Mechanism and Machine Design

III B. Tech V semester (Autonomous IARE R-16)

BY

Mr. M Vijay Kumar
Assistant Professor

DEPARTMENT OF AERONAUTICAL ENGINEERING
INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
DUNDIGAL, HYDERABAD - 500 043

Course Outcomes

COs	Course Outcome
CO1	Describe the concept of mechanisms and machines in which all the links and their mechanism studied.
CO2	Determine the velocity and acceleration diagrams for different mechanisms using graphical methods.
CO3	Understand the concept of plane motion of body and gyroscopic motion precession in which gyroscopic mechanism is studied.
CO4	Explore the concept of cams and followers, steering gear mechanism to understand real time applications of mechanisms.
CO5	Introduction to gears and gear mechanism where different tooth profiles of gear is designed.

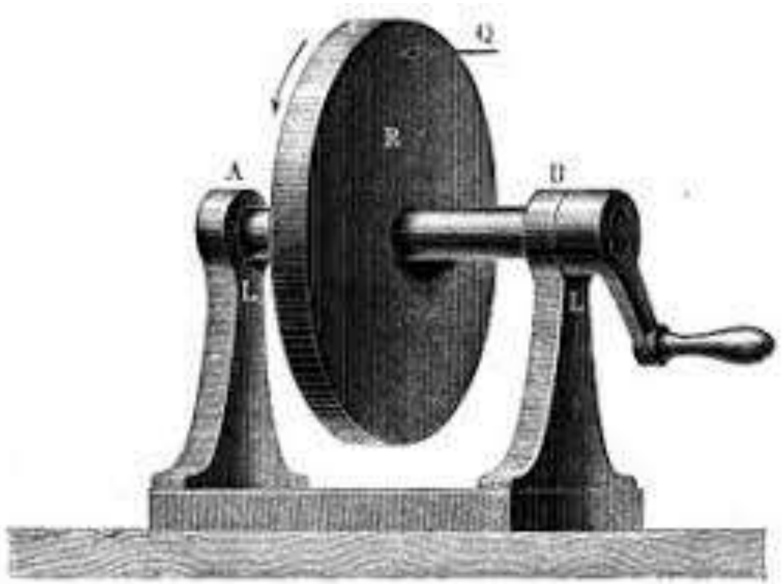
UNIT - I
MECHANISM AND MACHINES

Course Learning Outcomes

CLOs	Course Learning Outcome
CLO1	Understand the kinematic links, kinematic pairs and formation of the kinematic chain.
CLO2	Distinguish between mechanism and machine.
CLO3	Design and develop inversions of quadratic cycle chain, slider crank mechanism, and double slider crank mechanism and cross slider mechanism.
CLO4	Demonstrate type synthesis, number synthesis and dimensional synthesis.

Introduction

Kinematics is the branch of mechanics which tells us about the motion without considering the cause of motion. In this portion, we study the displacement, speed and acceleration without bothering about the input force or torque.



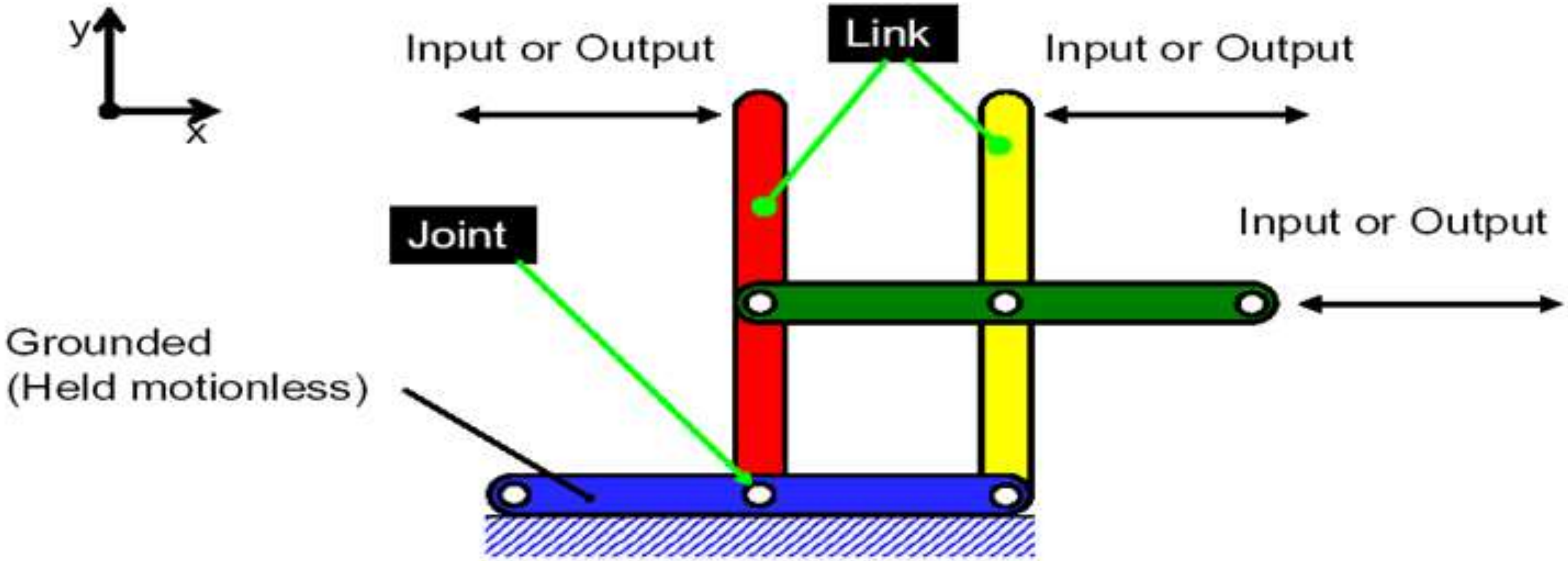
MACHINE

A machine is a mechanism or collection of mechanisms, which transmit force from the source of power to the resistance to be overcome.

Though all machines are mechanisms, all mechanisms are not machines

What is linkage?

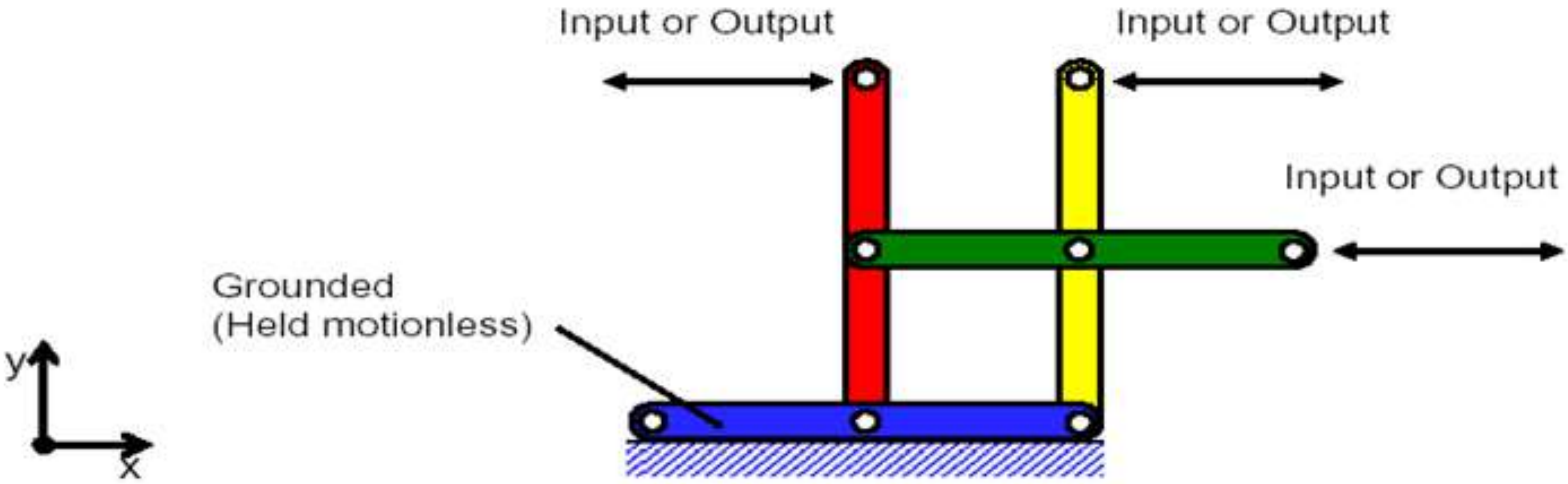
A mechanism used to define motion (kinematics) &/or transfer energy using links & joints



Linkage classification

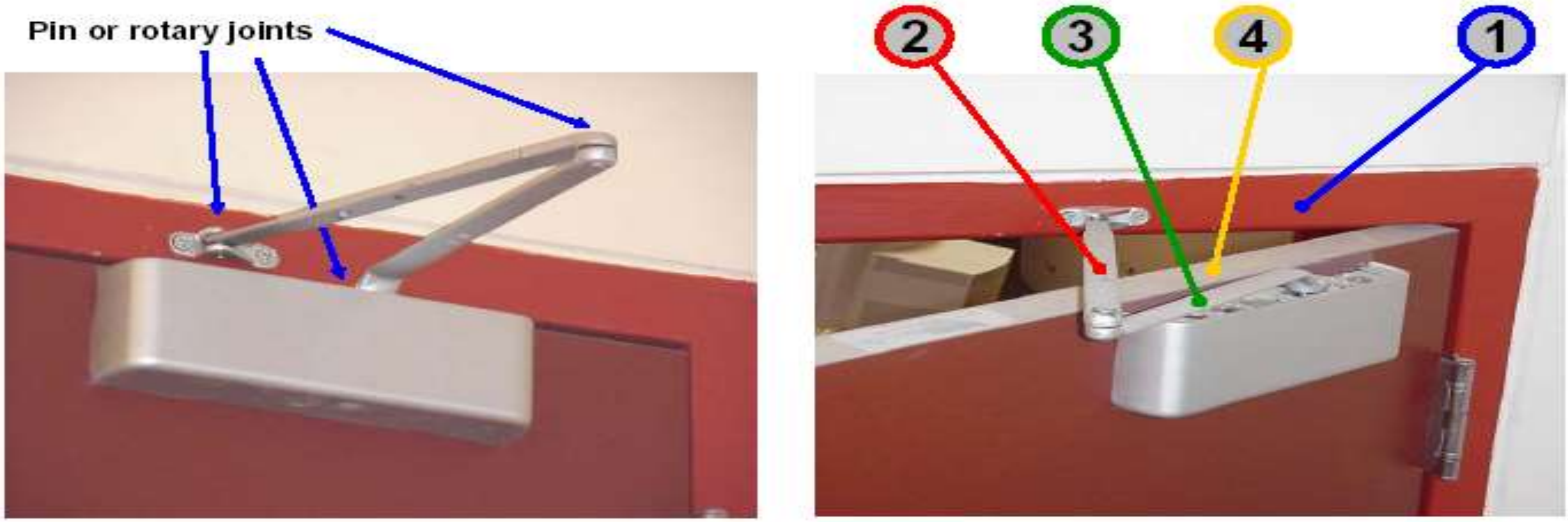
Linkages are classified by:

- The number of links (we will deal with 4-bar linkages)
- Type of links (we will deal with bars and sliders)
- Connection between links (we will deal with pinned, spherical and sliding joints)



4 bar mechanism

Example: 4 bar door damper linkage



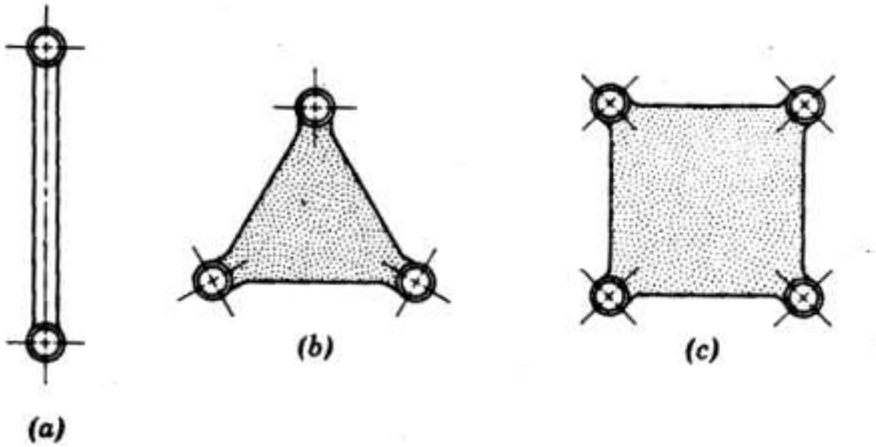
1	= Wall	or	Link 1	This is the grounded (held still)
2	= Bar 2	or	Link 2	
3	= Bar 3	or	Link 3	
4	= Door	or	Link 4	

LINK OR ELEMENT

Any body (normally rigid) which has motion relative to another .

Types of links:

1. Binary link
2. Ternary link
3. Quaternary link



KINEMATIC PAIRS

A mechanism has been defined as a combination so connected that each moves with respect to each other. A clue to the behavior lies in in the nature of connections, known as kinetic pairs.

The degree of freedom of a kinetic pair is given by the number independent coordinates required to completely specify the relative movement.

TYPES OF KINEMATIC PAIRS

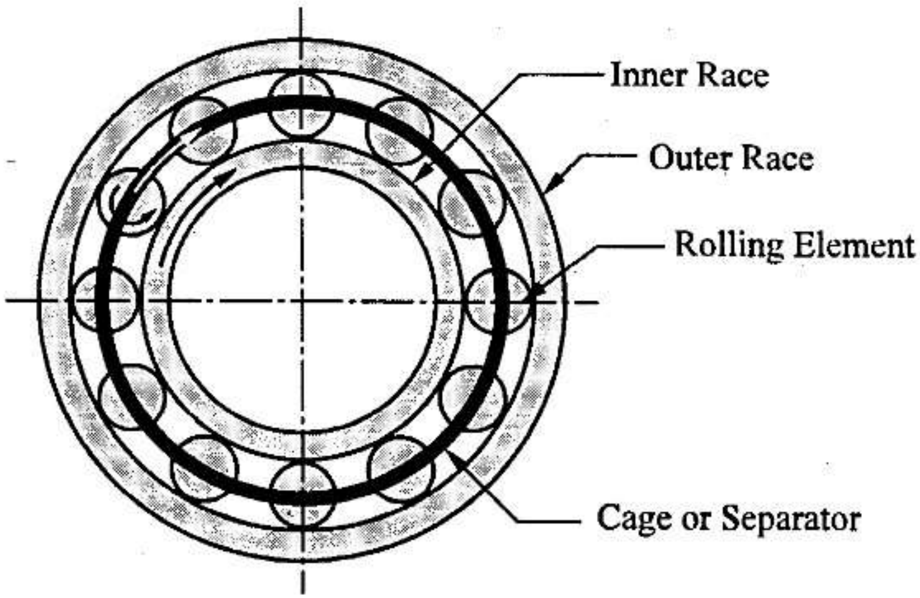
Based on nature of contact between elements

(i) **Lower pair** : The joint by which two members are connected has surface contact.

A pair is said to be a lower pair when the connection between two elements are through the area of contact. Its 6 types are

TYPES OF KINEMATIC PAIRS

(ii) Higher pair: The contact between the pairing elements takes place at a point or along a line.

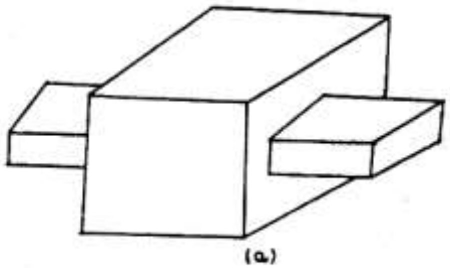


TYPES OF KINEMATIC PAIRS

Based on relative motion b

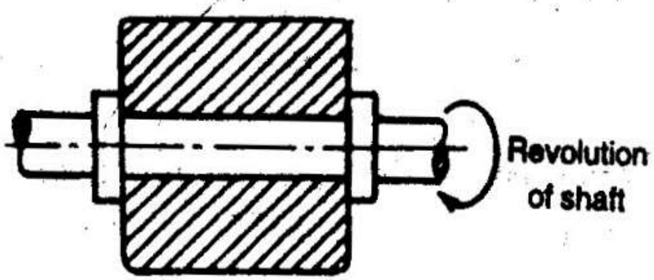
pairing elements

(a) Siding pair [DOF = 1]



(b) Turning pair (revolute pair

[DOF = 1]

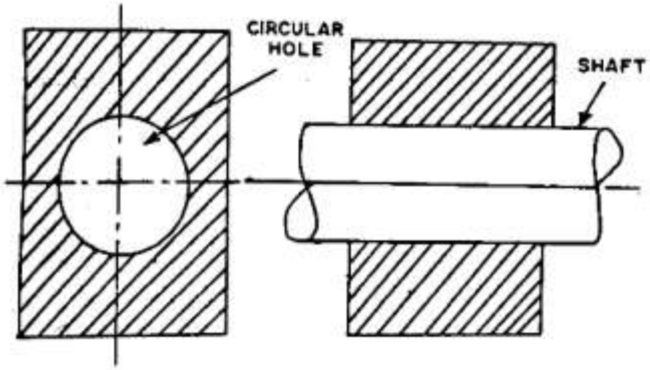


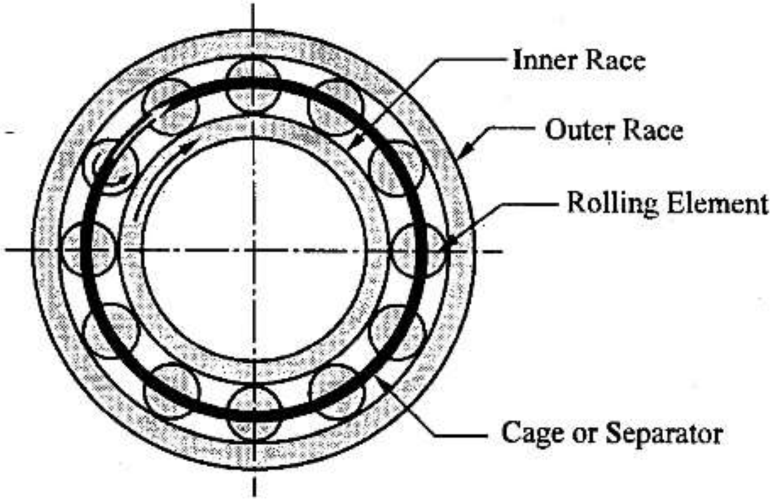
TYPES OF KINEMATIC PAIRS

Based on relative motion between pairing elements

(c) Cylindrical pair [DOF = 2]

(d) Rolling pair
[DOF = 1]



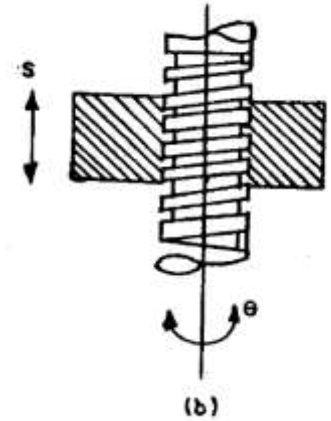


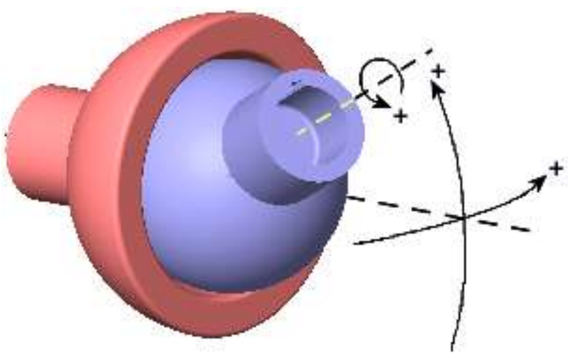
TYPES OF KINEMATIC PAIRS

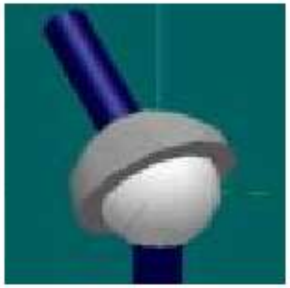
Based on relative motion between pairing elements

(e) Spherical pair [DOF = 3]

(f) Helical pair or screw pair [DOF = 1]





