17 When a slider moves an a fixed link having curved surface, then instantaneous centre
f. lies at _________________ [ ]
a) At point of constant 
b) At centre of curvature 
c) At ∞ tangential to circular curvature 
d) None

18. Number of instantaneous centers of a under mechanism are ______ [ ]
a) 2 
b) 4 
c) 6 
d) None

19. Number of instantaneous centre q a single slider crank chair are_____ [ ]
a) 2 
b) 4 
c) 6 
d) None

20. Number of instantaneous centre of double slider crank chair are ____ [ ]
a) 2 
b) 4 
c) 6 
d) None

21. Which of the following mechanism have carioles complaint of acceleration__ [ ]
  g. a) Four bar linkage 
b) Quite return motion mechanism of shaper
22. Which of the following mechanism do not have carioles of acceleration? 

\[ \text{[ ]} \]

i. a) Four bar linkage 
   b) Crank and slotted lever mechanism 

ii. c) Whit worth acceleration motion mechanism 
   d) None 

23. In a whit worth mechanism, the angle turned by crank during return stroke (Idle Stroke) is $90^\circ$ then ratio of time of cutting to return stroke is______ 

\[ \text{[ a)3} \quad \text{b) 1/3} \quad \text{c) 1} \quad \text{d) None} \]

24. When a crank rotates with uniform angular velocity them tangential 

i. component of acceleration is ________________.

\[ \text{[ ]} \]

25. In a whit worth mechanism the slotted line is rotating with angular velocity ‘w’ in crank wise direction and slider slides along slotted link with velocity ‘V’ then 

i) Magnitude of cariole complaint of acceleration is________________

\[ \text{[ a) } \frac{2w}{w} \quad \text{b) } 2vw \quad \text{c) } vw \quad \text{d) } \frac{w}{w} \]

ii) Direction of coriolis comport of acceleration is__________________

\[ \text{[ a) Parallel to slotted to link} \quad \text{b) } \bot \text{ r to slotted link} \]
\[ \text{c) Inched to slotted link} \quad \text{d) None} \]

26. If \( r = \) crow radius, \( l = \) connects rod length \( n = \frac{l}{r} \), \( Q = \) angle mode by crank with 2DC \( W = \) angle of velocity of f crank 

i. Expression for displacement of slider is__________________________

ii. Expression for velocity of slider is______________________________

iii. Expression for acceleration of slider is__________________________

27. Scale for Klein’s velocity diagram is______________________________

28. Scale for Klein’s acceleration diagram of__________________________
29. Klein’s constriction is used only for _______________________________ [   ]
   j. a) Four bar chain b) single slider crank chair
   k. c) Double slider crank chair d) whit worth mechanism

30. Klein’s Velocity diagram is _________________________________ [   ]
   l. a) Rectangle b) Velocity c) Square d) None

31) For a rigid link, velocity of one end relative to other end of the link will be
   m. Parallel to the link
   n. Perpendicular to the link
   o. At center of circle
   p. On their point of contact

32) Linear velocity of a point on a link relative to any other point on the links will be
   q. Parallel to line joining the two points
   r. Perpendicular to the line joining the two points
   s. Perpendicular to lower end of the link
   t. None

33) Acceleration of any point in a mechanism is determined by
   u. Analytical method
   v. Graphical method
   w. Both
   x. None

34) Component of acceleration parallel to the velocity of the particle at the given instant is known as
   y. Radial component
   z. Tangential component
   aa. Coriolis component
   bb. None

35) When a point on a link moves along a straight line, its acceleration will only have
   a. Radial component
   b. Tangential component
   c. Coriolis component
   d. All of the above
36) The sense of tangential acceleration of a link is
   e. same as that of velocity
   f. opposite to the velocity
   g. can be either same or opposite to velocity
   h. None

36) Direction of tangential acceleration is
   a. along the angular velocity
   b. opposite to the angular velocity
   c. Both
   d. Perpendicular to the angular velocity

37) Component of acceleration, perpendicular to the velocity of the particle, at a given instant is known as
   a. Radial component
   b. Tangential component
   c. Coriolis component
   d. All of the above

