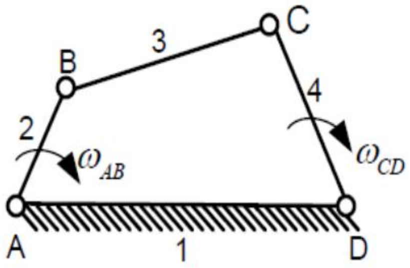
ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

KINEMATICS AND DYNAMICS OF MACHINES NOTES

An **Instantaneous (I-centre)** is a centre of rotation of a moving body relative to another body. I-centre can be .. a point on a member which another member rotates around, permanently or instantaneously; a point in common place between two members The velocities are equal (both in direction and magnitude) at the ICentre.



Number of instantaneous centres in a mechanism

The number of instantaneous centers (N) in a kinematic chain is equal to the number of possible combinations of two links.

$$N = \frac{n(n-1)}{2}$$

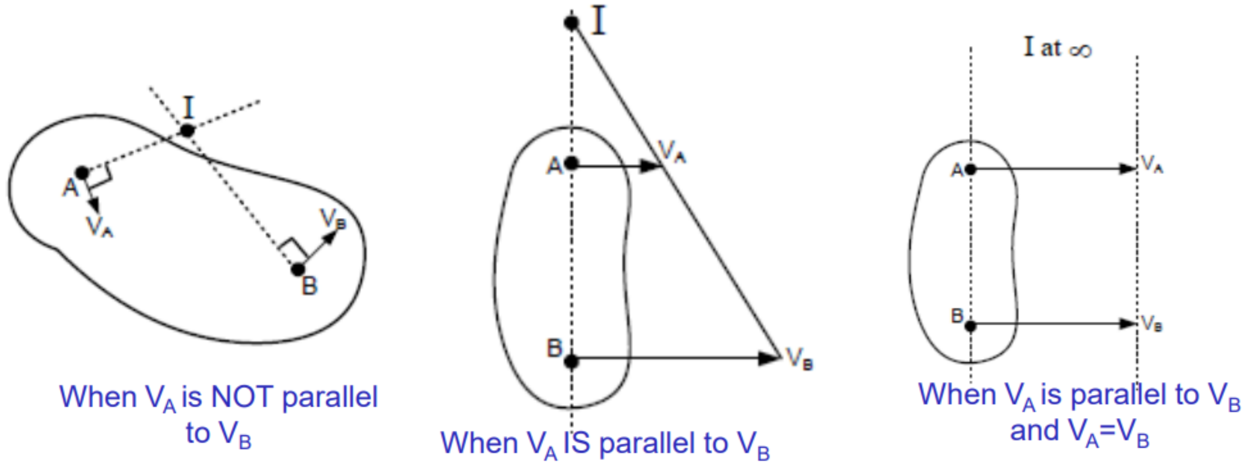
Where n = number of links.

Properties of the instantaneous centre

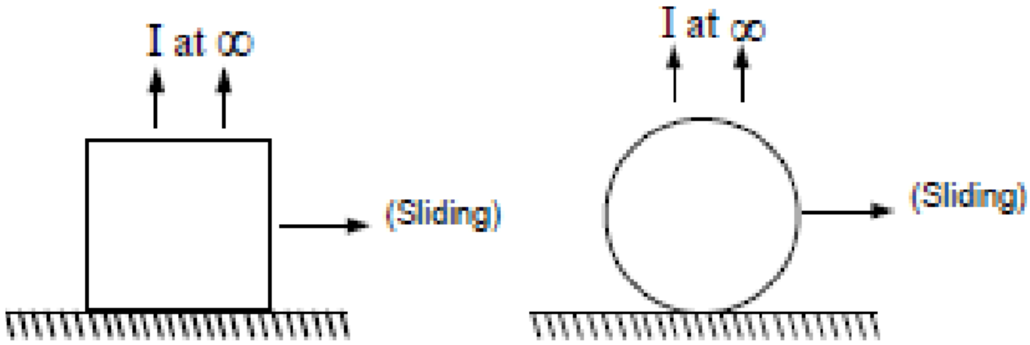
A rigid link rotates instantaneously relative to another link at the instantaneous centre for the configuration of the mechanism considered. The two rigid links have no linear velocity relative to each other at the instantaneous centre. At this point the two rigid links have the same linear velocity relative to the third rigid link.