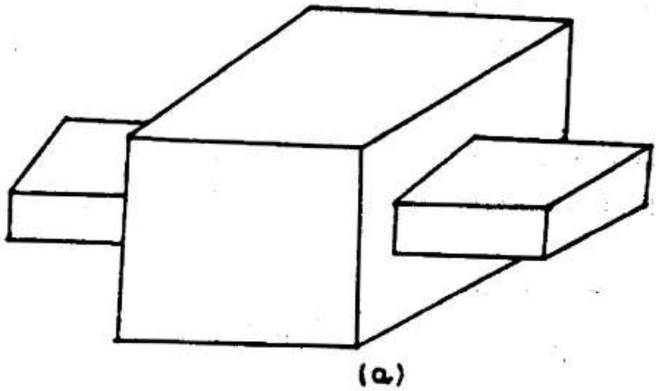


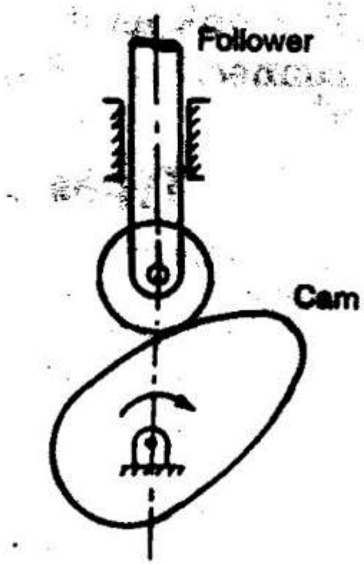
TYPES OF KINEMATIC PAIRS

Based on the nature of mechanical constraint

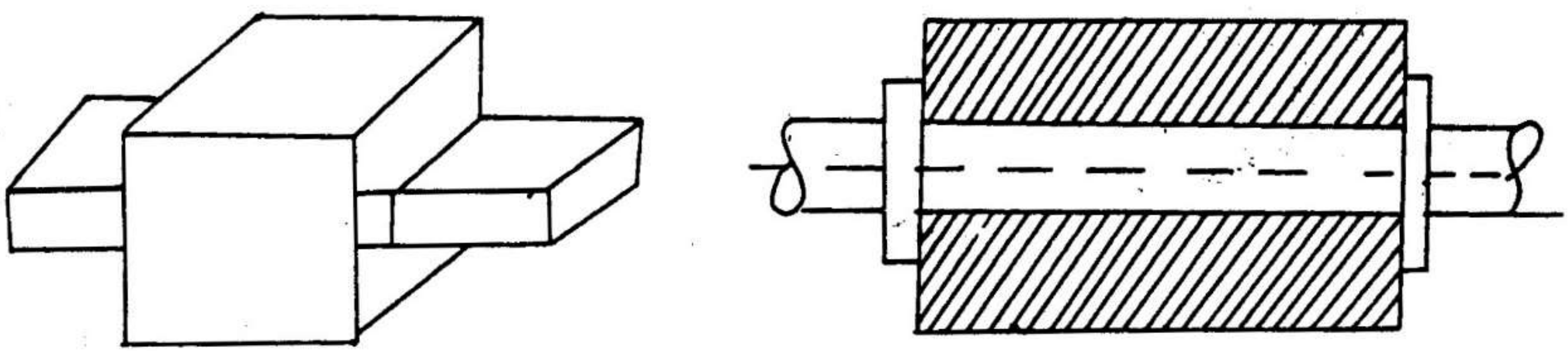
(a) Closed pair

(b) Unclosed or force closed pair



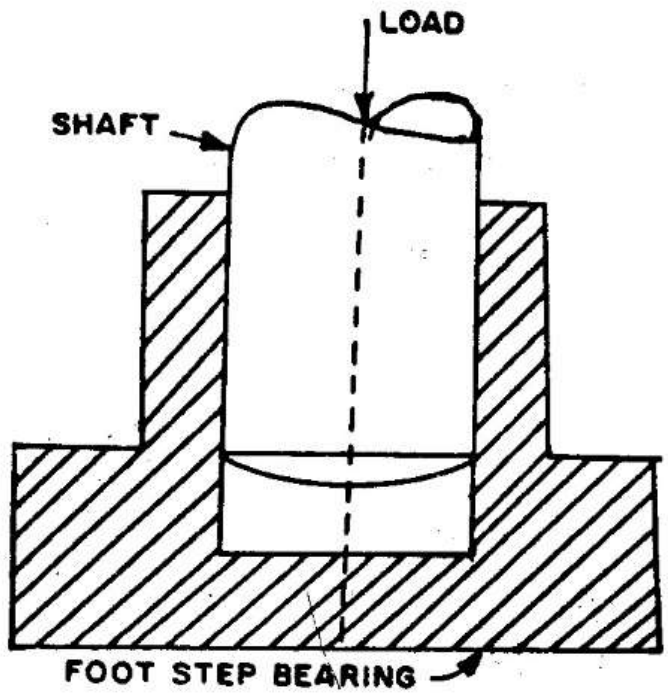


(a) Completely constrained motion



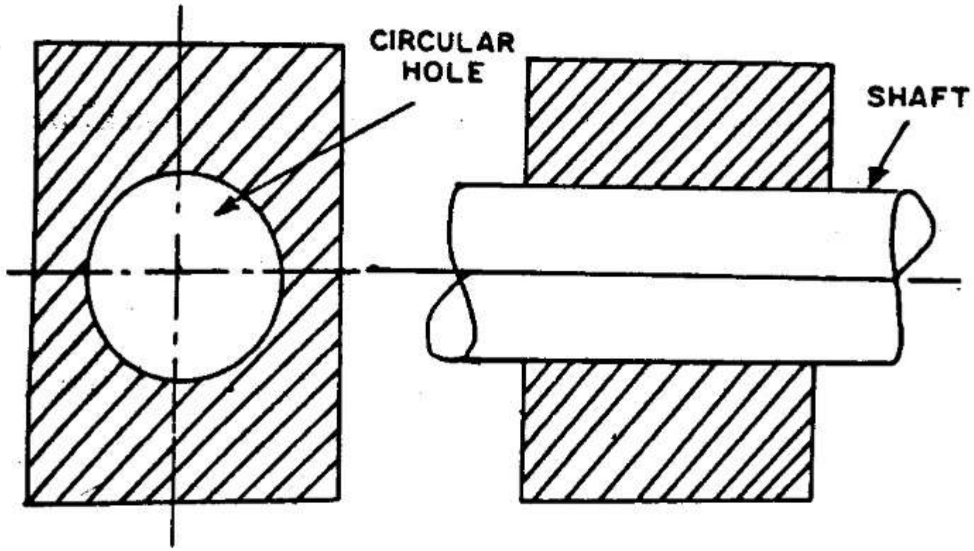
CONSTRAINED MOTION

(b) Successfully constrained motion



CONSTRAINED MOTION

(c) Incompletely constrained motion



KINEMATIC CHAIN

Group of links either joined together or arranged in a manner that permits them to move relative to one another

<u>Relation between Links, Pairs and Joints</u>

L=2P-4

J=(3/2) L – 2

L => No of Links

P => No of Pairs

J => No of Joints

L.H.S > R.H.S => Locked chain

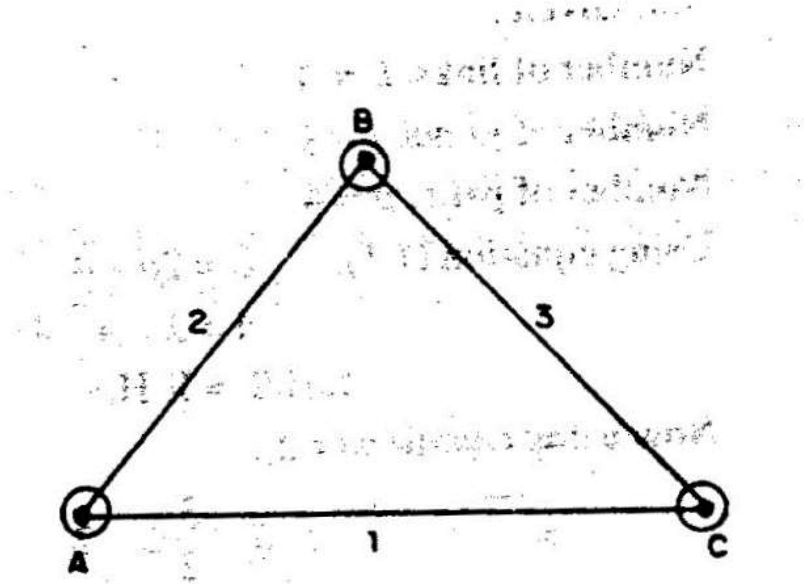
L.H.S = R.H.S => Constrained Kinematic Chain

L.H.S < R.H.S => Unconstrained Kinematic Chain

LOCKED CHAIN (Or) STRUCTURE

Links connected in such a way that no relative motion is possible.

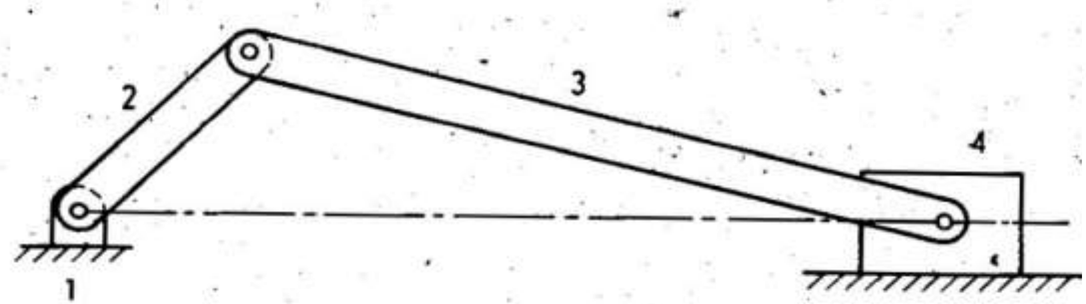
L=3, J=3, P=3 L.H.S>R.H.S

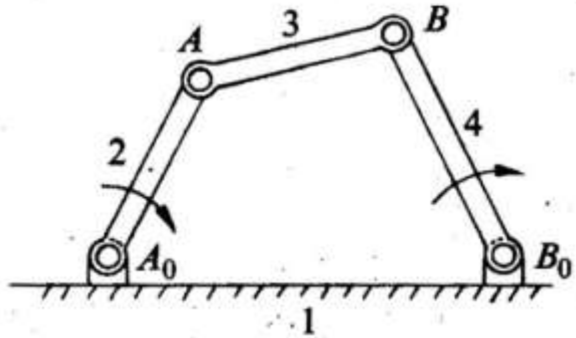


Kinematic Chain Mechanism

Slider crank and four bar mechanisms

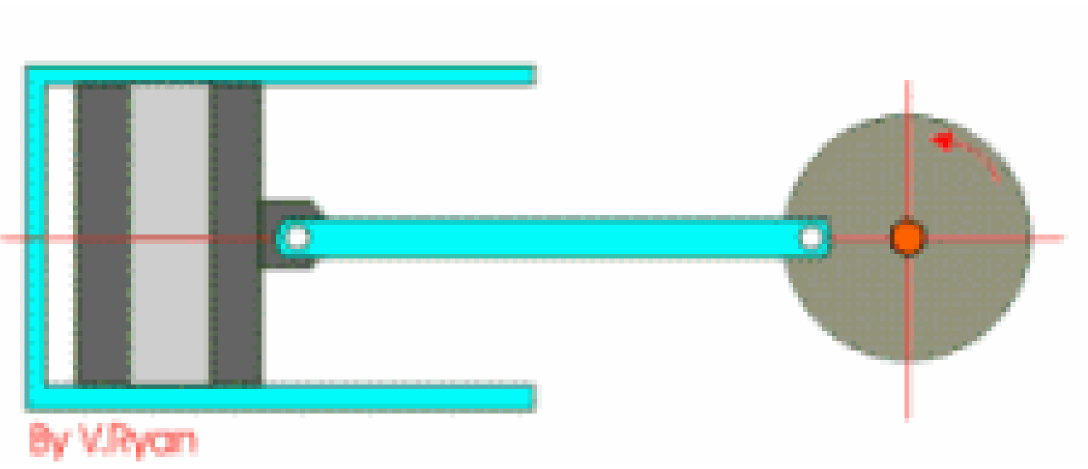
L=4, J=4, P=4 L.H.S=R.H.S





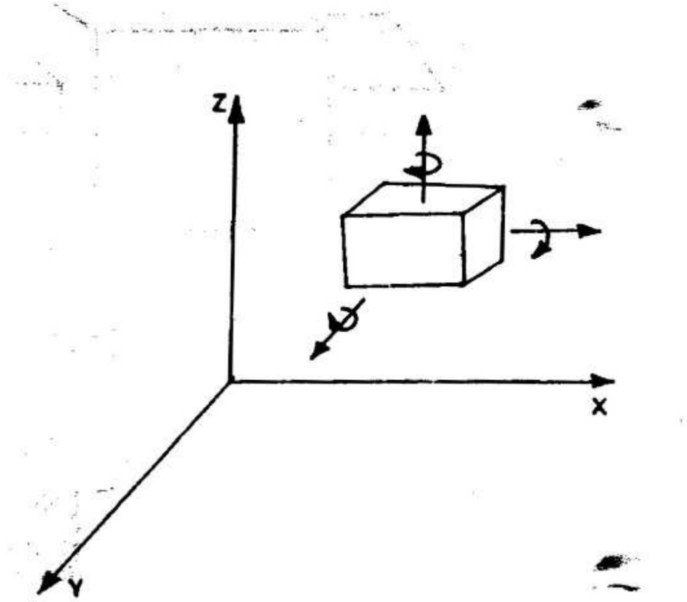
Slider crank mechanism

Working of slider crank mechanism



DEGREES OF FREEDOM (DOF):

It is the number of independent coordinates required to describe the position of a body



Degrees of freedom/mobility of a mechanism

It is the number of inputs (number of independent coordinates) required to describe the configuration or position of all the links of the mechanism, with respect to the fixed link at any given instant.

GRUBLER'S CRITERION

Number of degrees of freedom of a mechanism is given by

$$F = 3(n-1)-2l-h$$

Where,

F = Degrees of freedom

n = Number of links in the mechanism.

l = Number of lower pairs, which is obtained by counting the number of joints. If more than two links are joined together at any point, then, one additional lower pair is to be considered for every additional link.

h = Number of higher pairs

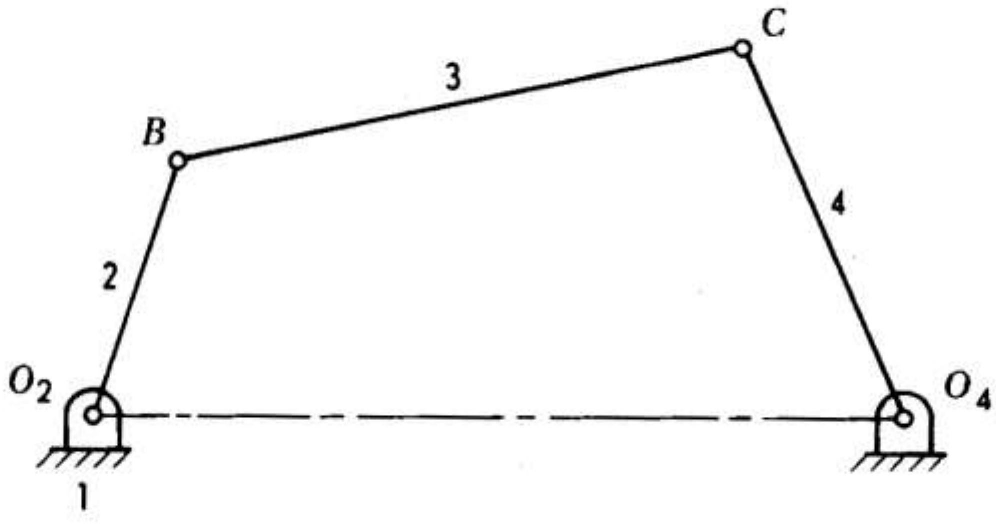
Examples - DOF

F = 3(n-1)-2l-h

Here, n = 4, l = 4 & h = 0.

F = 3(4-1)-2(4) = 1

i.e. one input to any one link will result in definite motion of all the links.



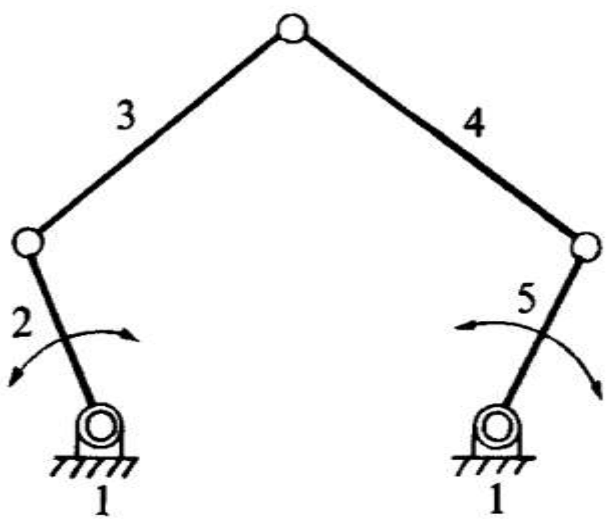
Examples - DOF

$F = 3(n-1)-2l-h$

Here, $n = 5$, $l = 5$ and $h = 0$.

$F = 3(5-1)-2(5) = 2$

I.e., two inputs to any two links are required to yield definite motions in all the links.



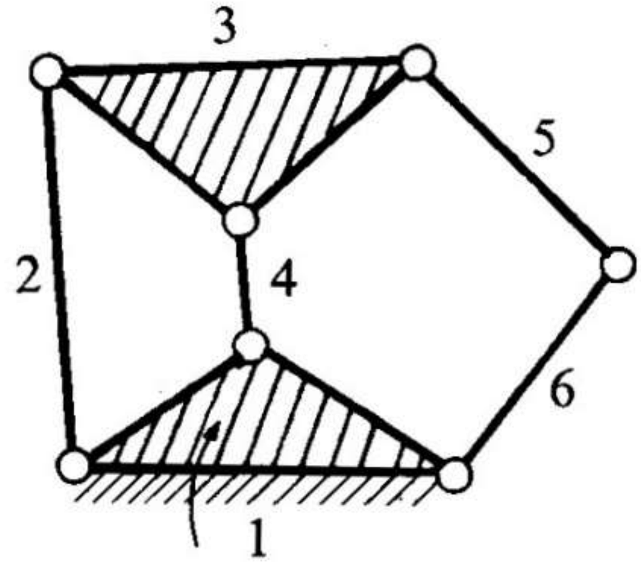
Examples - DOF

F = 3(n-1)-2l-h

Here, n = 6, l = 7 and h = 0.

F = 3(6-1)-2(7) = 1

I.e., one input to any one link will result in definite motion of all the links.

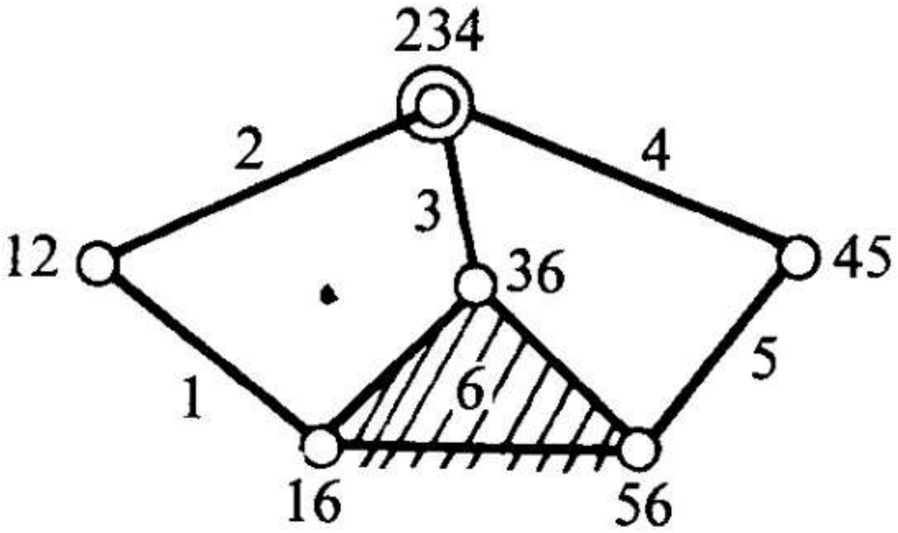


Examples - DOF

F = 3(n-1)-2l-h

Here, n = 6, l = 7 (at the intersection of 2, 3 and 4, two lower pairs are to be considered) and h = 0.

F = 3(6-1)-2(7) = 1

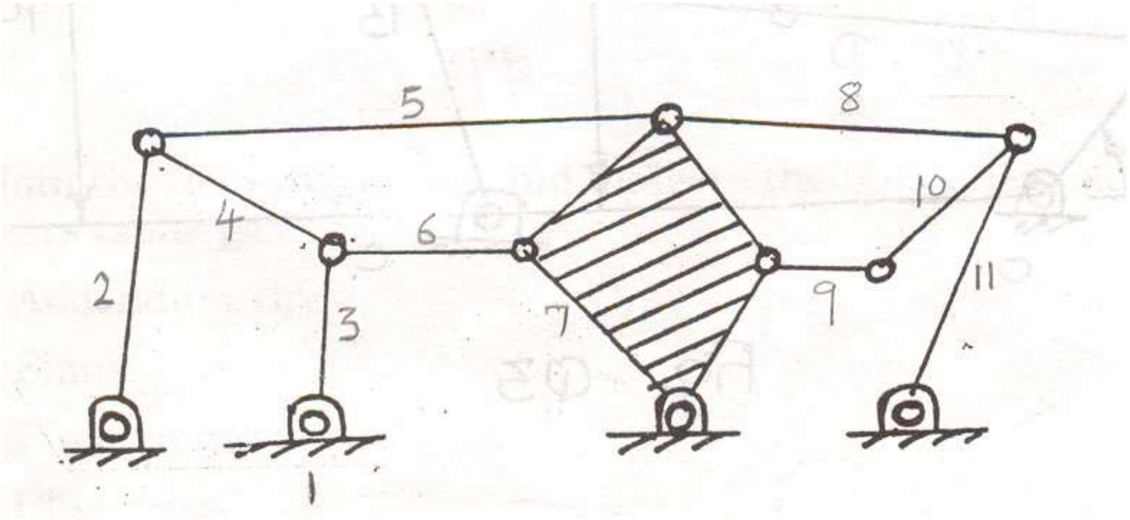


Examples - DOF

F = 3(n-1)-2l-h

Here, n = 11, l = 15 (two lower pairs at the intersection of 3, 4, 6; 2, 4, 5; 5, 7, 8; 8, 10, 11) and h = 0.