38) Radial & Tangential component of a particle at any instant will be
   a. Parallel to each other
   b. Opposite to each other
   c. Perpendicular to each other
   d. At 45° to each other

39) When end point of a link moves with constant angular velocity, its acceleration will have only
   a. Radial component
   b. Tangential component
   c. Coriolis component
   d. All of the above

40) A point ‘B’ on a rigid link moves with respect to ‘A’ with angular velocity \( \omega \) rad/sec of link AB about A, the radial component of the acceleration of B with respect to A, is

41) \[ \begin{align*}
   \text{a) } V_{ba}^2 & \quad \text{b) } V_{ba} & \quad \text{c) } V_{ba} \cdot AB & \quad \text{d) } V_{ba}^2 \cdot AB \\
   \text{i. } & \quad \text{AB} & \quad \text{AB}
   \end{align*} \]

42) Where \( V_{ba} \) is linear velocity of B with respect to A

43) In a rigid link AB, the point B moves with respect to A. The angular acceleration of link AB will be equal to
   a) Radial acceleration    b) Tangential acceleration
If a particle of a link has a velocity which changes both in magnitude & direction at any instant, then it must have components of acceleration

- Centrifugal & tangential
- Centripetal, centrifugal & tangential
- Centripetal, centrifugal & gravitational
- Centripetal, centrifugal, gravitational & tangential

The tangential component of acceleration of the slider with respect to the coincident point on the link is known as

- Radial component
- Tangential component
- Coriolis component
- None

The Coriolis component of acceleration acts

- Parallel to the sliding surface
- Perpendicular to the sliding surface
- At 45° to the sliding surface
- None

The coriolis component of acceleration will exist if any of the two coincidental points

- have same center of rotation
- have relative angular velocity of sliding
- have linear relative velocity of sliding accompanied by the rotation about fixed centers
- none

According to the coriolis law if a point moves along a path having rotation, the absolute acceleration of the point is equal to the

- Absolute acceleration of the point relative to coincident point in the path.
- Absolute acceleration of the coincident point in the path
- Coriolis component acceleration
- Vector sum of a, b & c above.

The direction of coriolis component of acceleration is the direction of relative velocity vector for the two coincidental points as rotated by 90° in the direction of angular velocity of rotation of the link

- rotated by 90° in the direction of angular velocity of rotation of the link
- rotated by 180° in the direction of angular velocity of rotation of the link
- in the direction directly opposite to that of angular velocity
d. None

50 The coriolis component of acceleration leads the sliding velocity by
   a. $30^\circ$
   b. $45^\circ$
   c. $90^\circ$
   d. $180^\circ$

51 The coriolis component of acceleration exist when a point moves along a path which has
   a. Rotational motion
   b. Linear motion
   c. Tangential acceleration
   d. Gravitational acceleration

52 If a slider moves with a velocity $v$ on a link revolving at angular velocity $\omega$, the magnitude of coriolis component of acceleration is
   a) $V\omega$
   b) $2V\omega$
   c) $\sqrt{2}V\omega$
   d) $V\omega/2$

53 The coriolis component is encountered in
   a. Slider crank mechanism
   b. 4-bar chain mechanism
   c. Quick return mechanism
   d. All of the above

54 The coriolis component exist in
   a. Shaper mechanism
   b. Tangent cam mechanism
   c. Link sliding in a swiveling pin
   d. All of the above

55 Coriolis component is considered if
   a. The point considered moves on a path that rotates
   b. The point considered moves along a path that is stationary
   c. The point considered moves along a circular path
   d. The point considered moves in any curvilinear path

56 If a point moves along a straight line which is rotating, then the tangential component of acceleration is
   a) $v^2/r$
   b) $dv - \omega^2 r$
   c) $dv/dt$
   d) $2v\omega + r\alpha$
   1. $dt$

59 A slider sliding at 10cm/sec on a link, which is rotating at 60 rpm, is subjected to coriolis acceleration of magnitude
60. The component of acceleration parallel to the link is called
   a. Radial
   b. Tangential
   c. Coriolis
   d. Absolute