Rules to Locate Instantaneous Centres by Inspection

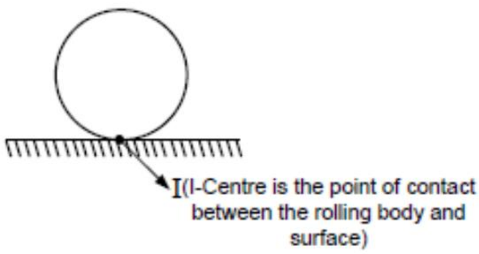
In a pivoted joint, the centre of the pivot is the I-centre for the two links of the pivot.



In a sliding motion, the I-centre lies at infinity in a direction perpendicular to the path of motion of the slider. This is because the sliding motion is equivalent to a rotary motion of the links with the radius of curvature as infinity.



In a pure rolling contact of the two links, the I-centre lies at the point of contact at the given instant. It is because the two points of contact on the two bodies have the same linear velocity and thus there is no relative motion of the two at the point of contact which is the I-centre

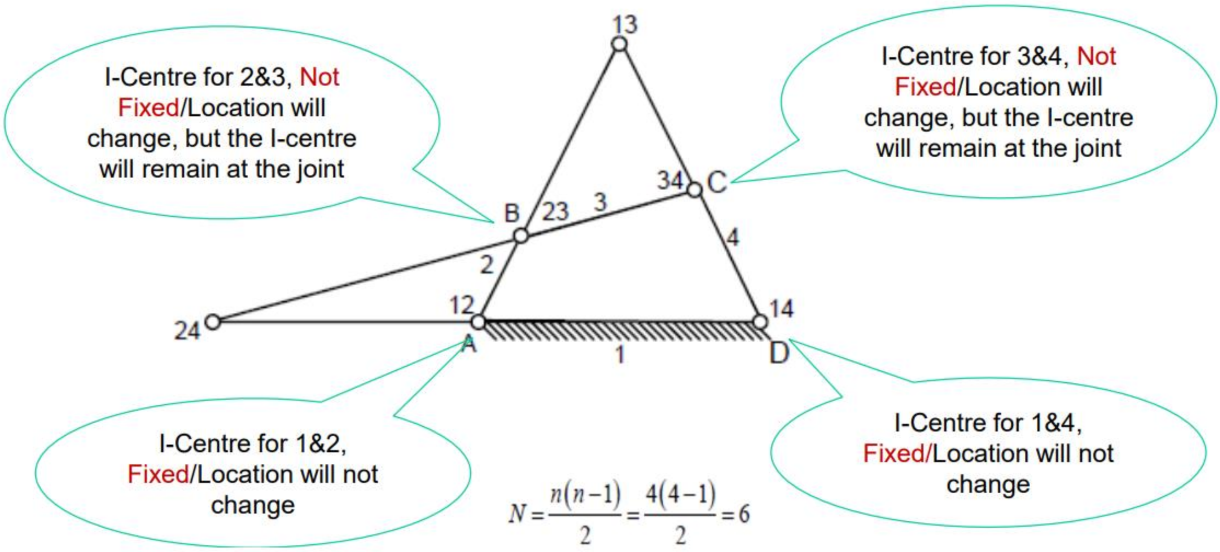


Types of Instantaneous Centres

The instantaneous centres for a mechanism are of the following types. Fixed Instantaneous centres Permanent Instantaneous centres. Neither fixed nor permanent instantaneous centres The first two types are together known as primary instantaneous centres and third type is known as secondary instantaneous centres.

Example

Consider the 4-bar mechanism shown below. The I-centres 12, 14, 23 and 34 are permanent (i.e., are at the joints), and can be located by inspection.

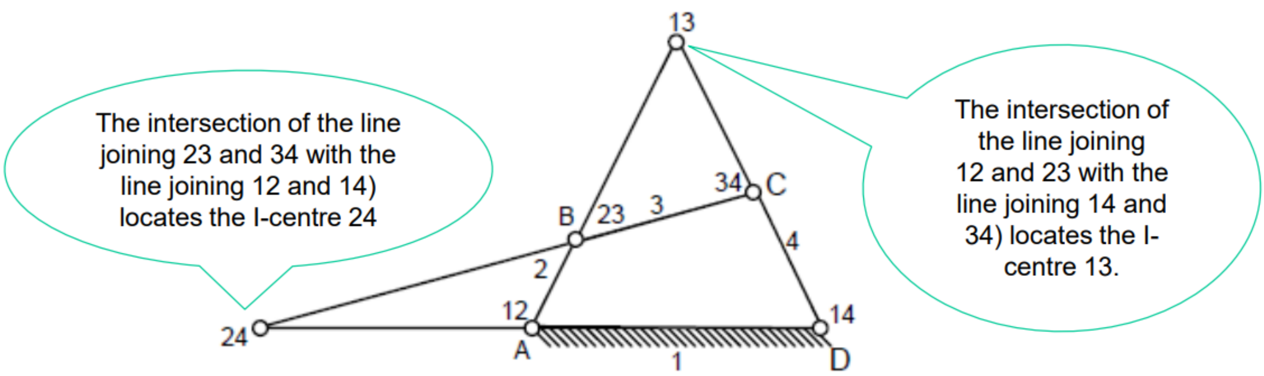


$$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

Kennedy’s theorem

If three plane bodies have relative motion among themselves, their I-centre must lie on a straight line.