F = 3(11-1)-2(15) = 0

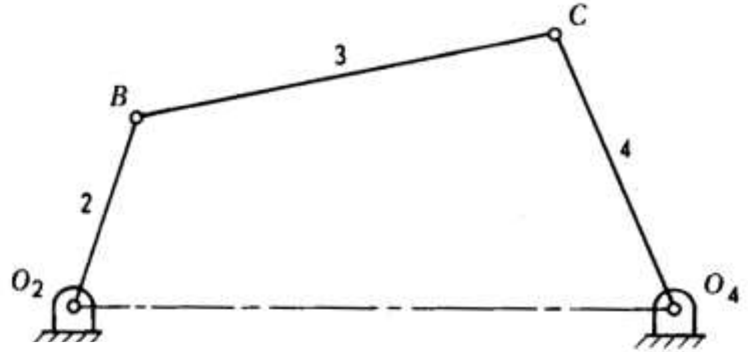


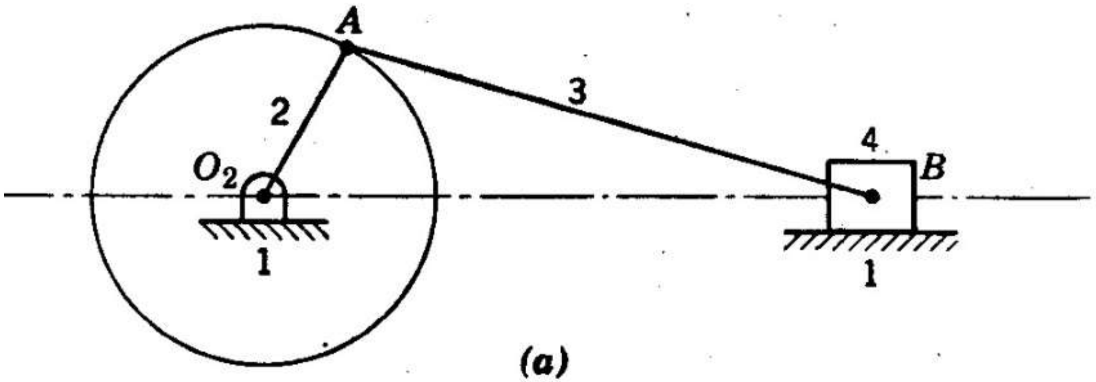
Grashoff Law

The sum of the shortest and longest link length should not exceed the sum of the other two link lengths.

s+l < p+q

(e.x) (1+2) < (3+4)





(a)

INVERSION OF MECHANISM

A mechanism is one in which one of the links of a kinematic chain is fixed. Different mechanisms can be obtained by fixing different links of the same kinematic chain. These are called as inversions of the mechanism.

INVERSION OF MECHANISM

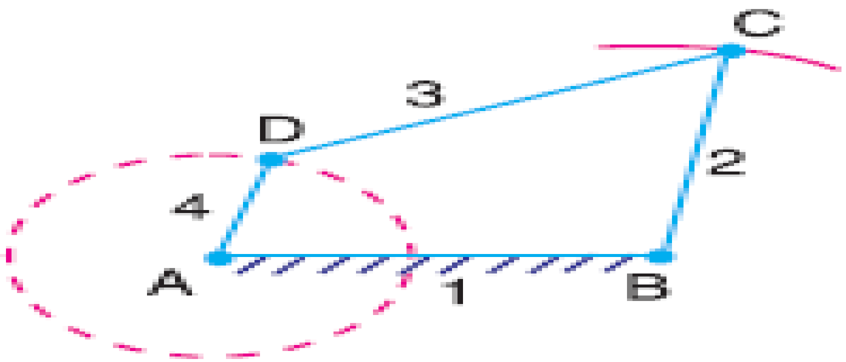
1.Four Bar Chain

2.Single Slider Crank

3.Double Slider Crank

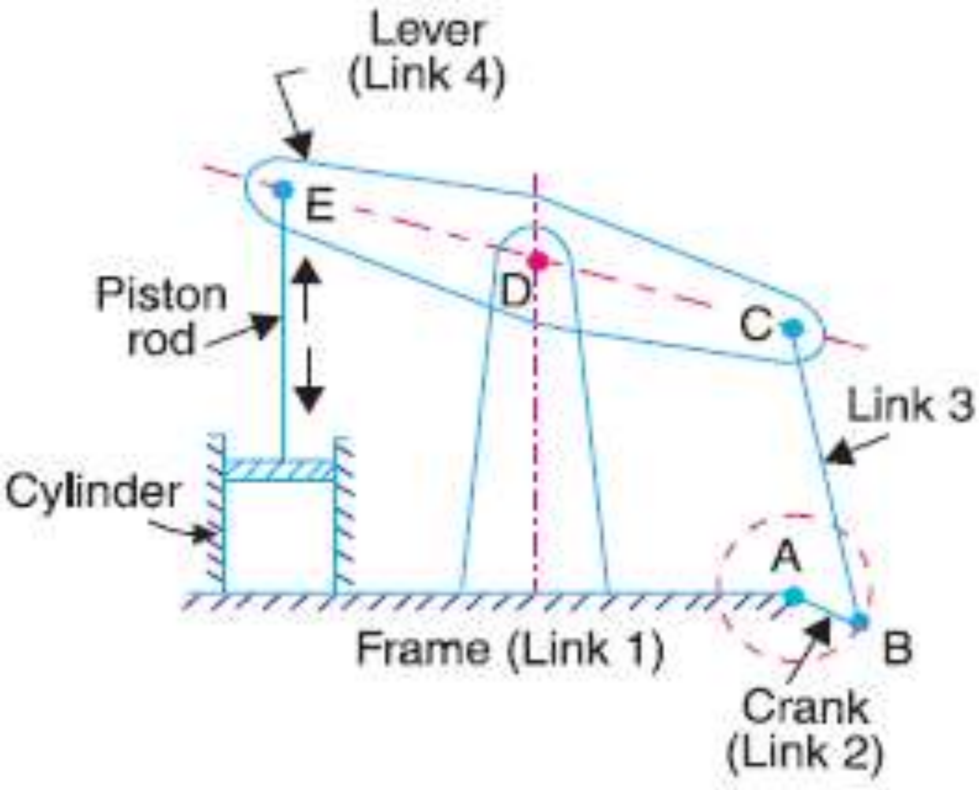
INVERSION OF MECHANISM

1.Four Bar Chain - Inversions

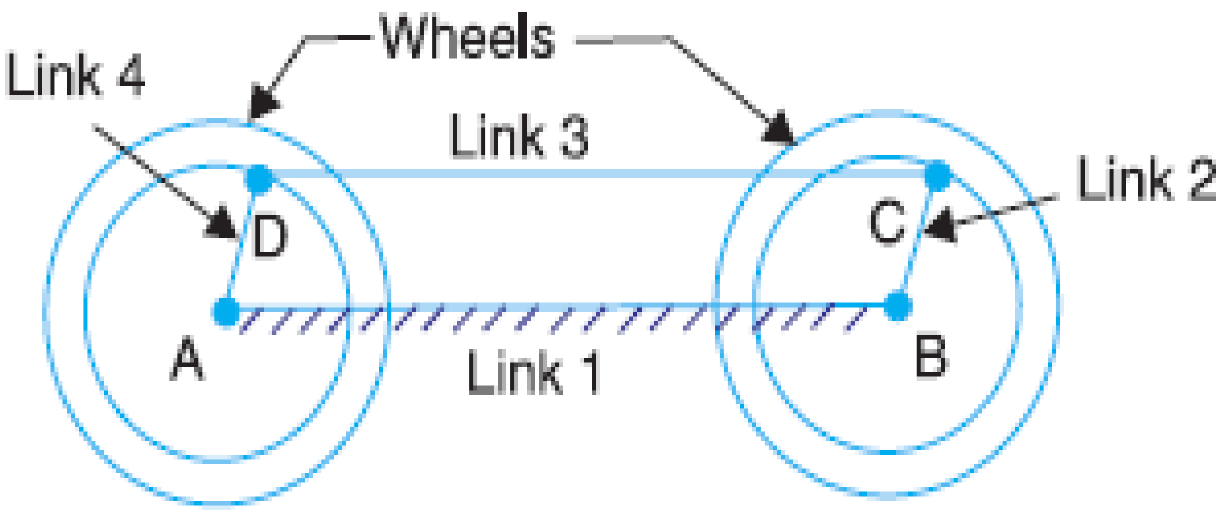


INVERSION OF MECHANISM

Beam Engine (crank &Lever)

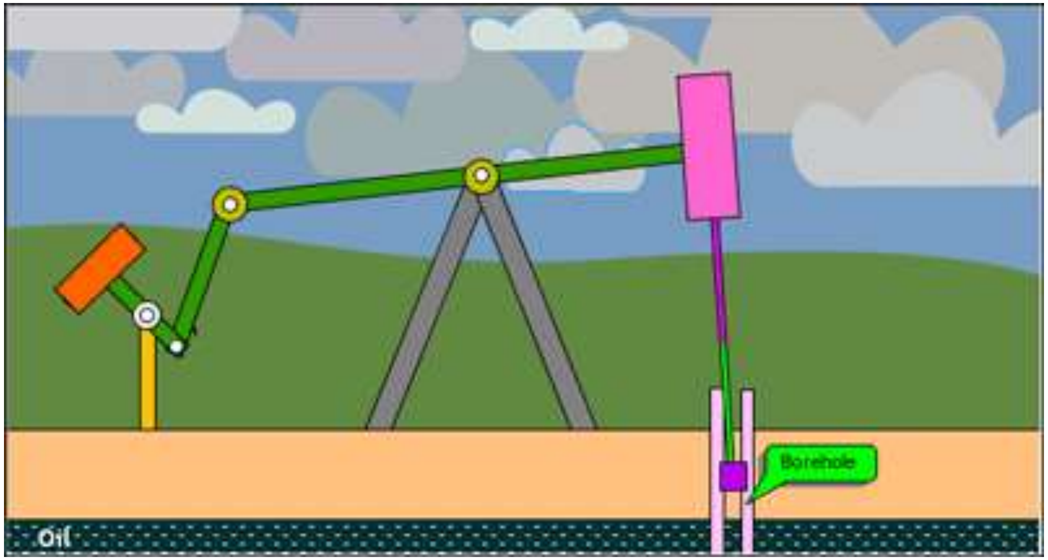


Double Crank mechanism



2.Single Slider Crank Inversions

Pendulum pump



INVERSION OF MECHANISM

2.OSCILLATING CYLINDER

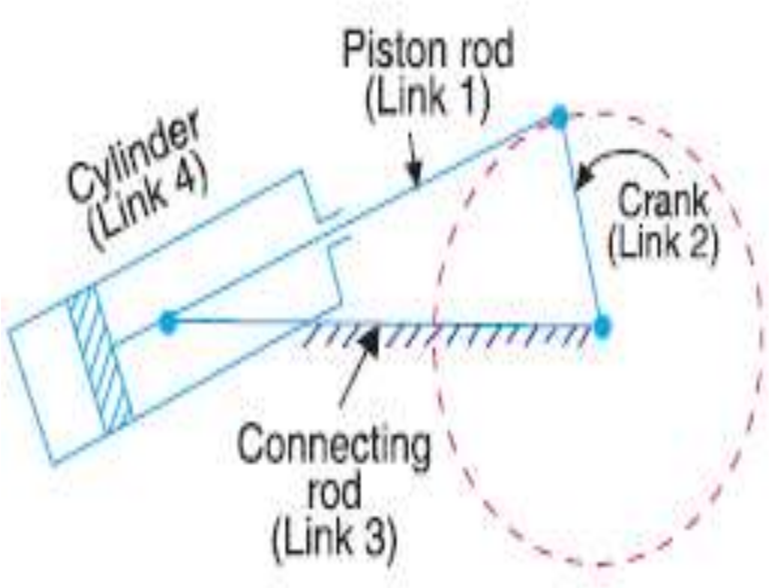


Fig. 5.24. Oscillating cylinder engine.

INVERSION OF MECHANISM

3.ROTARY IC ENGINE

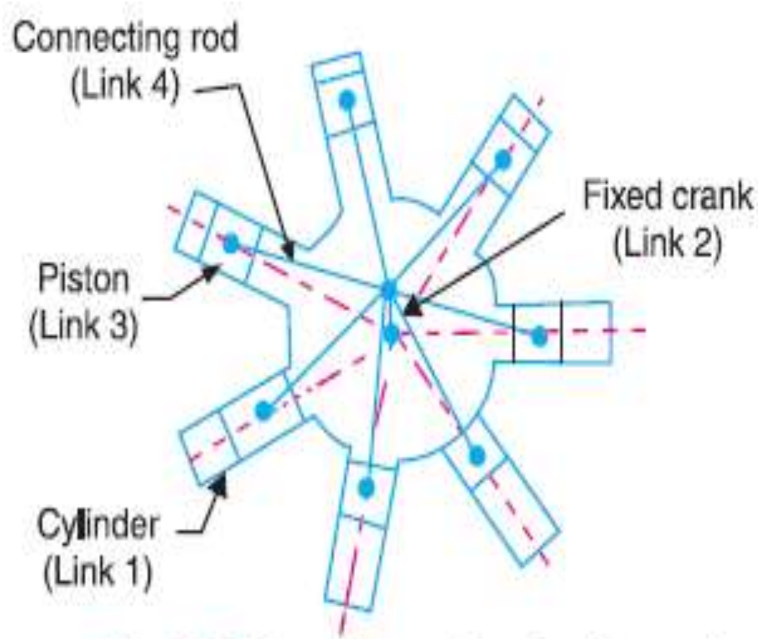
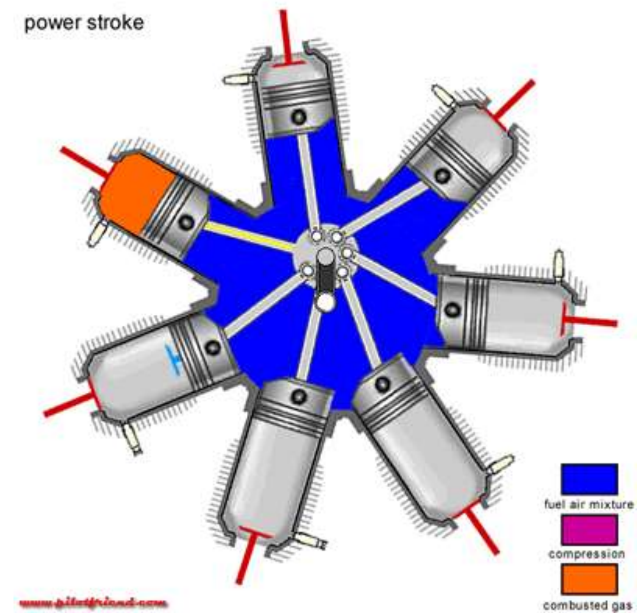
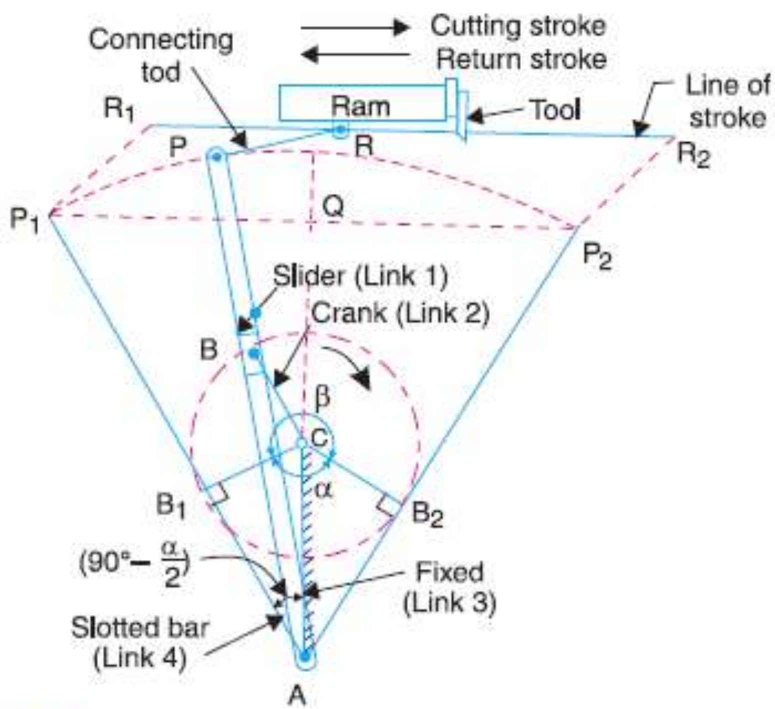


Fig. 5.25. Rotary internal combustion engine.



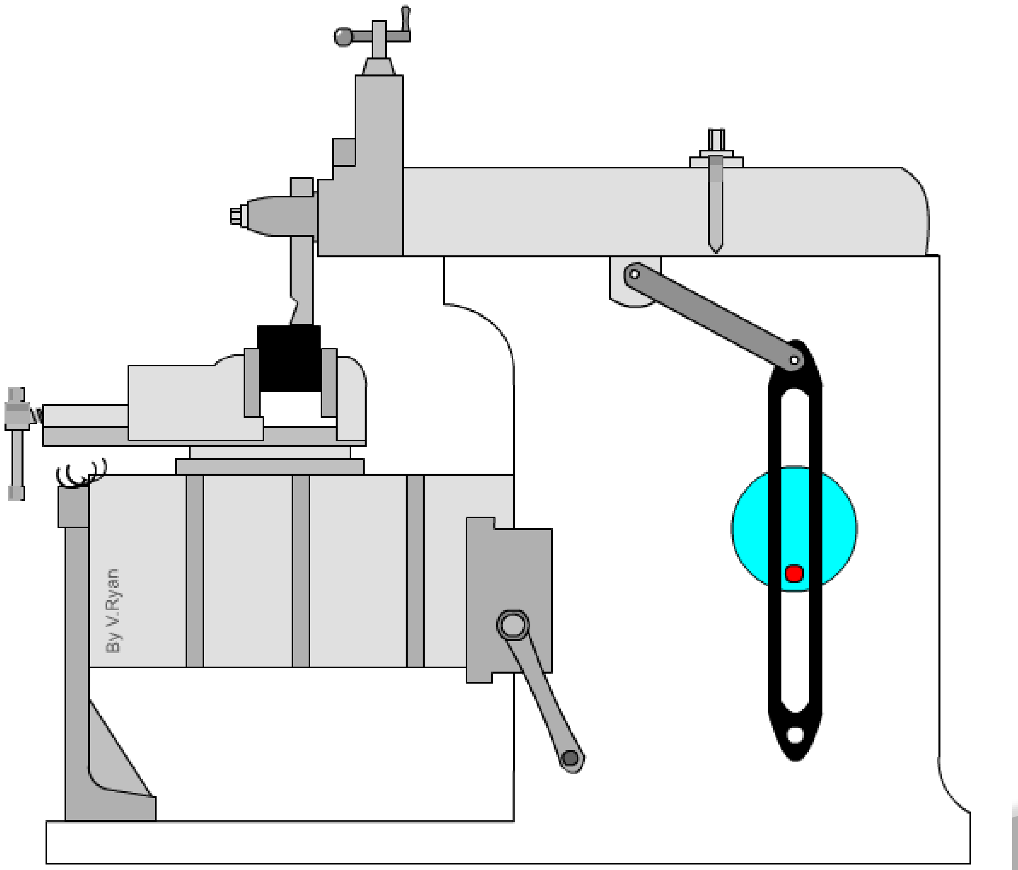
4.Crank and Slotted Lever Mechanism (Quick-Return Motion Mechanism)



ig. 5.26. Crank and slotted lever quick return motion mechanism.