61. When the crank rotates with uniform speed, it has
   a. Only radial acceleration
   b. Only tangential acceleration
   c. Only Coriolis acceleration
   d. None

62. The total number of instantaneous centers for a mechanism containing \( n \) links is given by
   a. \( (n-1)/2 \)
   b. \( n(n-1)/2 \)
   c. \( n \)
   d. \( n/2 \)

63. If three bodies move relative to each other then according to Kennedy’s theorem their instantaneous center will lie on
   a. Parabolic curve
   b. Ellipse
   c. Circle
   d. Straight line

64. The relative instantaneous center of two bodies having a point of contact, lies
   a. At the point of contact
   b. On the common tangent
   c. On the common normal
   d. None

65. Two links are said to have a pure rolling contact if their instantaneous center lies
   a. On their point of contact  b) At the center of curvature
   b. c) At the pin joint d) At infinity

66. Property of instantaneous center is
   a. Rigid link rotates instantaneously relative to another link at the instantaneous center for the configuration of the mechanism considered
   b. Two rigid links have the same linear velocity relative to the third rigid link
   c. Two rigid links have no linear velocity relative to each other at the instantaneous center
   d. All of the above
67 Magnitude of velocities of the points on a rigid link is inversely proportional to the distance from the points to the instantaneous center and is
   a. Perpendicular to the line joining the point to the I.C
   b. Parallel to the line joining the point to the I.C
   c. All of the above
   d. None

68 Instantaneous centers which remain in the same plane for all configuration of the mechanism, are known as
   a. Fixed I.C
   b. Permanent I.C
   c. Neither fixed nor permanent I.C
   d. None

69 I.C which move on the mechanism, moves but joints are of permanent nature, are known as
   a. Fixed I.C
   b. Permanent I.C
   c. Neither fixed nor permanent I.C
   d. None

70 I.C which vary with the configuration of mechanism, are known as
   a. Fixed I.C
   b. Permanent I.C
   c. Neither fixed nor permanent I.C
   d. None

71 When a slider moves as a fixed link having curved surface, their instantaneous center lies
   a. On their point of contact
   b. At the center of curvature
   c. At the pin joint
   d. At infinity

72 When two links are connected by a pin joint their I.C lies
   a. On their point of contact
   b. At the center of curvature
   c. At the pin joint
   d. At infinity

73 When a slider moves as a fixed link having straight surface, their instantaneous center
   a. On their point of contact     b) At the center of curvature
b. c) At the pin joint d) at infinity

74 When a slider moves as a fixed link having constant radius of curvature will have its I.C
   a. At the pin joint
   b. At infinity
   c. On their point of contact
   d. At the center of circle

75 Klein’s construction gives a graphical construction for
   a. Acceleration polygon
   b. Velocity polygon
   c. Angular polygon
   d. All of the above

76 Klein’s construction is used to determine
   a. Displacement of various parts
   b. Acceleration of various parts
   c. Velocity of various parts
   d. Angular acceleration of various parts

77 Klein’s construction is used when crank has a
   a. Uniform angular velocity
   b. Non uniform angular velocity
   c. Non uniform angular acceleration
   d. Uniform angular acceleration

Numerical Problems:

1. In a four link mechanism, the dimensions of links are as under; AB=50 mm; BC=66 mm; CD=56 mm and AD=100 mm. At the instant when ALDAB=60°, the link ‘AB’ has angular Velocity of 10.5 rod /Sec in counter clock wise direction and has a retardation of 26 rod/Sec. Determine
   (i) Velocity of point ‘C’.
   (ii) Velocity of point ‘E’ on link ‘BC’ when BE=40 mm.
   (iii) Angular Velocities of link ‘BC’ and ‘CD’.
   (iv) Velocity of an offset point ‘F’ on link ‘BC’ if BF=45 mm, CF=30 mm and BCF is read clock wise.
(v) Velocity of an offset point ‘G’ on link ‘CD’ if CG=24 mm, DG=44 mm and DCG is read clock wise.

(vi) Velocity of rubbing at pins A, B, C and D when rods of pins are 30, 40, 25 and 35 mm respectively.