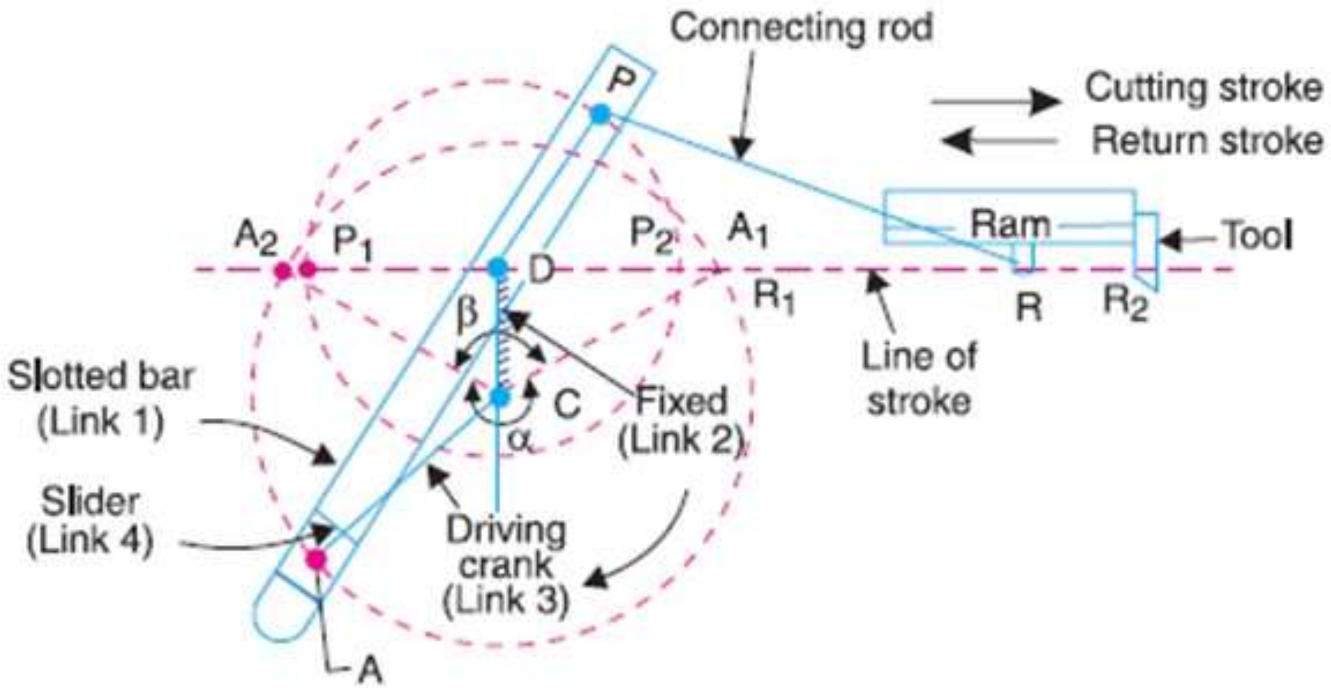
INVERSION OF MECHANISM

Quick-Return In Shaper M/C

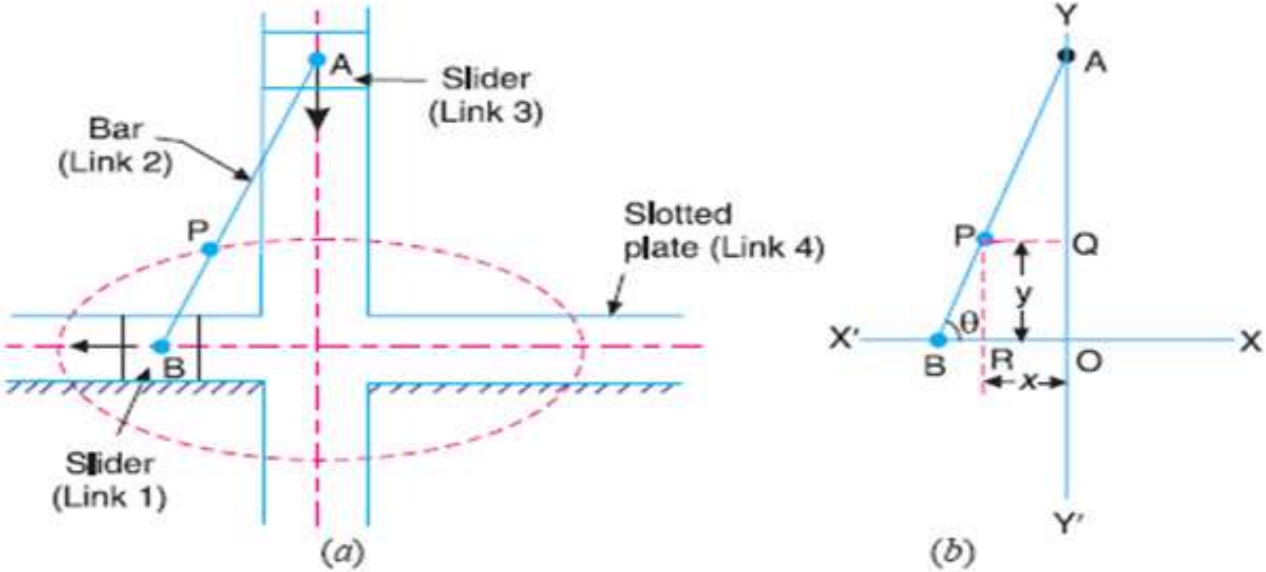


INVERSION OF MECHANISM

Whit worth quick-return mechanism

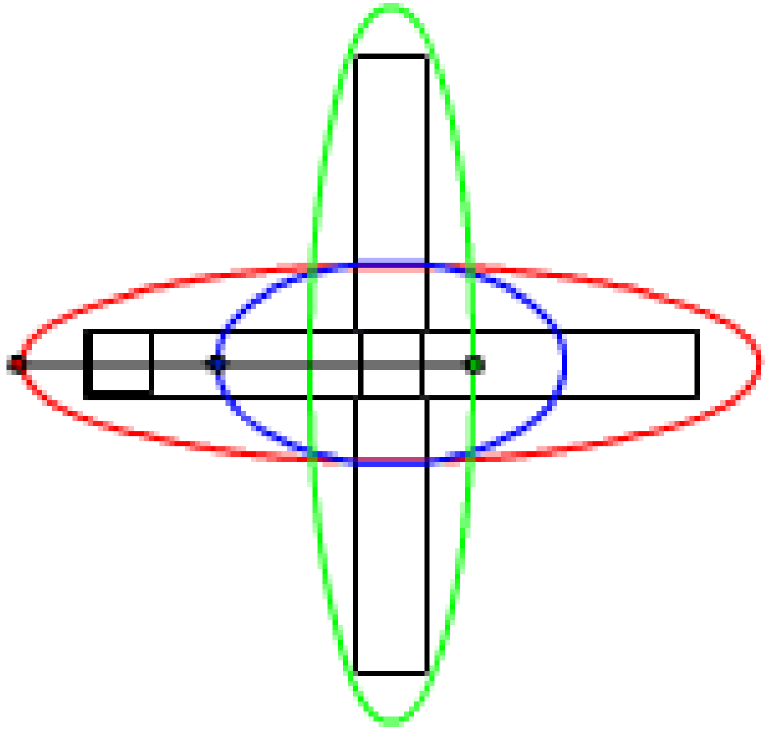


3.Double Slider Crank
Inversions



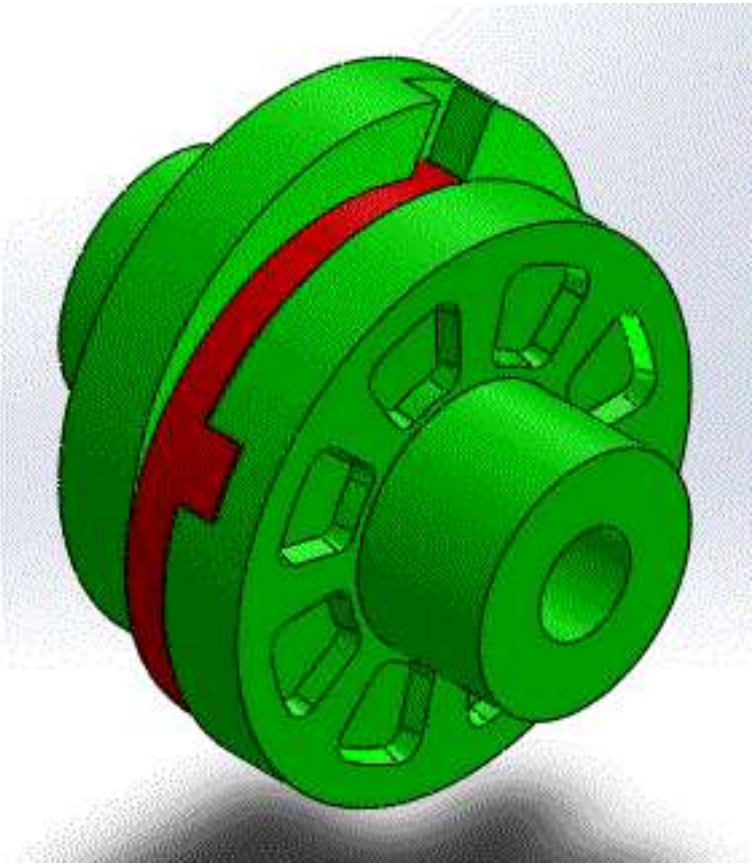
INVERSION OF MECHANISM

Elliptical trammel



INVERSION OF MECHANISM

Old hams coupling



UNIT - II
KINEMATIC ANALYSIS OF MECHANISMS

Course Learning Outcomes

CLOs	Course Learning Outcome
CLO5	Construct Graphical methods of velocity polygon and acceleration polygons for a given configuration diagram.
CLO6	Understand other methods of acceleration diagrams like Klien’s construction.
CLO7	Develop secondary acceleration component i.e. Correli’s component involving quick return mechanisms
CLO8	Alternative approach for determining velocity by using I centers and centroids methods.

Introduction

- Definition of acceleration
- Acceleration analysis using relative acceleration equations for points on same link
- Acceleration on points on same link Graphical acceleration analysis
- Algebraic acceleration analysis
- General approach for acceleration analysis
- Coriolis acceleration
- Application
- Rolling acceleration

Acceleration

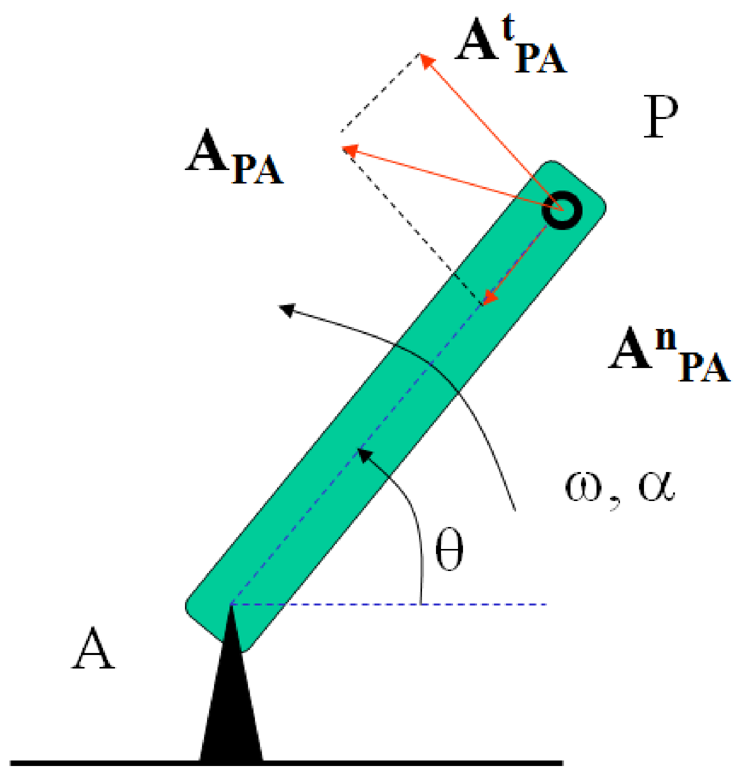
Definition of acceleration :

Angular = α= rate of change in angular velocity

Linear = **A** = rate of change in linear velocity

(Note: a vector will be denoted by either a bold character or using an arrow above the character)

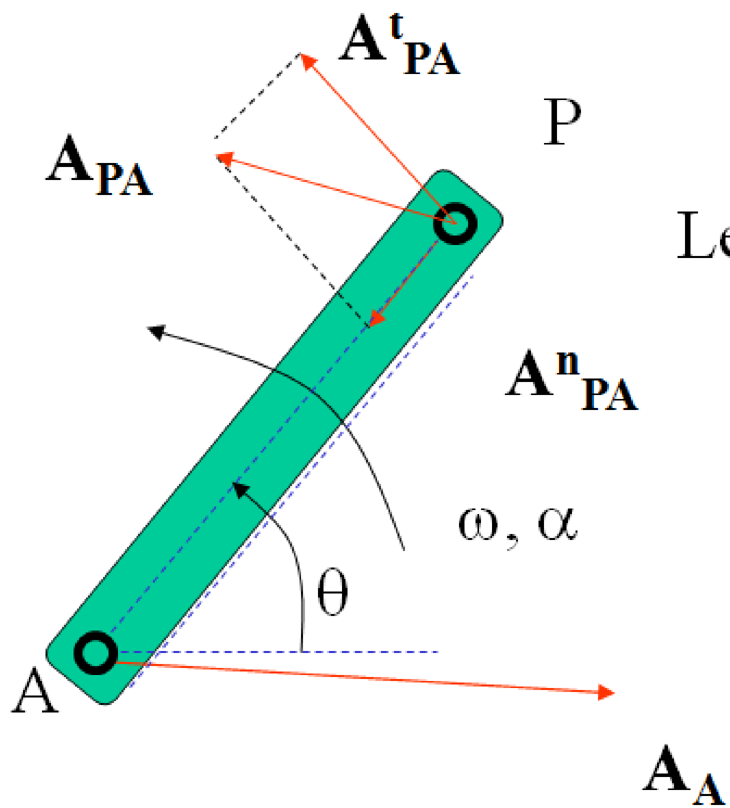
Acceleration of link in pure rotation



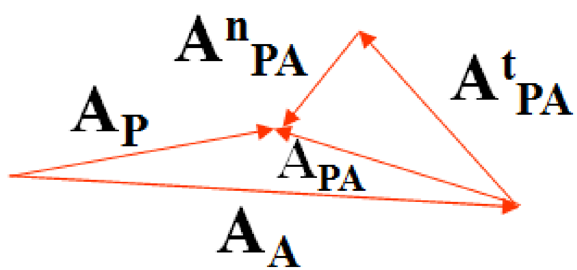
Length of link: p

Magnitude of tangential component = $p\alpha$,
magnitude of normal component = $p\,\omega^2$

Acceleration of link, general case



Length of link: p



$$A_P = A_A + A_{PA}$$

Acceleration of link

Problem definition: given the positions of the links, their angular velocities and the acceleration of the input link (link 2), find the linear accelerations of A and B and the angular accelerations of links 2 and 3.

Solution:

Find velocity of A

Solve graphically equation:

$$\vec{A}_B = \vec{A}_A + \vec{A}_{BA} \quad \Leftrightarrow$$

$$\vec{A}_B^t + \vec{A}_B^n = \vec{A}_A + \vec{A}_{BA}^t + \vec{A}_{BA}^n$$

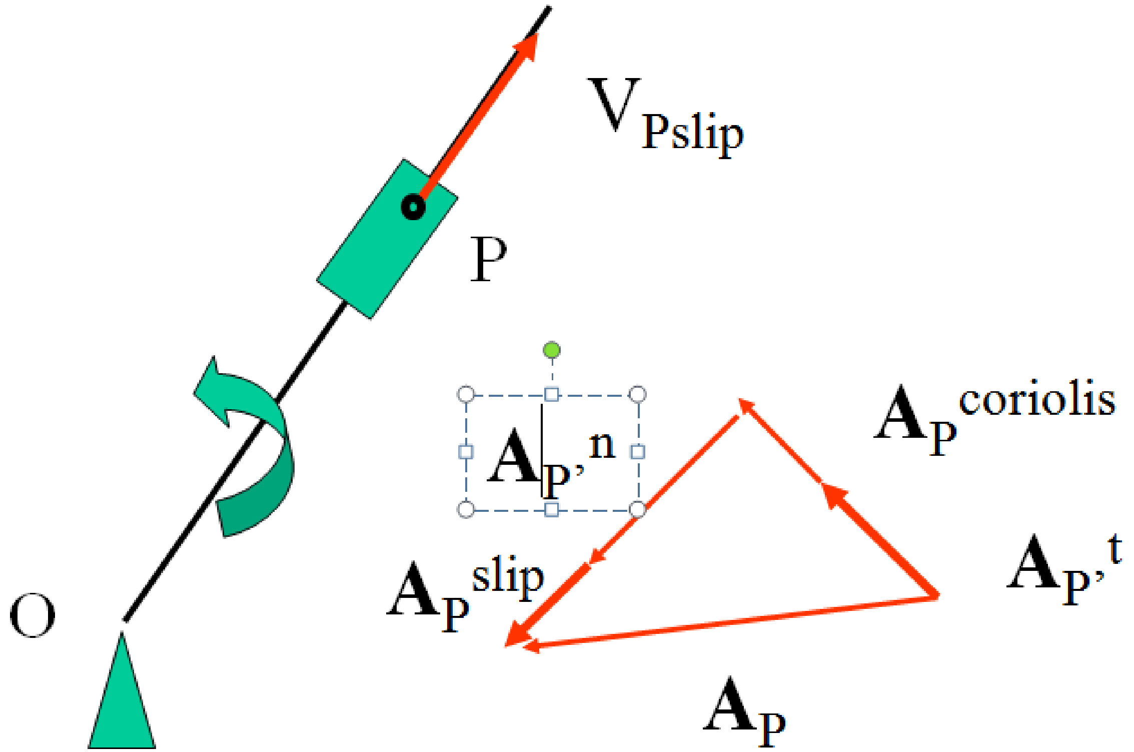
Find the angular accelerations of links 3 and 4

Coriolis acceleration

Whenever a point is moving on a path and the path is rotating, there is an extra component of the acceleration due to coupling between the motion of the point on the path and the rotation of the path. This component is called Coriolis acceleration.

Coriolis acceleration

A_P^{slip}: acceleration of P as seen by observer moving with rod



Coriolis acceleration

Coriolis acceleration is normal to the radius, OP, and it points towards the left of an observer moving with the slider if rotation is counterclockwise. If the rotation is clockwise it points to the right.

To find the acceleration of a point, P, moving on a rotating path: Consider a point, P', that is fixed on the path and coincides with P at a particular instant. Find the acceleration of P', and add the slip acceleration of P and the Coriolis acceleration of P.