(vii) Angular acceleration of links ‘BC’ and ‘CD’.

(viii) Linear acceleration of points ‘E’, ‘F’ and ‘G’.

2. In a slider crank chain mechanism, the crank is 480 mm long and rotates at 20 rod/sec in counter clock wise direction. Length of connecting rod is 1.6m. When crank turns 60° from IDC determine.

(i) Velocity of slider.

(ii) Velocity of point ‘E’ located at a distance of 450 mm on the connecting rod extended.

(iii) Acceleration of slider at ‘B’.

(iv) Acceleration of point ‘E’.

(v) Angular acceleration of link ‘AB’.

3. An engine crank shaft drives a retroaction pump through a mechanism a shown in fig. The crank rotates at 160 rpm in clock wise direction diameter of pump piston at ‘F’ is 200 mm, Dimensions of various link are OA=170mm, AB=660, BC=510 mm, CD=170mm, DE=830mm for the position of crank shown in diagram determine.

(i) Velocity of cross head at E.

(ii) Velocity of rubbing at ins A,B,C & D, the diameters being 40,30,30 and 50 mm respectively.

(iii) Forque required at shaft ‘O’ to overcome a pressure of 300 km/m² at pump piston ‘F’.
4. For the Whitworth quick return mechanism shown in figure, the dimensions of links are: OP (crank) = 240 mm, OA = 150 mm, AR = 165 mm, RS = 430 mm. The crank rotates at an angular velocity of 2.5 rad/sec. At the movement when the crank makes an angle of 45° with vertical, calculate
   (i) Velocity of ram’s
   (ii) Velocity of slider ‘P’ on slotted lever.
   (iii) Angular velocity of link ‘RS’

5. For the crank slotted lever mechanism shown in fig. determine acceleration of ram ‘D’ of crank rotates at 120 rpm in anti-clockwise direction. Also determine angular acceleration of slotted link given AB = 150 mm, slotted are = OC = 700 mm, link CD = 200 mm.
6. In a swiveling joint mechanism, as shown in figure crank ‘OA’ is rotating clock wise at 100 rpm length of the various links are; OA=50 mm, AB=350mm, AD=DB; DE=EF=250mm and CB=125mm. Horizontal distance between fixed points ‘O’ and “C’ is 300 mm and vertical distance between ‘F’ and ‘C’ is 250 mm.

For the given configuration determine (i) Velocity of slider (ii) Angular velocity of link DE (iii) velocity of the sliding link in swivel block and (iv) acceleration of sliding link DE in the trunnion.

7. The mechanism of a stone crusher is shown in figure along with various dimensions of links in mm. If crank ‘OA’ rotates at uniform velocity of 120 rpm, determine velocity of point (Jaw) when crank ‘OA’ is inched at an angle of 30° to horizontal. What will be the torque required at crank ‘OA’ to overcome a horizontal force of unknown at ‘K’.
8. In the pump mechanism shown in figure, OA= 320mm, AC=680 mm, OQ=650mm. for the given configuration determine.
   (i) Angular velocity of slider
   (ii) Sliding velocity of plunger
   (iii) Absolute velocity of plunger if crank rotates at 20 rod be clock wise.

   Also determine linker acceleration of slider ‘C’


10. In a pin jointed u bar mechanism, AB= 300mm, BC=CD=360mm and AD=600 mm, (fixed link). LBAD=60° other crank rotates at a speed of 100 rpm. Locate all instantaneous centers and determine angular velocity of link ‘BC’.

11. For a single slider crank mechanism, crank OB=100mm, connecting rod AB=400mm. If crank rotates at an angular velocity of lrorod/Sec clock wise, find (i) velocity of slider ‘A’ and angular velocity of connecting rod AB use instantaneous centre method and LAOB=45°.

12. Type question
13. Figure shows configuration of Whitworth quick return mechanism. Length of fixed link ‘OA’ and crank ‘OP’ are 200 mm and 350 mm respectively. Other lengths are AR=200 mm AND RS=400 mm. Find velocity of ram using instantaneous centre method when crank makes an angle of $120^0$ with fixed link and has angular velocity of 10 rod/Sec.