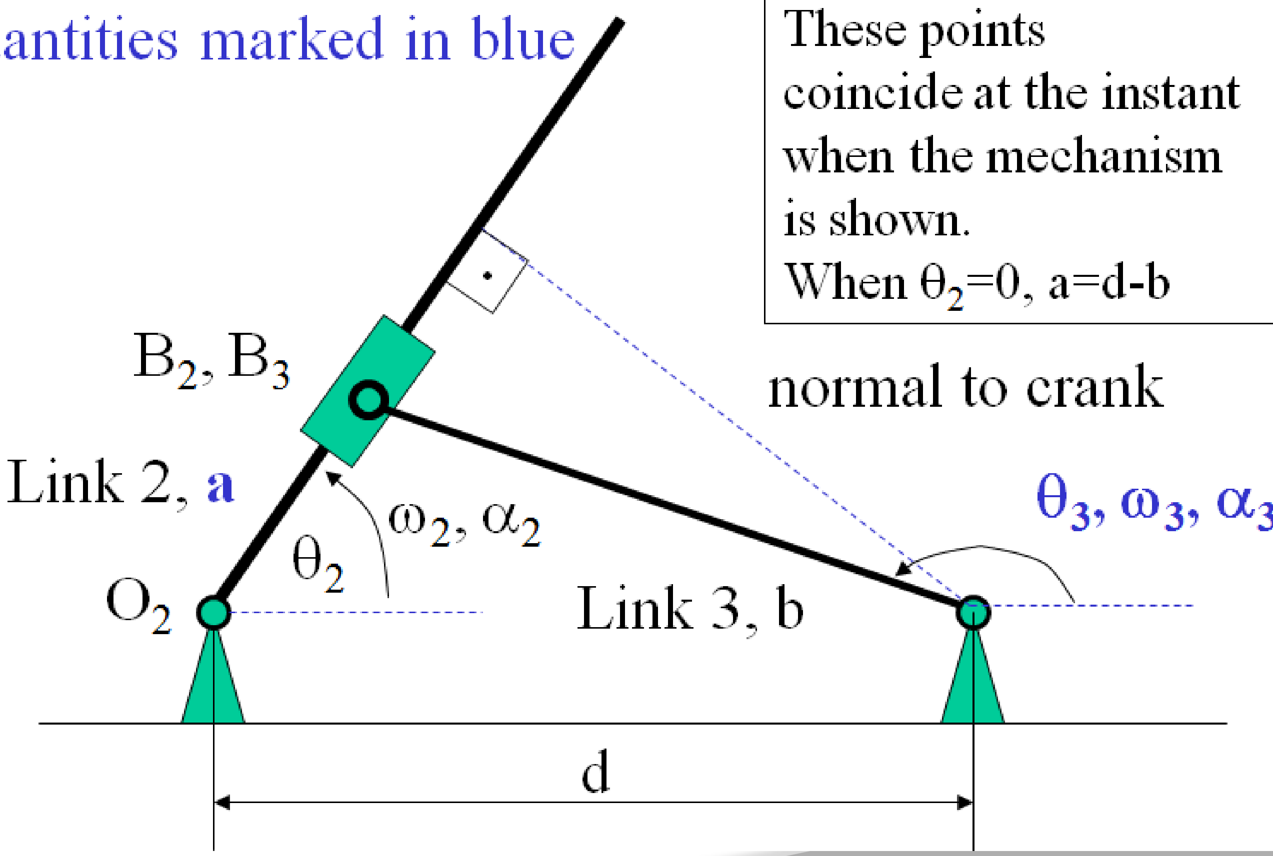
Coriolis acceleration=$2 \cdot \omega \cdot V_{slip}$

$\mathbf{A}_P$=acceleration of P'+acceleration of P seen from observer moving with rod+Coriolis acceleration=$\mathbf{A}_{P'}+\mathbf{A}_P^{slip}+\mathbf{A}_P^{Coriolis}$

Application: crank-slider mechanism

Unknown quantities marked in blue

B2 on link 2
B3 on link 3
These points coincide at the instant when the mechanism is shown.
When $\theta_2=0$, a=d-b



General approach for kinematic analysis

- Represent links with vectors. Use complex numbers. Write loop equation.
- Solve equation for position analysis
- Differentiate loop equation once and solve it for velocity analysis
- Differentiate loop equation again and solve it for acceleration analysis

Position analysis

$$a = d\cos\theta_2 - \sqrt{b^2 - d^2\sin^2\theta_2}$$

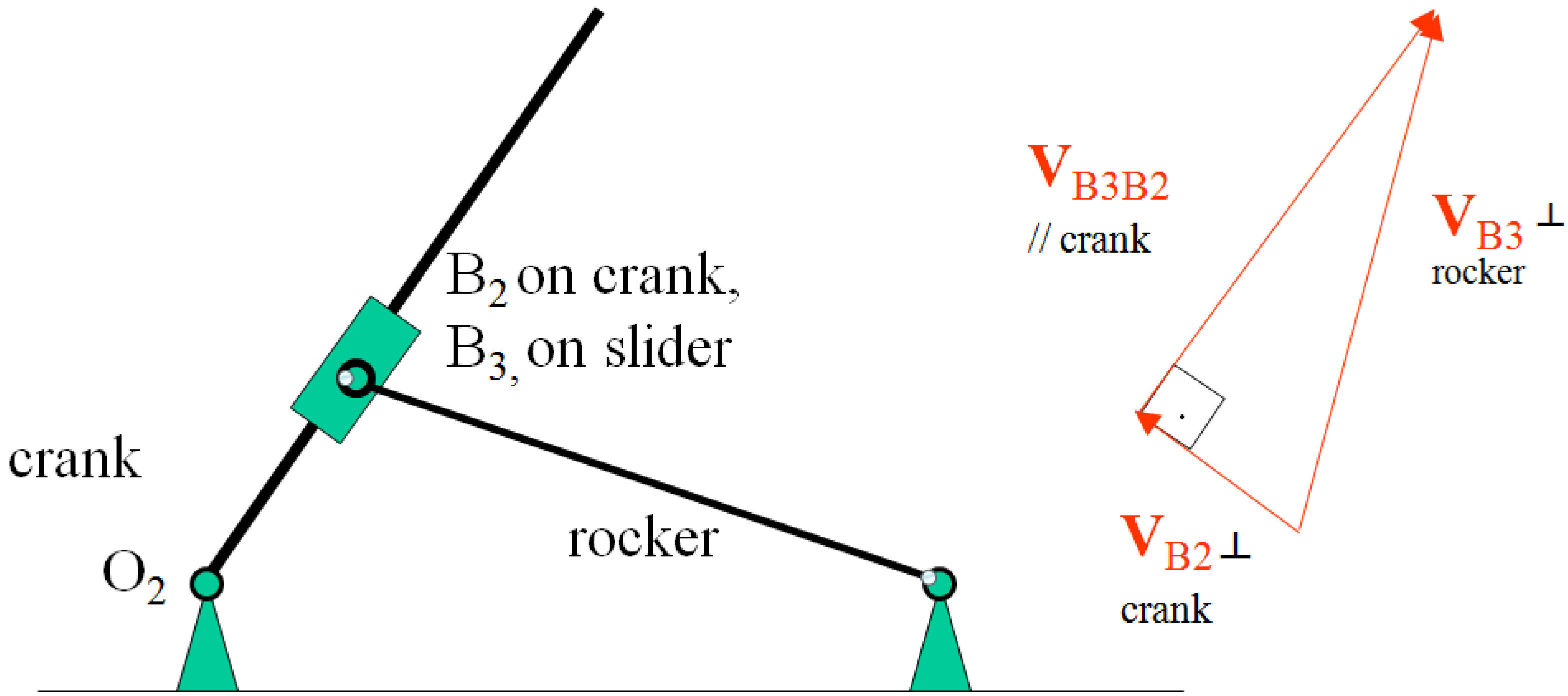
$$\theta_3 = \sin^{-1}\left(\frac{a}{b}\sin\theta_2\right)$$

Make sure you consider the correct

quadrant for θ_3

Velocity analysis

$$V_{B3} = V_{B2} + V_{B3B2}$$



Velocity analysis

$$\omega_3 = \frac{a\omega_2}{b} \frac{1}{\cos(\theta_2 - \theta_3)}$$

$$\dot{a} = -a\omega_2 \frac{\sin(\theta_3 - \theta_2)}{\cos(\theta_3 - \theta_2)}$$

$\dot{a}$ is the relative velocity of B_3 w.r.t. B_2

Acceleration analysis

$$\ddot{a} = \frac{B\cos\theta_3 + C\sin\theta_3}{\cos(\theta_2 - \theta_3)}$$

$$\alpha_3 = \frac{C\cos\theta_2 - B\sin\theta_2}{-b\cos(\theta_2 - \theta_3)}$$

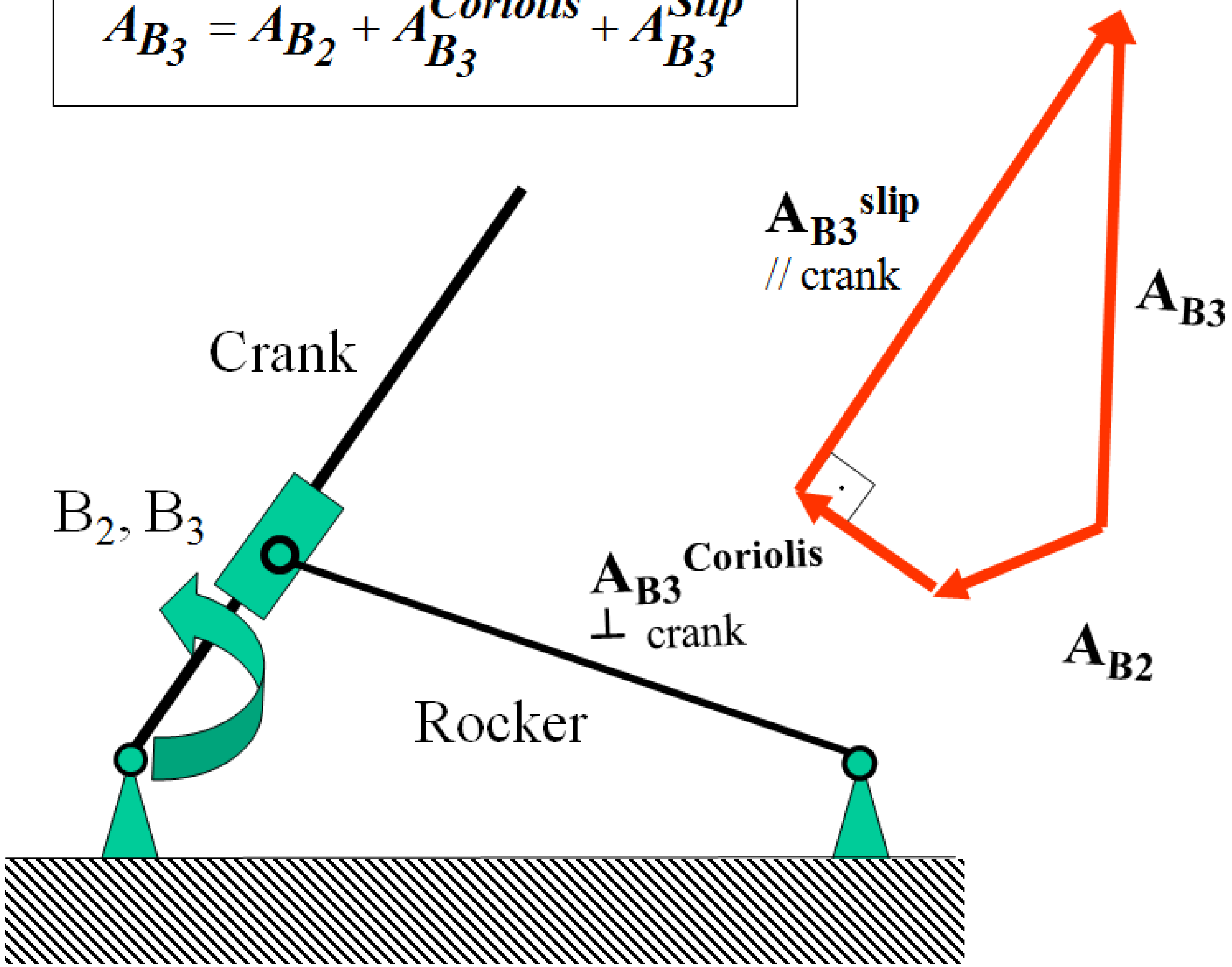
Where:

$$B = 2\dot{a}\omega_2 \sin\theta_2 + a\alpha_2 \sin\theta_2 + a\omega_2^2 \cos\theta_2 - \omega_3^2 b\cos\theta_3$$

$$C = -2\dot{a}\omega_2 \cos\theta_2 - a\alpha_2 \cos\theta_2 + a\omega_2^2 \sin\theta_2 - \omega_3^2 b\sin\theta_3$$

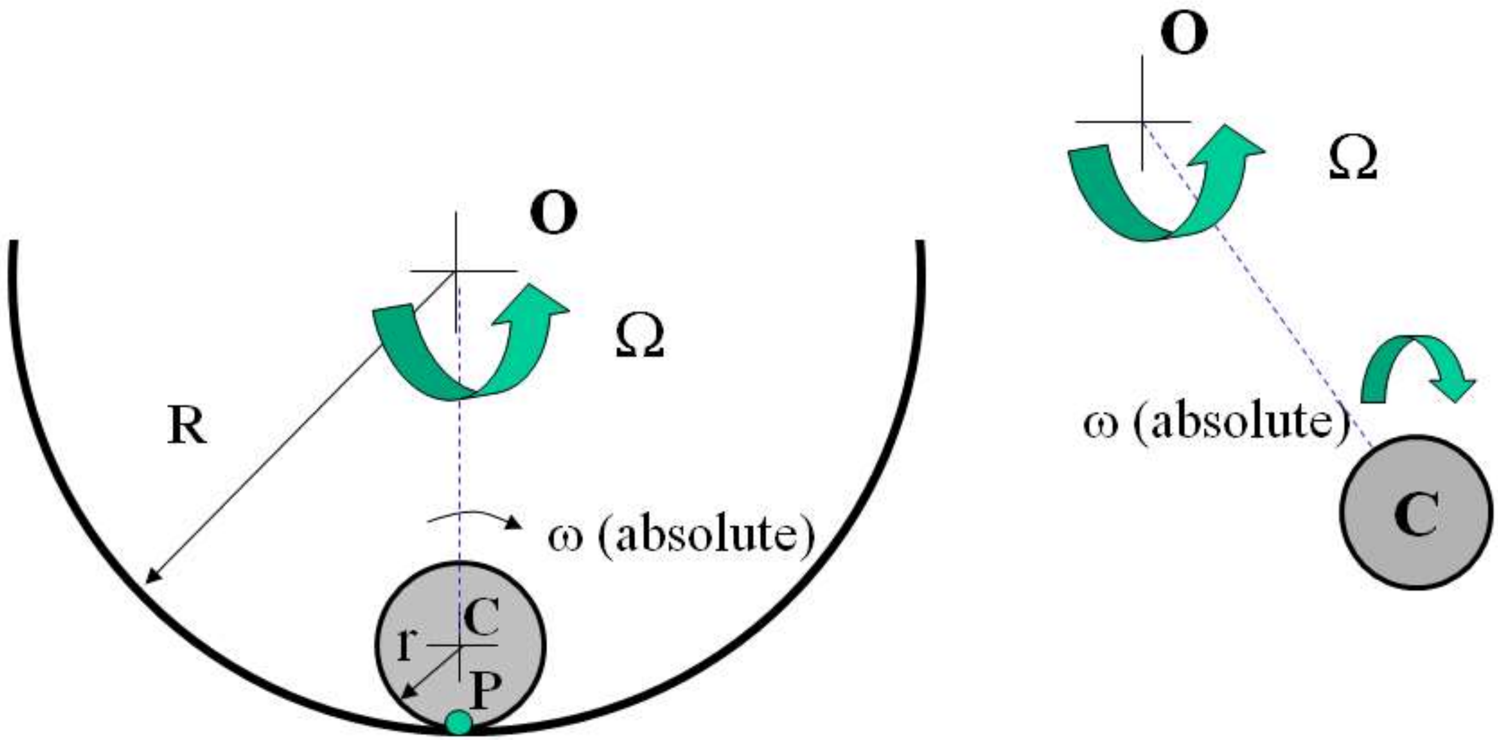
Relation between accelerations of B_2 (on crank) and B slider)

$$A_{B_3} = A_{B_2} + A_{B_3}^{Coriolis} + A_{B_3}^{Slip}$$



Rolling acceleration

First assume that angular acceleration, α, is zero



No slip condition: $V_P=0$

UNIT - III
PLANE MOTION OF BODY & GYROSCOPIC MOTION PRECESSION

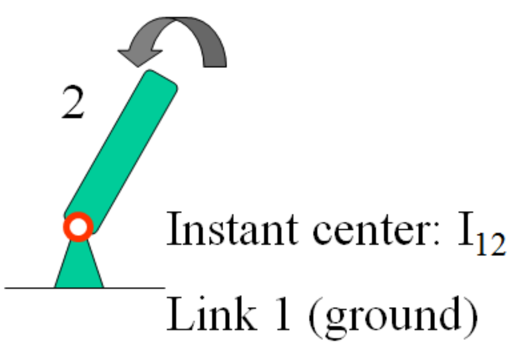
Course Learning Outcomes

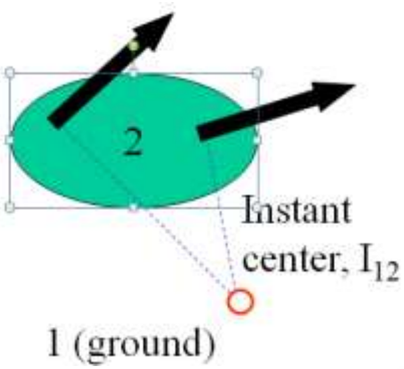
CLOs	Course Learning Outcome
CLO9	Significance of relative motion between two bodies, three centre's in line theorem
CLO10	Application of instantaneous centre, simple mechanisms and determination of angular velocity of points and links
CLO11	Applications of gyroscope, free and restrained, working principle, the free gyro, rate gyro, integrating gyro as motion measuring instruments
CLO12	The effect of precession on the stability of vehicles, Applications of motorbikes, automobiles, airplanes and ships

Introduction

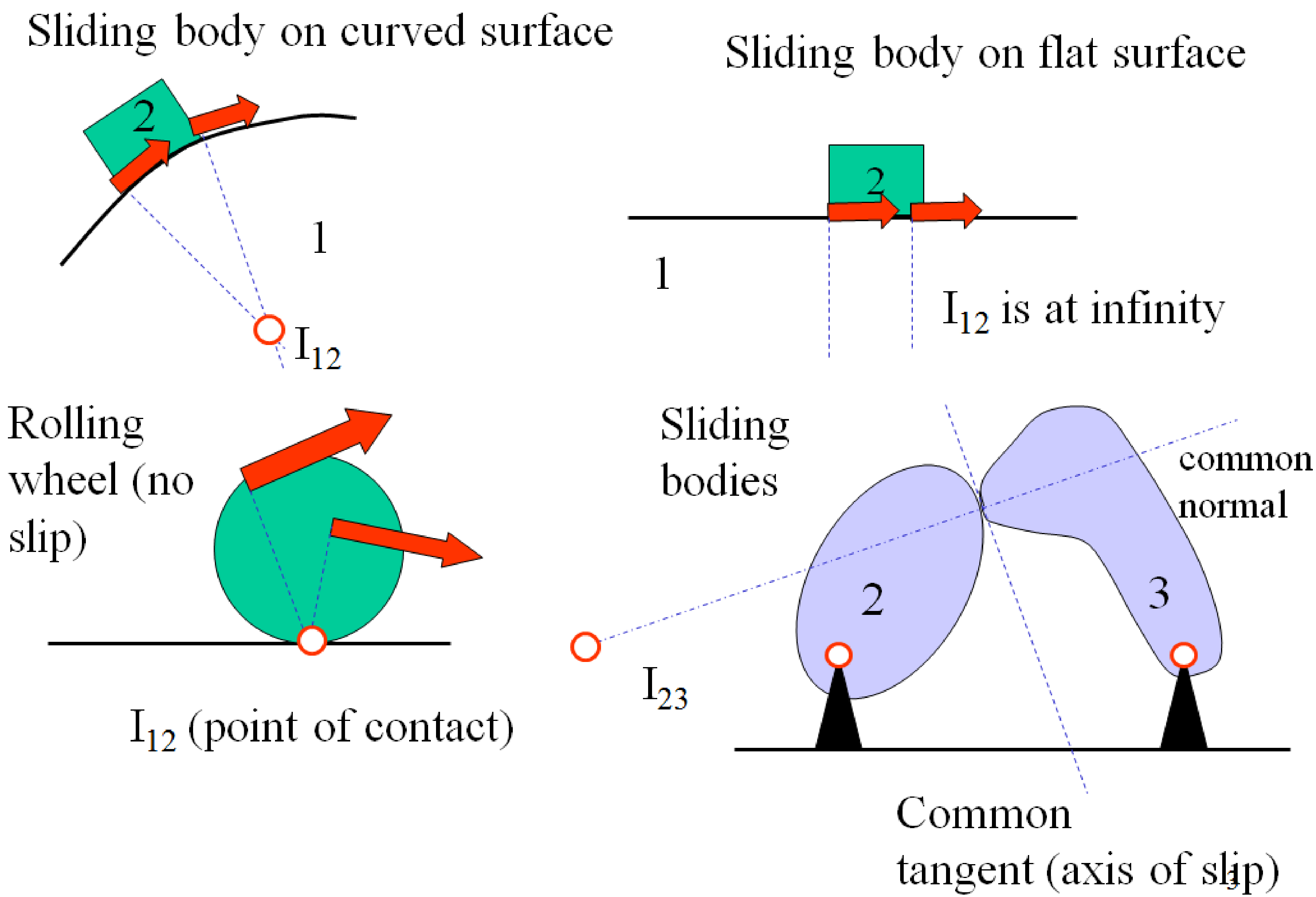
Instant center - point in the plane about which a link can
be thought to rotate relative to another link
(this link can be the ground)

An instant center is either (a) a pin point or a (b) two points
- - one for each body -- whose positions coincide
and have same velocities.