14. For the crank and slotted lever quick return motion mechanism of shaper shown in figure-3 (problem.5) determine velocity of ram ‘D’ using instantaneous centre method.

15. Figure shows mechanism of sewing machine needle box. For the given configuration, find velocity of needle fixed to slider ‘D’ when crank ‘OA’ rotates at 40 rod/Sec.

16. For a single slider crank chain mechanism, crank OB=100 mm, connecting rod AB=400 mm. If the crank rotates at an angular velocity of 10 rad/Sec clockwise. Determine velocity and acceleration of slider by Klein’s construction method.

UNIT – V - GEARS

**Learning Objects:**

By the end of Unit-IV, the student should be able to

- State the use and applications of universal coupling.
- Derive the expression for ratio of shaft velocities (I/P and output)
- Derive the condition for equal speeds of driving and driven shafts.
- Compute maximum and minimum output shaft velocities.
- Derive expression for angular acceleration of driven shaft.
- Solve the numerical problems related to universal coupling.
- State the drawback of single Hooks Joint (Universal Coupling)
- Draw the sketch of double Hooks joint.
- Write how drawback with single Hooks joint can be eliminated in double Hooks joint.
- State condition for steering gear mechanism.
- List out different types of steering gear mechanism.
- Draw the sketches of Davis and Ackerman’s steering gear mechanism.

**Essay Questions:**

1. What is Hooks joint? State its application.
2. Derive the expression for ratio of shall velocities.
3. What is the drawback of universal coupling and how it can be overcome?
4. Explain why two Hooks joint are used for transt motion from engine to differential of automobile.
5. Draw the polar diagram depicting salient features of driven shall speed and derive the condition for equal of driving and driven shall for a universal coupling.
6. Describe double hooks joint and explain what happens if the forks attached to intermediate shaks are in perpendicular planes.
7. What is fundamental equation of steering gear? Which steering gear full fills this condition?
8. An Ackerman steering gear doesn’t satisfy fundamental equation of steering yet it is widely used shy?
9. Describe functioning of Davis steering gear and obtain the condition for correct steering in case of Davis steering gear.
10. Compare Davis steering gear and Ackerman steering gear.

**Objective Questions:**

1. For one complete rotation of driving shaft, how many times the speeds of driving

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and driven shaft will be equal.

2. For connecting two shafts which are inclined at small angles coupling is used.
   \[
   \begin{array}{cccc}
   \text{a)} & 1 & \text{(b)} & 2 \\
   \text{(c)} & 3 & \text{(d)} & 4 \\
   \end{array}
   \]

3. Maximum speed of driven shaft.
   \[
   \begin{array}{cccc}
   \text{a)} & N \cos \alpha & \text{(b)} & \frac{N}{\cos \alpha} \\
   \text{(c)} & N \cos^2 \alpha & \text{(d)} & N \\
   \end{array}
   \]

   \[
   \begin{array}{cccc}
   \text{a)} & N \cos \alpha & \text{(b)} & \frac{N}{\cos \alpha} \\
   \text{(c)} & N \cos^2 \alpha & \text{(d)} & N \\
   \end{array}
   \]

5. Maximum fluctuation is speed of universal coupling is _____________
   \[
   \begin{array}{cccc}
   \text{a)} & W \sin \alpha \cos \alpha & \text{(b)} & W \tan \alpha \sin \alpha \\
   \text{(c)} & W \cos \alpha & \text{(d)} & \frac{W}{\cos \alpha} \\
   \end{array}
   \]

6. Condition for equal speeds of driving shaft and driven shaft of a universal coupling is __________
   \[
   \begin{array}{cccc}
   \text{a)} & \tan \theta = \pm \sqrt{\frac{\sin \alpha}{\cos \alpha}} & \text{(b)} & \tan \theta = \pm \sqrt{\frac{\cos \alpha}{\cos \alpha}} \\
   \text{(c)} & \tan \theta = \pm \sqrt{\frac{\cos \alpha}{\cos \alpha}} & \text{(d)} & \text{None} \\
   \end{array}
   \]

7. Application of universal coupling is _____________
   \[
   \begin{array}{cccc}
   \text{a)} & \text{b)} & \text{c)} & \text{d)} \\
   \end{array}
   \]

8. In automobiles ___________ coupling is used to connect gear box and differential.

9. In multiple spindle drilling machine _________________ coupling is used.

10. ______________ coupling is used in horizontal column and kineme milling machine.

11. Disadvantage of single Hooks joint is ____________________.
In double hooks joint forks of intermediate shafts are in same plane. If speed of driving shaft is ‘n’ and angle between intermediate shaft and output shaft is $\alpha$ than

12. Maximum speed of intermediate shaft is _______
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

13. Minimum speed of intermediate shaft is _______
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

14. Maximum speed of output shaft is ____________
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

15. Minimum speed of output shaft is ____________
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

In double Hooks joint if the forks attached to intermediate shaft are in perpendicular plane and if speed of driving shaft is ‘n’ then

16. Maximum speed of intermediate shaft is _______
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

17. Minimum speed of intermediate shaft is _______
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } \frac{N}{\cos^2 \alpha} \quad \text{ (d) } N$

18. Maximum speed of output shaft is ____________
   \[
   \text{[ ]}
   \]
   a) $N \cos \alpha$ \quad \text{ (b) } \frac{N}{\cos \alpha} \quad \text{ (c) } N \cos^2 \alpha \quad \text{ (d) } \frac{N}{\cos^4 \alpha}$
19. Minimum speed of output shaft is ____________
   [   ]
   a) $N \cos \alpha$   (b) $\frac{N}{\cos \alpha}$   (c) $N \cos^2 \alpha$   (d) $\frac{N}{\cos^2 \alpha}$

20. ______________ type of steering gear has only tanning pairs.
21. ______________ type of steering gear has sliding pairs.
22. ______________ steering gear satisfies the condition for correct steering perfectly.
23. Condition for correct steering gear is _____________________.
24. _____________________ steering gear is widely used.

**Numerical Problems:**

1. Two inclined shafts are connected by means of a universal joint. Speed of driving shaft is 100 rpm. If total fluctuation of speed is not to exceed 12.5% of means speed, what is the maximum possible inclination between the shafts.

   With this angle what will be maximum acceleration to which driven shaft is subtracted to and when this will occur.

2. Angle between axes of two shafts connected by Hooks joint is $18^0$, determine angle turned by driving shaft when velocity ratio is maximum and unity.

3. A Hooks joint connects two shafts whose axes are inclined at $150^0$. Driving shafts rotates at 120 rpm driven shaft operates against a steady torque of 150 numbers and carries a flywheel whose mass is 45 kg with radius of gyration of 150mm. find maximum torque which will be exerted by driving shaft.

4. Driving shaft of Hooks joint runs at 240 rpm and angle between shafts is $20^0$.

   Driven shaft when attached mass 5.5 kg and radius of gyration of 150mm.

   (i) If steady torque of 200 numbers resist rotation of driven shaft, find torque exerted at driving shaft when $Q=45^0$.

   (ii) At what value of $\alpha$ will total fluctuation be limited to 24 rpm.

5. A double Hooks joint is used to connect two shafts in same plane.

   Intermediate shaft is inclined at $20^0$ to driving shaft as well as driven shaft. Find maximum and minimum speeds of intermediate shaft and driven shaft, if driving shaft has a constant speed of 2500 rpm.
6. The ratio between width of from axis and that of wheel base of a steering mechanism is 0.4m. At the instant when front inner wheel is turned by $18^0$, what should be the angle turned by outer front wheel for perfect steering.

7. In a Davis steering gear, the length of the car between axles is 2.4m and steering pivots are 1.35m apart. Determine inclination of track arms to longitudinal axis of car when car moves in a straight path.

8. The track arms of a Davis steering gear is at a distance of 192mm from front main axle where as the difference between their lengths is 96mm. If the distance between steering portly of main axle is 1.4m, determine the length of chaise between front and rear wheels. Also find inclination of track arm to longitudinal axis of vehicle.