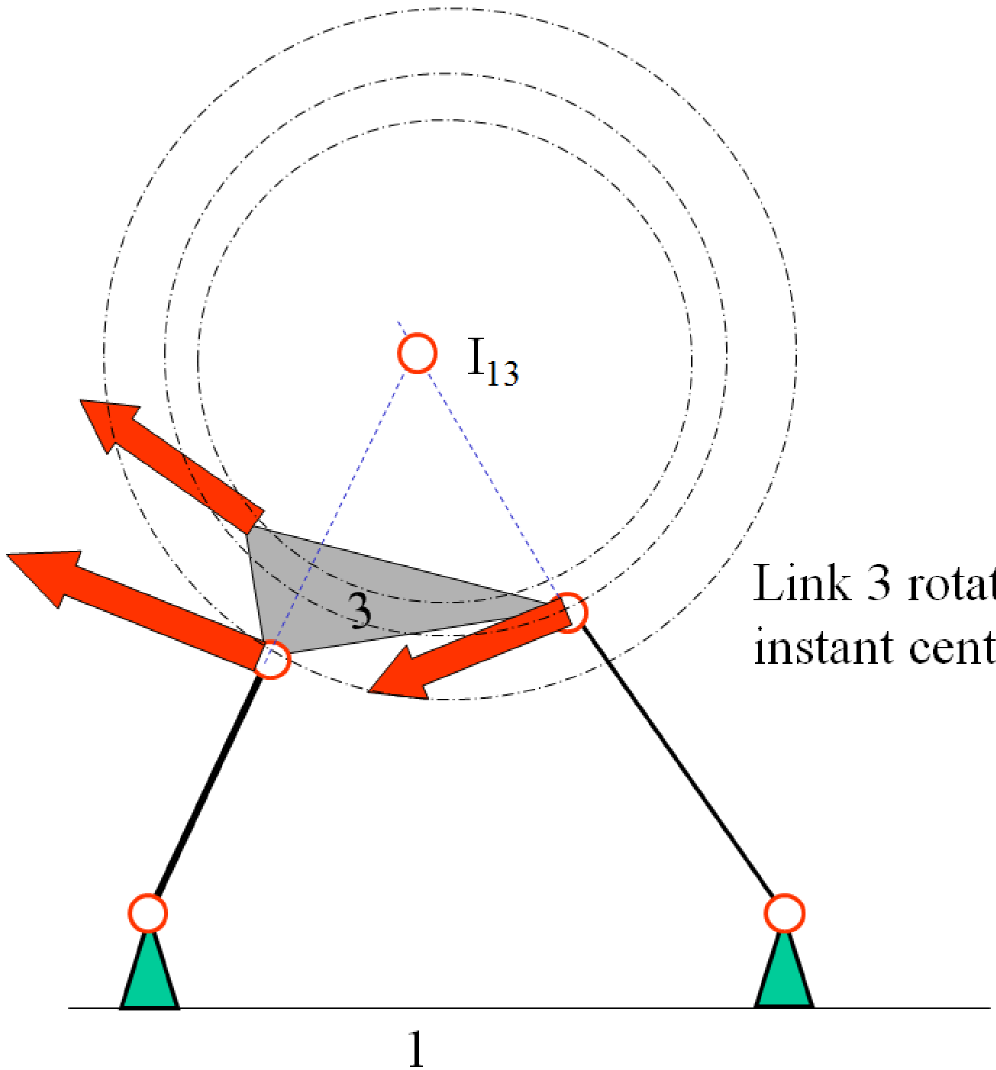




Rules for finding instant centers

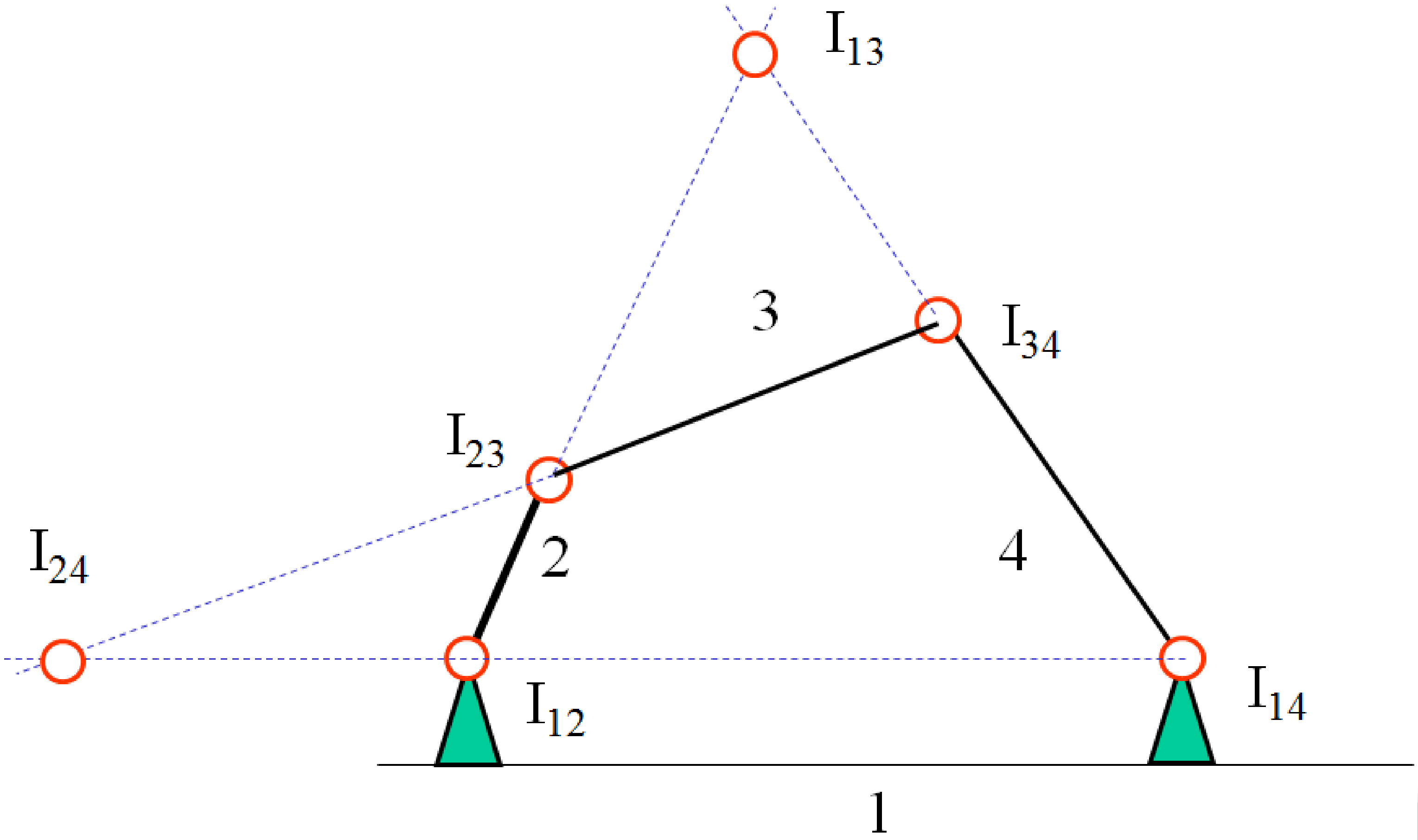


Link is pivoting about the instant center of this link and ground link



Link 3 rotates about instant center I_{13}

Instant centers of four-bar linkage

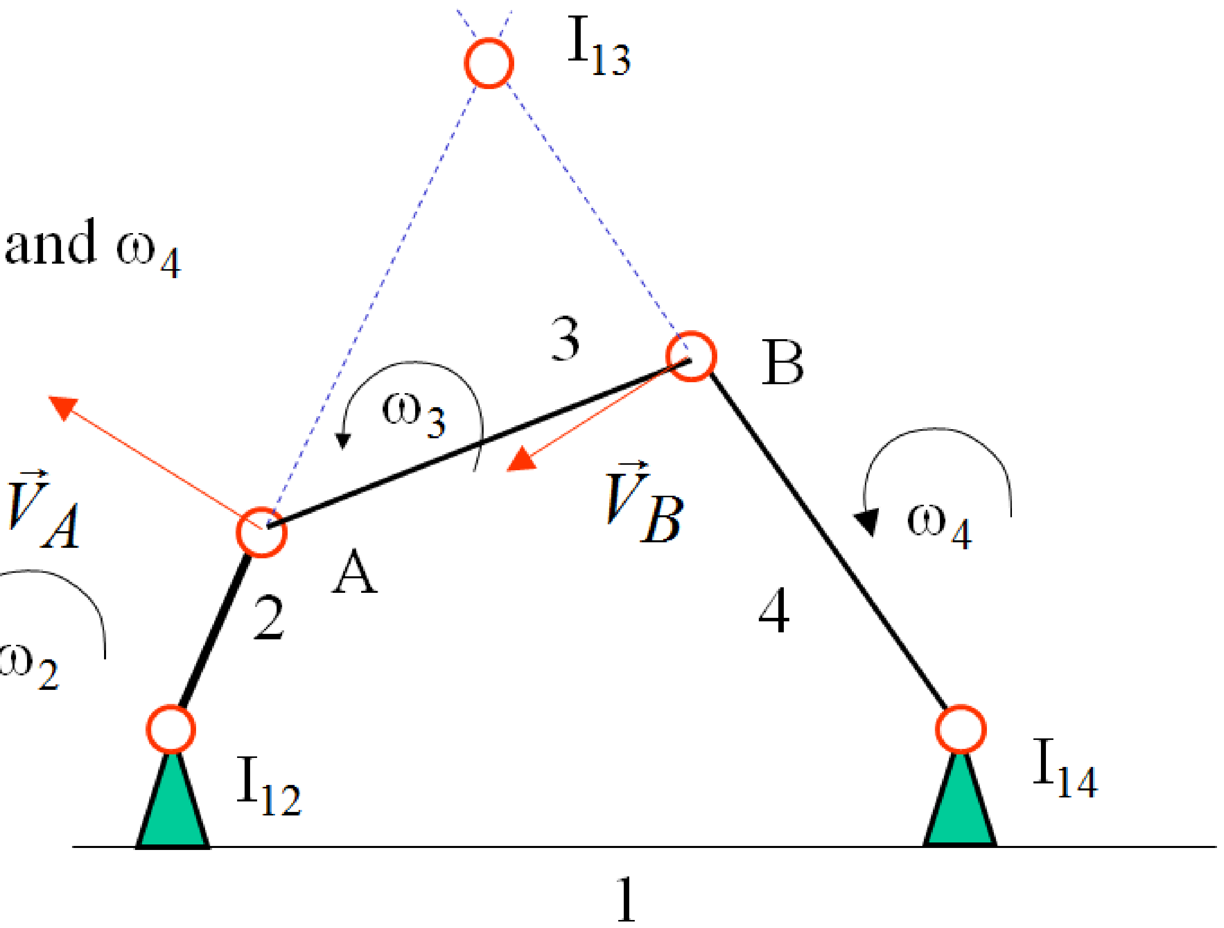


Velocity analysis using instant centers

Problem:

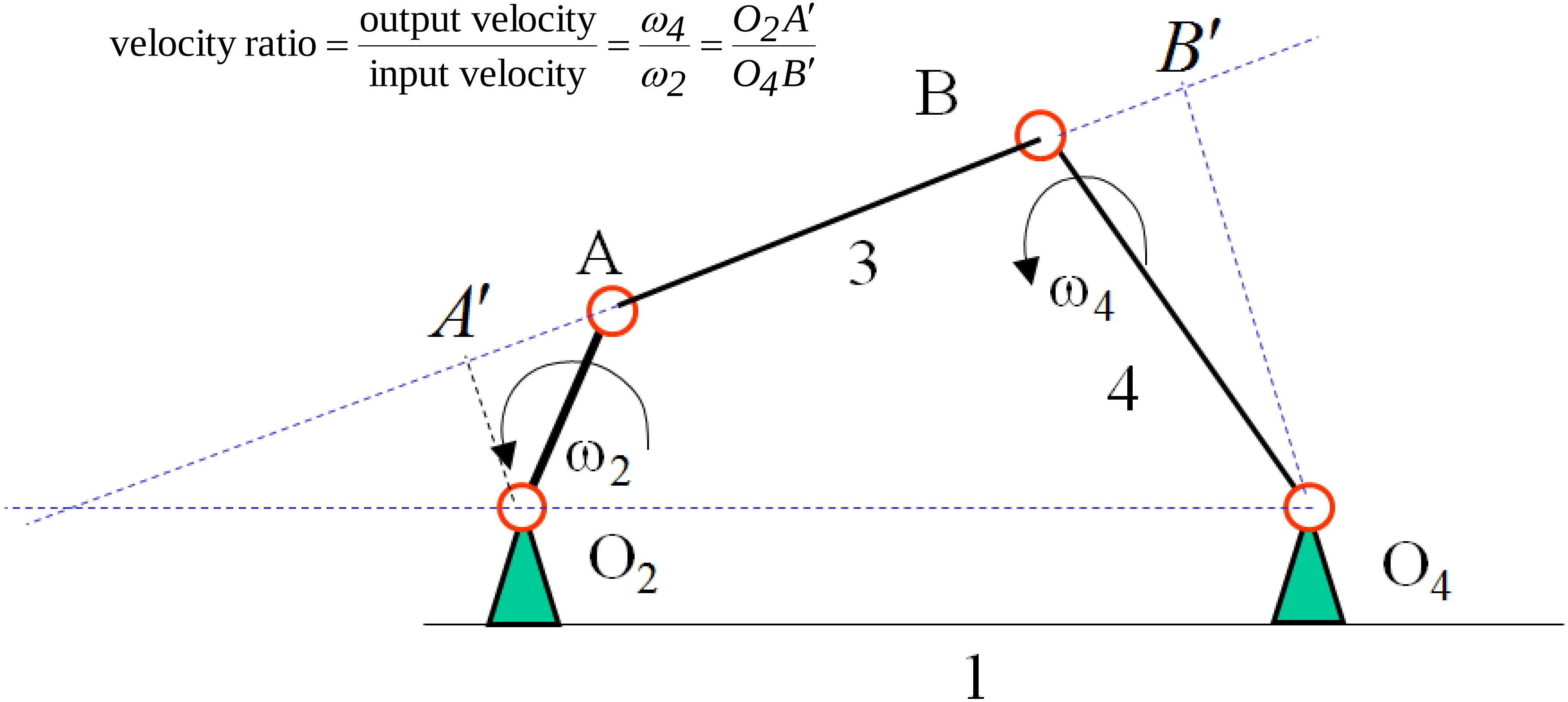
Know ω_2

Find ω_3 and ω_4



Velocity ratio

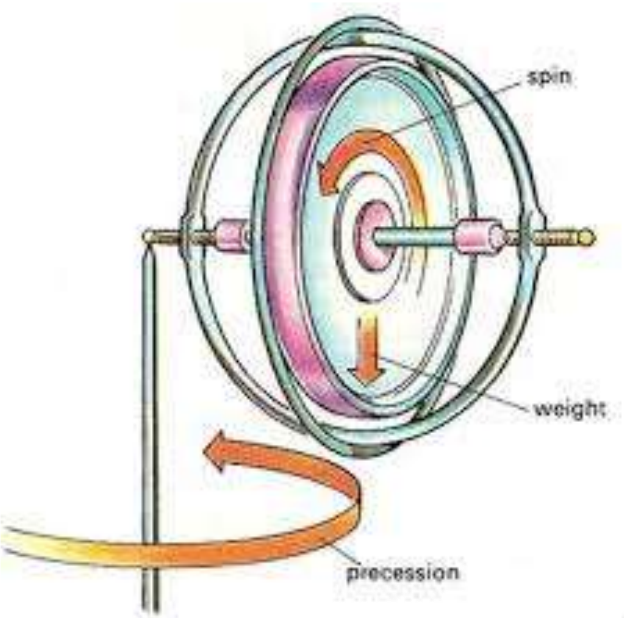
$$\text{velocity ratio} = \frac{\text{output velocity}}{\text{input velocity}} = \frac{\omega_4}{\omega_2} = \frac{O_2A'}{O_4B'}$$



Gyroscope

Definition:

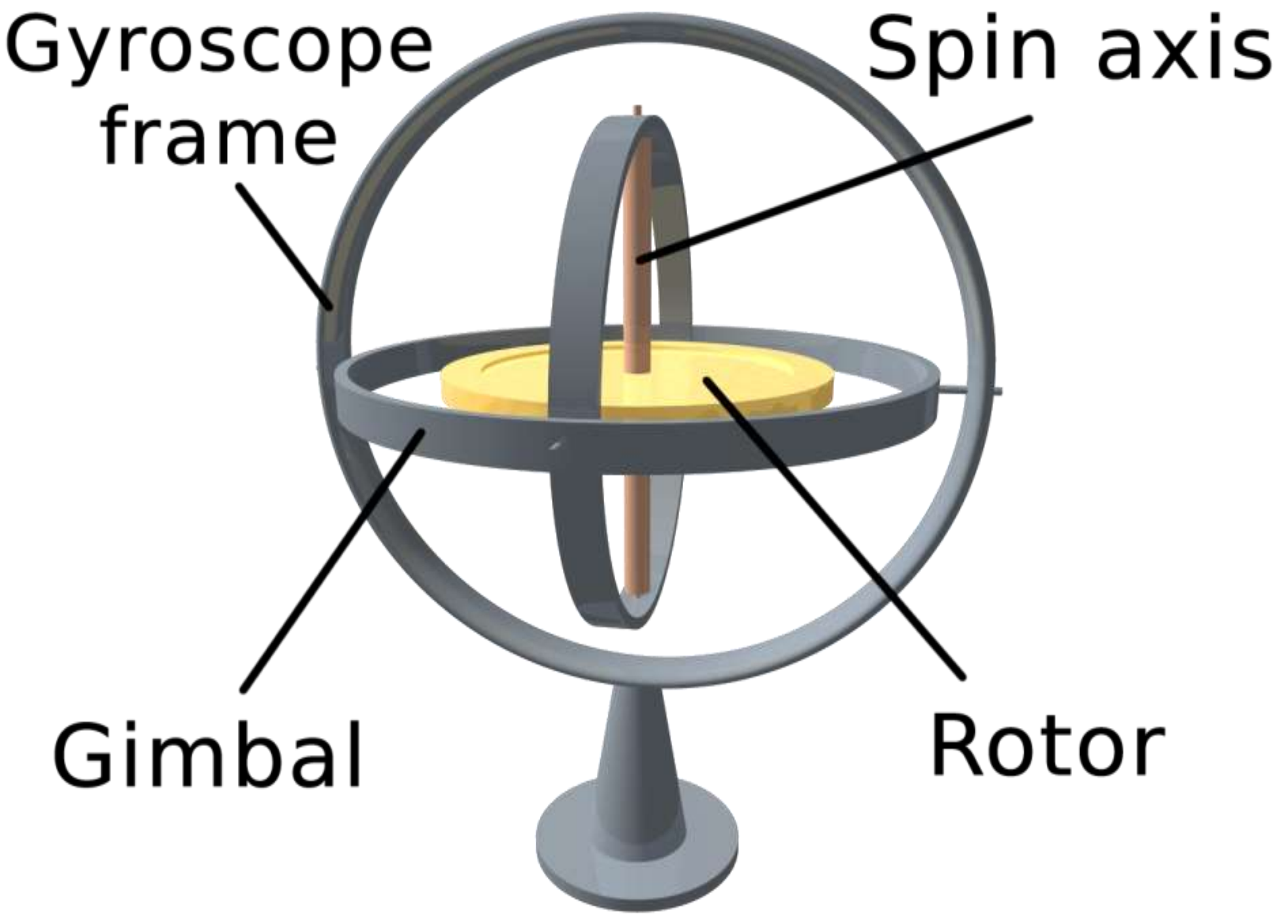
A gyroscope is a device for measuring or maintaining orientation, based on the principles of conservation of angular momentum



Gyroscope

A mechanical gyroscope is essentially a spinning wheel or disk whose axle is free to take any orientation. This orientation changes much less in response to a given external torque than it would without the large angular momentum associated with the gyroscope's high rate of spin.

Gyroscope



EXAMPLES

Gyroscopic effects are also central to things like yo-yos and Frisbees. Gyroscopes can be very perplexing objects because they move in peculiar ways and even seem to defy gravity. These special properties make gyroscopes extremely important in everything from your bicycle to the advanced navigation system on the space shuttle.

EXAMPLES

The essence of this device is a spinning wheel on an axle. The device once spinning, tends to resist changes to its orientation due to the angular momentum of the wheel.

“Balancing the spinning bicycle wheel”

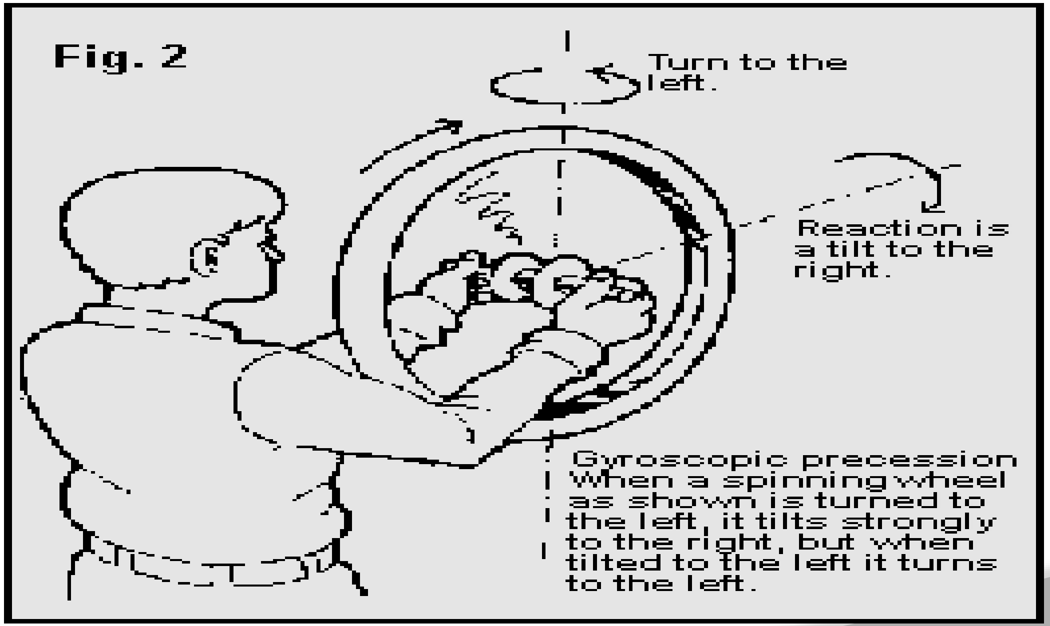


Fig. 2

PROPERTIES OF GYROSCOPES

Gyroscopes have two basic properties:

Rigidity and Precession

These properties are defined as follows:

1. RIGIDITY: The axis of rotation (spin axis) of the gyro wheel tends to remain in a fixed direction in space if no force is applied to it.
2. PRECESSION: The axis of rotation has a tendency to turn at a right angle to the direction of an applied force.

PRECESSION

The fundamental equation describing the behavior of the gyroscope is:

$$\tau = \frac{d\mathbf{L}}{dt} = \frac{d(I\omega)}{dt} = I\alpha$$

T= wp X I

where the vectors τ and L are, respectively, the torque on the gyroscope and its angular momentum, the scalar I is its moment of inertia, the vector ω is its angular velocity, and the vector α is its angular acceleration.

It follows from this that a torque τ applied perpendicular to the axis of rotation, and therefore perpendicular to L, results in a rotation about an axis perpendicular to both τ and L. This motion is called **precession**. The angular velocity of precession wP is given by the cross product:

PRECESSION

By convention, these three vectors, torque, spin, and precession, are all oriented with respect to each other according to the right-hand rule.

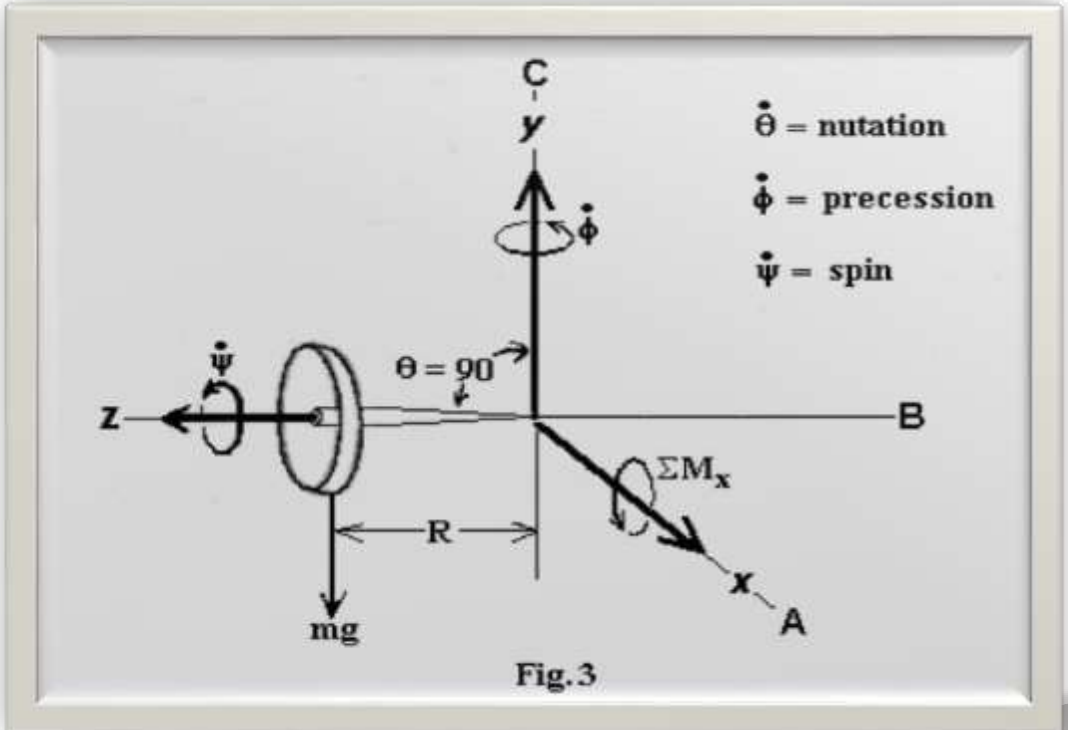
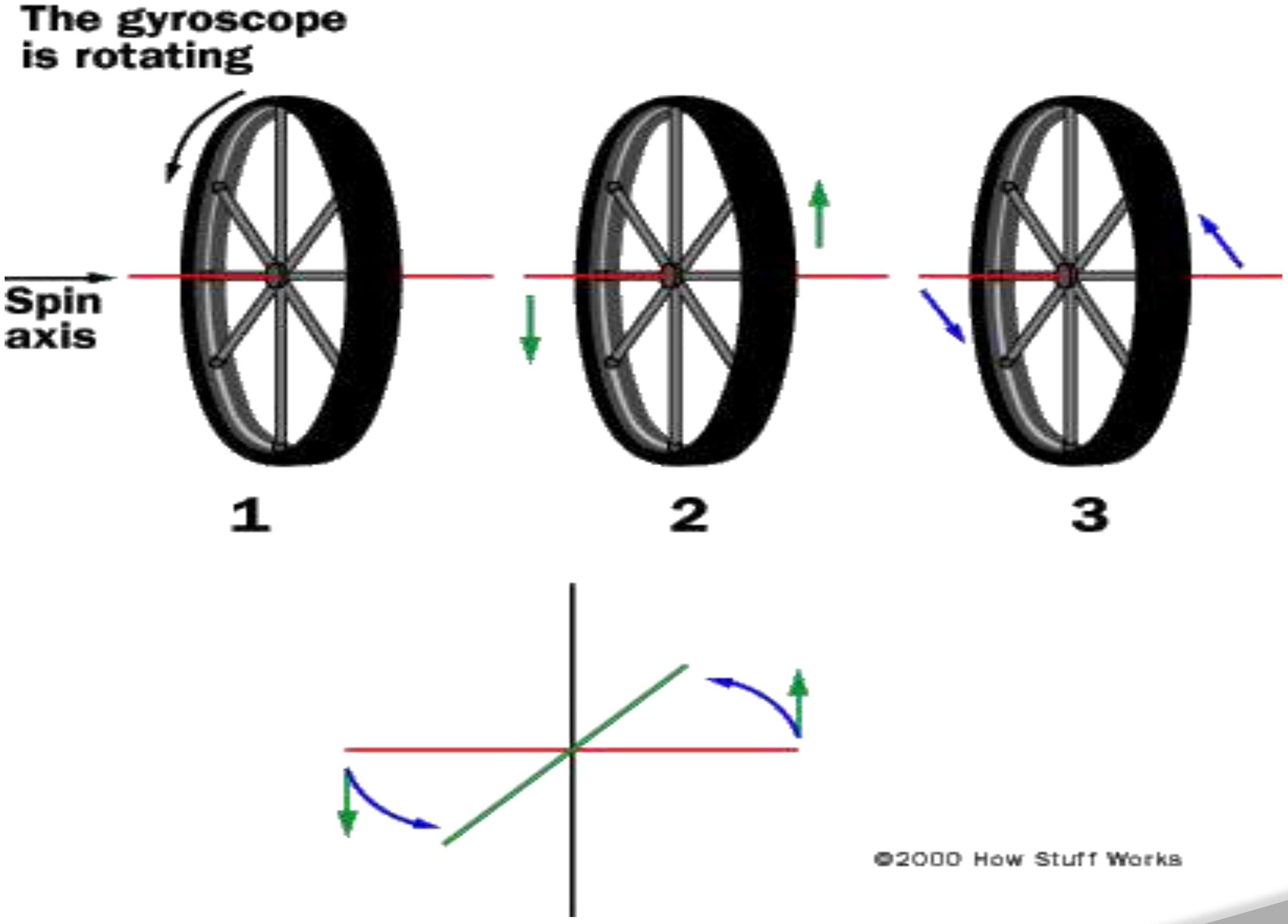


Fig.3

PRECESSION



The gyroscope is rotating
Spin axis
1
2
3
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PRECESSION

This effect is the cause of precession -The different sections of the gyroscope receive forces at one point but then rotate to new positions! When the section at the top of the gyro rotates 90 degrees to the side, it continues in its desire to move to the left. These forces rotate the wheel in the precession direction. As the identified points continue to rotate 90 more degrees, their original motions are cancelled. So the gyroscope's axle hangs in the air and processes.

Effect of Gyroscopic Couple on Aero planes

When the propeller rotates in anti-clockwise direction &:

1. The aero plane takes a right turn, the gyroscope will raise the nose and dip the tail.
2. The aero plane takes a left turn, the gyroscope will dip the nose and raise the tail.

Autopilot

A typical airplane uses gyroscopes in everything from its compass to its autopilot.

The Russian Mir space station used 11 gyroscopes to keep its orientation to the sun, and the Hubble Space Telescope has a batch of navigational gyros as well.

UNIT - IV
CAMS AND FOLLOWERS, STEERING GEARS

Course Learning Outcomes

CLOs	Course Learning Outcome
CLO13	Develop the Cam profiles and followers design
CLO14	Understand the uniform velocity, simple harmonic motion and uniform acceleration, maximum velocity and acceleration during outward and return strokes
CLO15	Understand the Davis steering gear, Ackerman‘s steering gear, velocity ratio
CLO16	Understand the hook‘s joint, single and double hooks joint, universal coupling, applications.

Introduction

- A cam is a mechanical member used to impart desired motion to a follower by direct contact.
- The cam may be rotating or reciprocating whereas the follower may be rotating, reciprocating or oscillating.
- Complicated output motions which are otherwise difficult to achieve can easily be produced with the help of cams.
- Cams are widely used in automatic machines, internal combustion engines, machine tools, printing control mechanisms, and so on.
- They are manufactured usually by die-casting, milling or by punch-presses.
- A cam and the follower combination belong to the category of higher pairs.

TYPES OF CAMS

Cams are classified according to

1. shape
2. follower movement
3. manner of constraint of the follower.

I. According to Shape

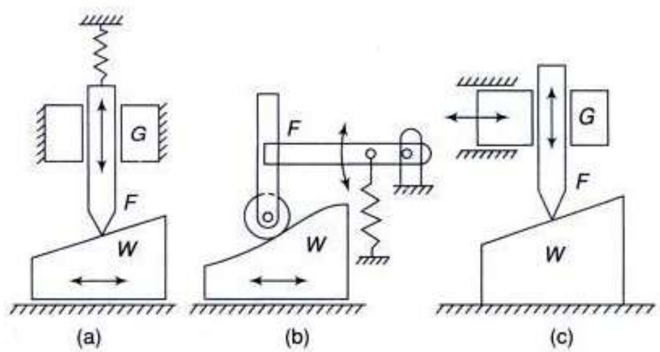
1) Wedge and Flat Cams

A wedge cam has a wedge W which, in general, has a translational motion.

The follower F can either translate [Fig.(a)] or oscillate [Fig.(b)].

A spring is, usually, used to maintain the contact between the cam and the follower.

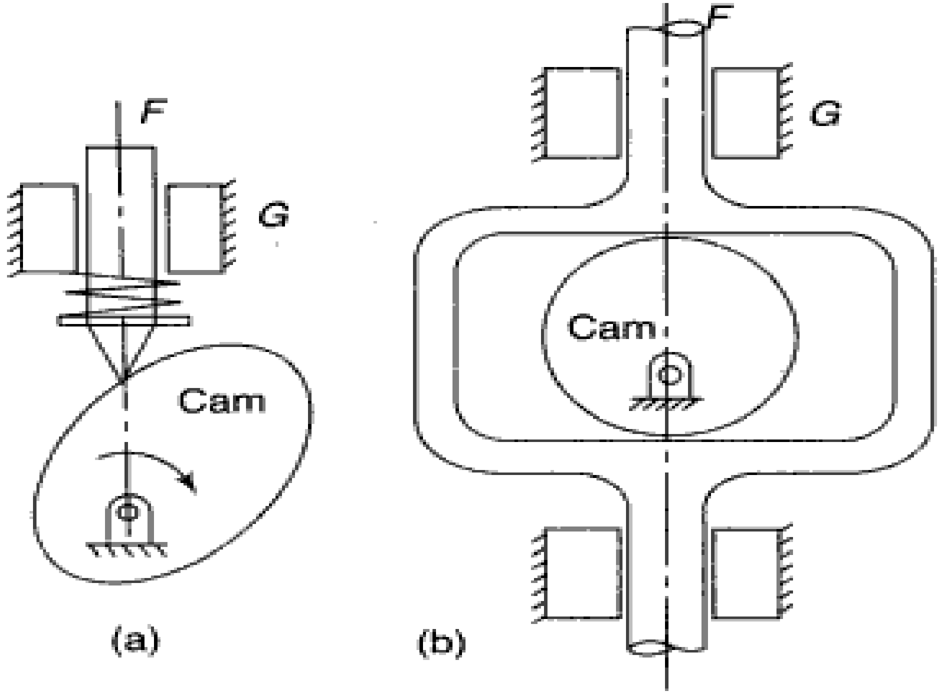
In Fig.(c), the cam is stationary and the follower constraint or guide G causes the relative motion of the cam and the follower.



2. Radial or Disc Cams

A cam in which the follower moves radially from the centre of rotation of the cam is known as a radial or a disc cam (Fig. (a) and (b)].

Radial cams are very popular due to their simplicity and compactness.



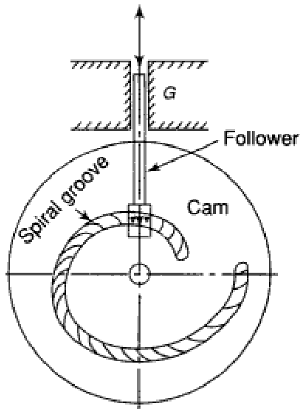
3. Spiral Cams

A spiral cam is a face cam in which a groove is cut in the form of a spiral as shown in Fig.

The spiral groove consists of teeth which mesh with a pin gear follower.

The velocity of the follower is proportional to the radial distance of the groove from the axis of the cam.

The use of such a cam is limited as the cam has to reverse the direction to reset the position of the follower. It finds its use in computers.



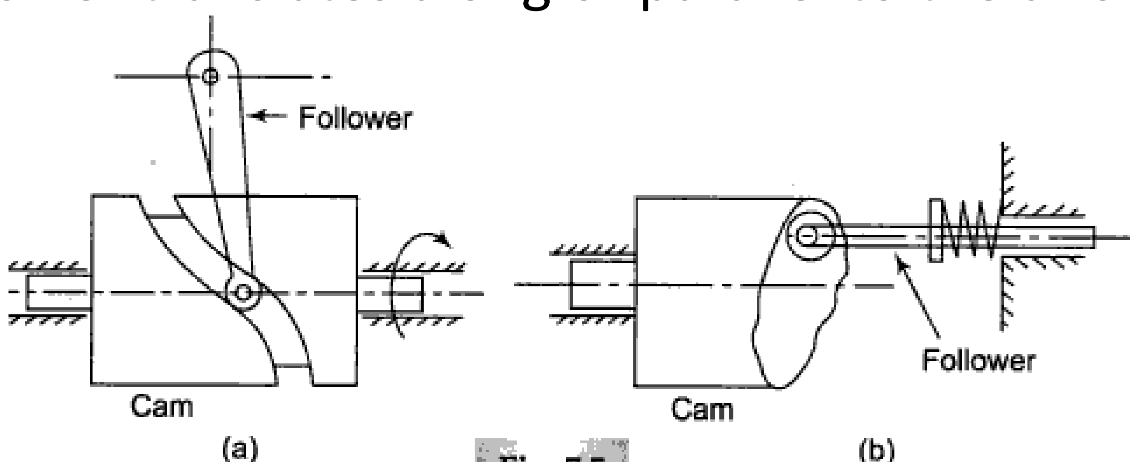
Cylindrical Cams

In a cylindrical cam, a cylinder which has a circumferential contour cut in the surface, rotates about its axis.

The follower motion can be of two types as follows: In the first type, a groove is cut on the surface of the cam and a roller follower has a constrained (or positive) oscillating motion [Fig.(a)].

Another type is an end cam in which the end of the cylinder is the working surface (b).

A spring-loaded follower translates along or parallel to the axis of the rotating cylinder.

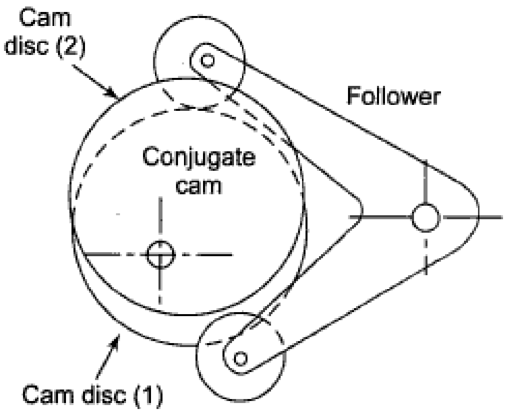


Conjugate Cams

A conjugate cam is a double-disc cam, the two discs being keyed together and are in constant touch with the two rollers of a follower (shown in Fig.).

Thus, the follower has a positive constraint.

Such a type of cam is preferred when the requirements are low wear, low noise, better control of the follower, high speed, high dynamic loads, etc.



Classification of Followers

1.According to the surface in contact.

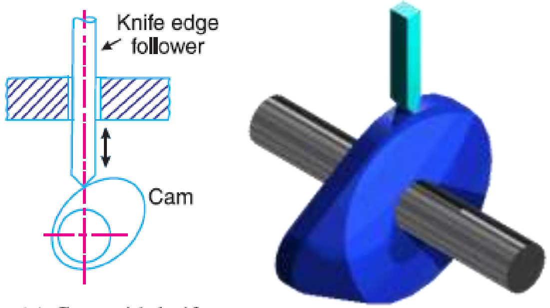
a)Knife edge follower.

When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig.(a).

The sliding motion takes place between the contacting surfaces (i.e. the knife edge and the cam surface).

It is seldom used in practice because the small area of contacting surface results in excessive wear.

In knife edge followers, a considerable side thrust exists between the follower and the guic



(*a*) Cam with knife edge follower.

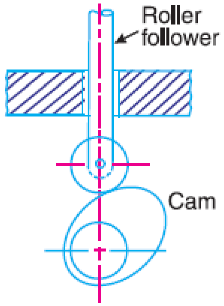
Roller follower

When the contacting end of the follower is a roller, it is called a roller follower, as shown in Fig. (b).

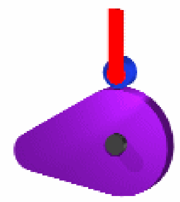
Since the rolling motion takes place between the contacting surfaces (i.e. the roller and the cam), therefore the rate of wear is greatly reduced.

In roller followers also the side thrust exists between the follower and the guide.

The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircraft engines.



(b) Cam with roller follower.

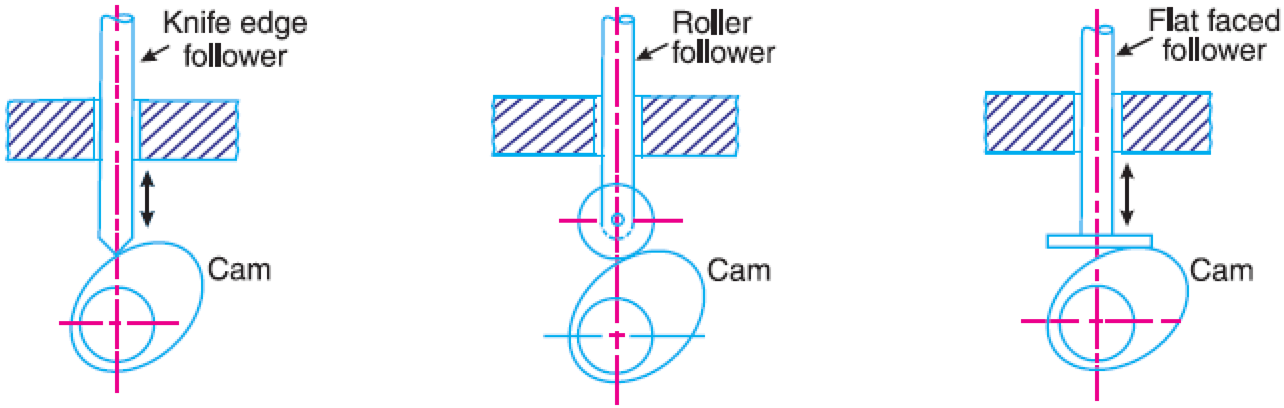


According to the motion of the follower

Reciprocating or translating follower.

When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower.

The followers as shown in Fig. (a) to (d) are all reciprocating or translating followers.

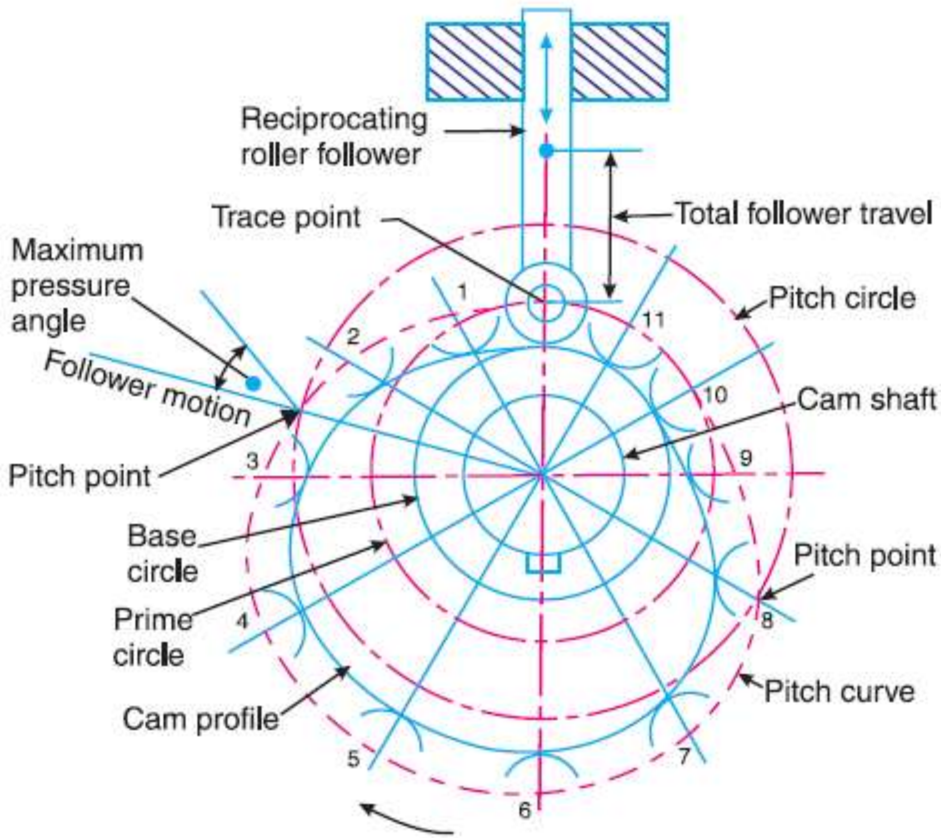


(*a*) Cam with knife edge follower.

(*b*) Cam with roller follower.

(*c*) Cam with flat faced follower.

Terms Used in Radial Cams



Motion of the Follower

The follower, during its travel, may have one of the following motions.

- Uniform velocity
- Simple harmonic motion
- Uniform acceleration and retardation
- Cycloidal motion

Steering Gears

Steering is the term applied to the collection of components, linkages, etc. which will allow a vehicle to follow the desired course.

An automobile is steered with the help of steering gears and linkages, which transfer the motion of the hand operated steering wheel to the pivoted front wheel hubs via steering column. The other parts that are used for steering a vehicle are steering wheel pads, steering shafts, steering boxes, steering arms and steering stabilizers. These parts are made of durable materials like stainless steel, iron, aluminum, copper, magnesium, titanium, platinum, rubber, and plastics.

FUNCTIONS OF STEERING SYSTEMS

- It helps in swinging the wheels to the left or right.
- It converts the rotary movement of the steering wheel into an angular turn of the front wheels.
- It multiplies the effort of the driver by leverage in order to make it fairly easy to turn the wheels.
- It absorbs a major part of the road shocks thereby preventing them to get transmitted to the hands of the driver

REQUIREMENTS OF STEERING SYSTEM

The steering system of any vehicle should fulfill the following requirements:

It should multiply the turning effort applied on the steering wheel by the driver.

It should be to a certain extent irreversible. In other words, the shocks of the road surface encountered by the wheels should not be transmitted to the driver's hands.

The mechanism should have self rightening effect i.e., when the driver releases the steering wheel after negotiating the turn, the wheel should try to achieve straight ahead position.

STEERING GEOMETRY

The term "steering geometry" (also known as "front-end geometry") refers to the angular Relationship between suspension and steering parts, front wheels, and the road surface. Because alignment deals with angles and affects steering, the method of describing alignment measurements is called steering geometry.

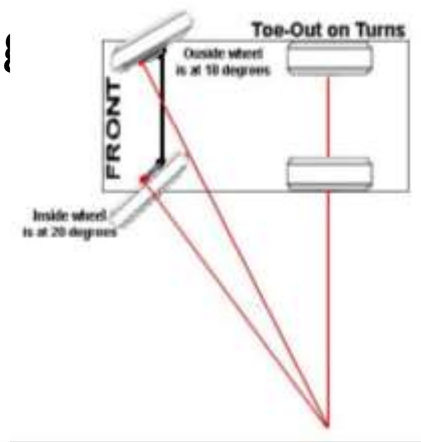
There are five steering geometry angles : Camber , Caster ,Toe, Steering axis inclination, and Toe-out on turns

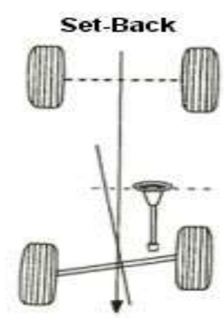
There are two more steering geometry angles that are not specific to each wheel but measure the spatial relationship among all four wheels .These are Setback and Thrust angle.

STEERING GEOMETRY

All steering geometry angles can be measured in degrees. However, toe out and Setback can be measured in terms of distance and may be given in inches or mm.

The 5 traditional alignment angles can be classified as tire wear angles or directional control angles. A tire wear angle helps prevent tire wear when correct and accelerates tire wear when incorrect. A directional control angle affect steering and handling. All 5 of the traditional alignment angles are directional control angles. The Thrust angle and setback hold importance for the effect they have on other ali





ACKERMANN STEERING GEOMETRY

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii.

Modern cars do not use pure Ackermann steering, partly because it ignores important dynamic and compliant effects. Some race cars use reverse Ackermann geometry to compensate for the large difference in slip angle between the inner and outer front tires while cornering at high speed. The use of such geometry helps reduce tyre temperatures during high-speed cornering but compromises performance in low speed maneuvers.

The intention of Ackermann geometry is to avoid the need for tyres to slip sideways when following the path around a curve. The geometrical solution to this is for all wheels to have their axles arranged as radii of a circle with a common centre point.

UNIT -V

GEARS AND GEAR TRAINS, DESIGN OF FOUR BAR MECHANISMS

Course Learning Outcomes

CLOs	Course Learning Outcome
CLO17	Derive the expression for minimum number of teeth to avoid interference in case of pinion and gear as well as rack and pinion.
CLO18	Application of different gear trains including epi-cyclic and deduce the train value using tabular and relative velocity method.
CLO19	Significance of differential gear box in an automobile while taking turn on the road.
CLO20	Enable the students to understand the importance of Freudenstein equation, Precession point synthesis, Chebyshev's method, structural error

Introduction

- Sometimes, two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called gear train or train of toothed wheels.
- The nature of the train used depends upon the velocity ratio required and the relative position of the axes of shafts.
- A gear train may consist of spur, bevel or spiral gears.

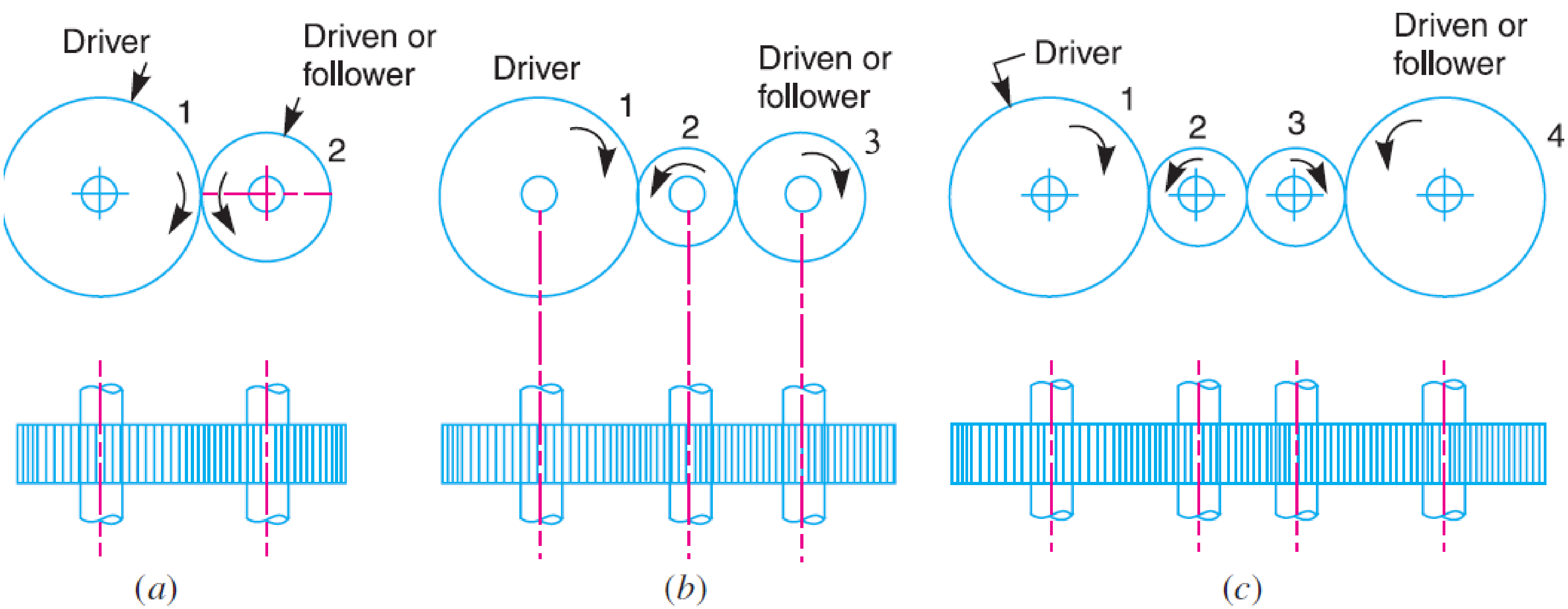
Types of Gear Trains

Following are the different types of gear trains, depending upon the arrangement of wheels :

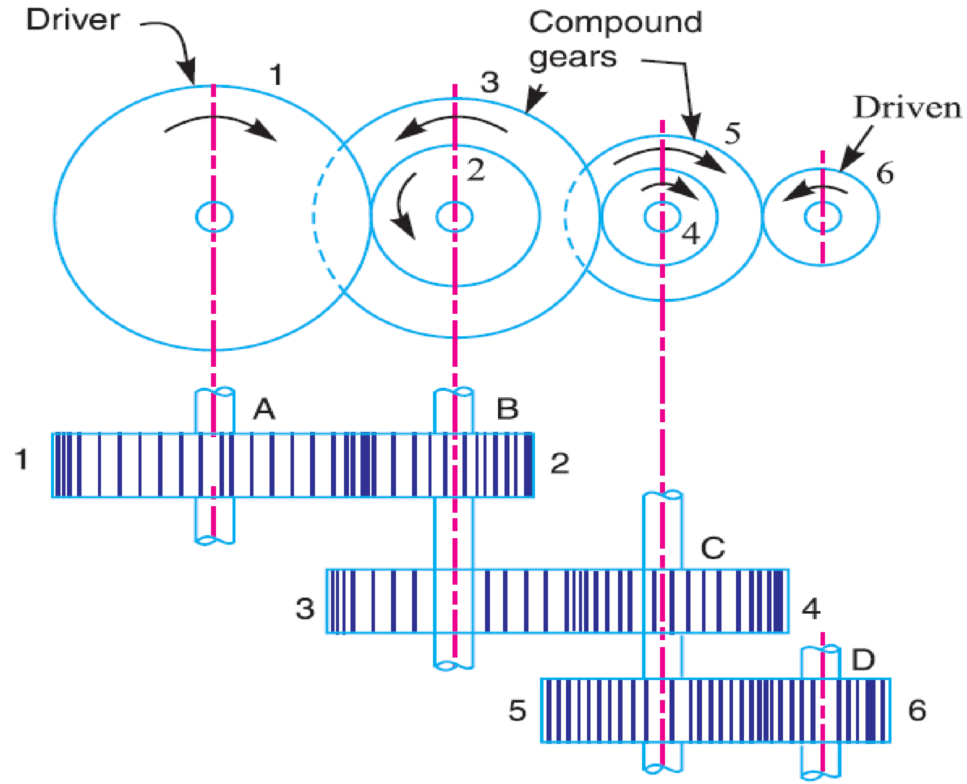
1. Simple gear train
2. Compound gear train
3. Reverted gear train
4. Epicyclic gear train

In the first three types of gear trains, the axes of the shafts over which the gears are mounted are fixed relative to each other. But in case of epicyclic gear trains, the axes of the shafts on which the gears are mounted may move relative to a fixed axis.

Simple Gear Train

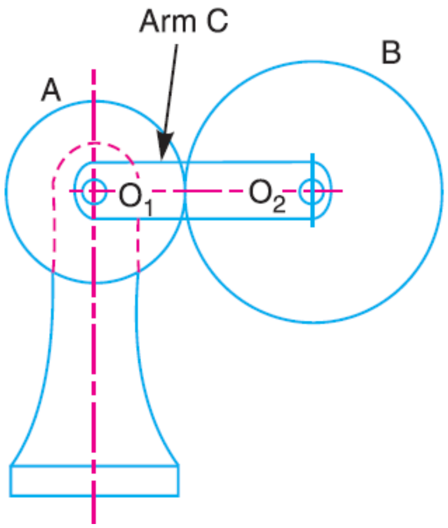


Compound Gear Train



Epicyclic Gear Train

- In an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis.
- A simple epicyclic gear train is shown in Fig., where a gear A and the arm C have a common axis at O1 about which they can rotate.
- The gear B meshes with gear A and has its axis on the arm at O2, about which the gear B can rotate.



Gears

- Gear terminology, law of gearing, Characteristics of involute action, Path of contact, Arc of contact, Contact ratio of spur, helical, bevel and worm gears.
- Interference in involute gears.
- Methods of avoiding interference and Back lash.

Comparison of involute and Cycloidal teeth, Profile modification.

Types of gears

According to the position of axes of the shafts.

a. Parallel

1.Spur Gear

2.Helical Gear

3.Rack and Pinion

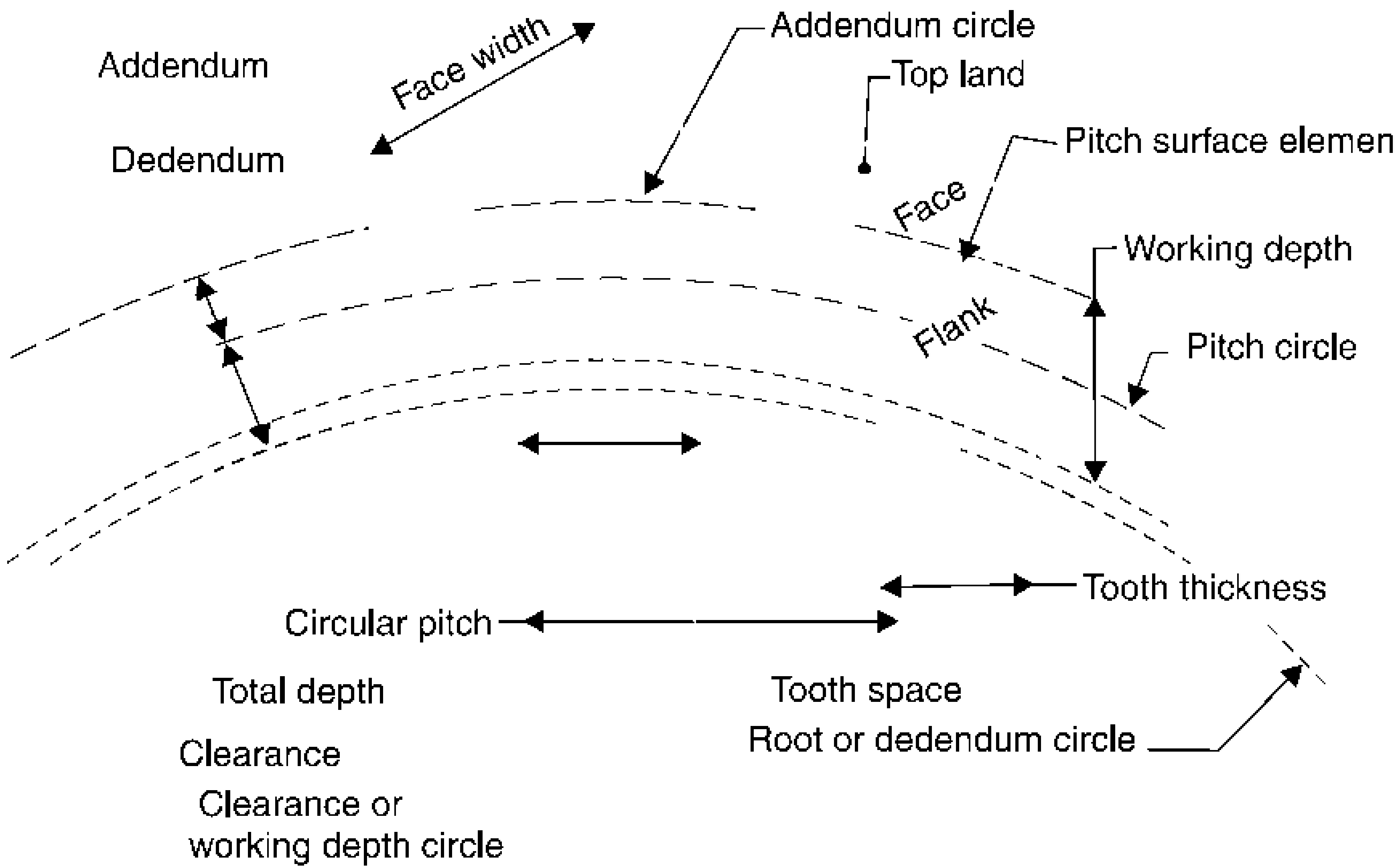
b. Intersecting

Bevel Gear

c. Non-intersecting and Non-parallel

worm and worm gears

Nomenclature of spur gears

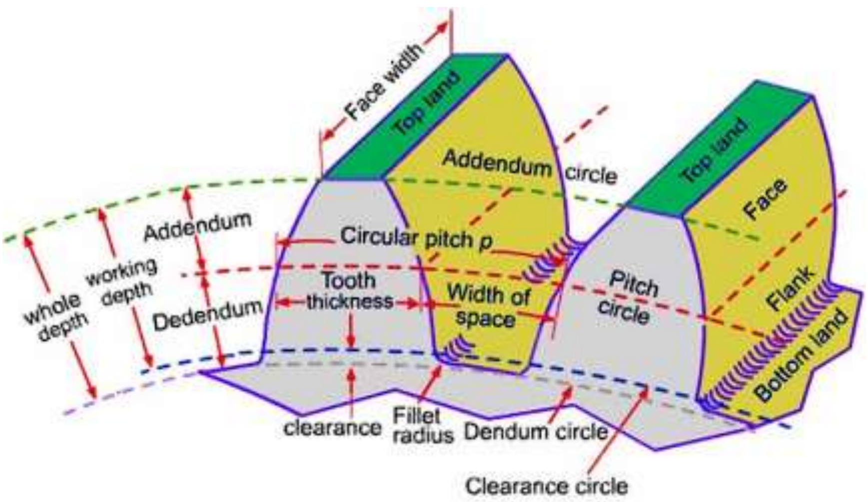


Nomenclature of spur gears

Pitch circle: It is an imaginary circle which by pure rolling action would give the same motion as the actual gear.

Pitch circle diameter: It is the diameter of the pitch circle. The size of the gear is usually specified by the pitch circle diameter. It is also known as pitch diameter.

Pitch point: It is a common point of contact between two pitch circles.



Forms of Teeth

In actual practice following are the two types of teeth commonly used

1. Cycloidal teeth, 2. Involute teeth.

Cycloidal Teeth

A cycloid is the curve traced by a point on the circumference of a circle which rolls without slipping on a fixed straight line.

When a circle rolls without slipping on the outside of a fixed circle, the curve traced by a point on the circumference of a circle is known as **epi-cycloid**.

On the other hand, if a circle rolls without slipping on the inside of a fixed circle, then the curve traced by a point on the circumference of a circle is called **hypo-cycloid.**

Four Bar mechanism

Grashof law: The sum of the shortest (S) and longest (L) links of a planar four-bar linkage must be smaller than the sum of the remaining two links (P, Q). In this case the shortest link can rotate 360degree relative to the longest link.

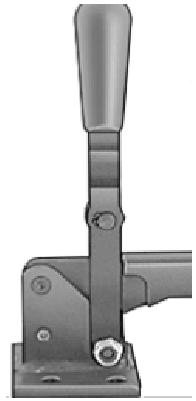
L + S < P + Q: crank-rocker, double-crank, rocker-crank, double-rocker

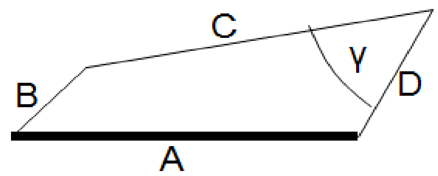
L + S = P + Q: crank-rocker, double-crank, rocker-crank, double-rocker, → note: linkage can change its closure in singularity positions (all links aligned)

If L + S > P + Q, double-rocker, no continuous rotation of any link

Four Bar mechanism

Transmission Angles – Four Bar





- A – ground link
- B – input link
- C – coupler
- D – output link

- Angle between coupler and output link should be 40º≤γ≤140º

→ Zero torque at output link if γ=0º or γ=180º

Other Basic Four Bar Design Methods

- Approximate function generation
- Approximate coupler point path generation
- Uncorrelated with input
- Correlated with input
- Slider crank synthesis by approximation

What possible advanced design methods

- Four coupler position synthesis
- Straight line motion
- Complex linkages (more than four bars)
- Spatial linkages