The I-centres 13 and 24 are neither fixed nor permanent can be located by applying Kennedy’s theorem



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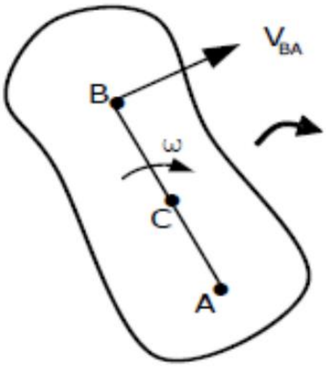


Velocity of any point on a link with respect to another point on the same link is always perpendicular to the line joining these points.

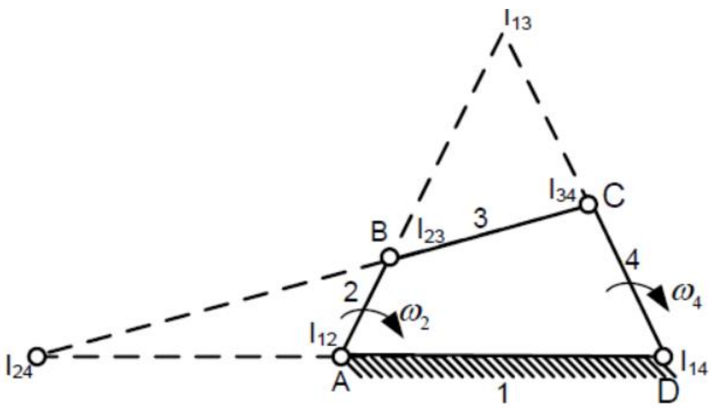
Let ω = angular velocity of link AB about A. Velocity of point B with respect to A,

$$V_{BA} = \omega.AB$$

Similarly the velocity of any point C on AB with respect to A,

$$V_{CA} = \omega.AC$$

Thus, $\frac{V_{CA}}{V_{BA}} = \frac{\omega.AC}{\omega.AB} = \frac{AC}{AB}$



a) locate common I-centre.

b) the velocity of this I-centre relative to a fixed third link is the same if the I-centre is considered on the first or the second link.

c) first consider the I-centre to be on the first link and obtain the velocity of the I-centre.

d) then, consider the I-centre to be on the second link and find its angular velocity.

Kinematics governs the geometry of motion without considering forces, ensuring wheels turn at precise relative angles, while **dynamics** handles the actual forces, torques, and inertial effects required to steer and stabilize the vehicle. Together, they dictate how a car responds to steering inputs, maintains tire grip, and provides sensory feedback to the drive.

Applications of kinematics and dynamics in automotive steering system

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Applications of Kinematics (Motion & Geometry)

Kinematics focuses on optimizing the link positioning and angles within the steering linkage to minimize tire wear and maximize maneuverability.

- **Ackermann Steering Geometry**: Configures steering linkages so the inner front wheel turns sharper than the outer wheel. This ensures all four wheels track smoothly around a single concentric turning point, preventing tires from scrubbing sideways during low-speed turns.
- **Toe and Camber Control**: Controls wheel orientation relative to the road surface during suspension travel. Proper kinematic design prevents unwanted toe-in or toe-out shifts, which keeps the car driving straight and prevents uneven tire tread wear.
- **Caster Angle Alignment**: Angles the steering axis forward or backward (similar to a bicycle fork). This kinematic offset creates a self-centering effect, naturally returning the steering wheel to the center position after completing a turn.

- **Bump Steer Mitigation**: Optimizes the lengths and angles of the tie rods relative to the suspension control arms. This prevents the wheels from turning on their own when hitting road bumps, keeping the vehicle on its intended path.

Applications of Dynamics (Forces & Torques)

Dynamics manages the physical forces acting between the road, the tires, and the steering system, ensuring high-speed stability and safety.

- **Cornering and Lateral Force Management**: Evaluates how centrifugal forces shift weight during turns. Engineers use these calculations to prevent vehicle roll and body lean while ensuring tires maintain maximum contact with the road
- **Steering Feedback & Feel**: Balances self-aligning torques from the tires with mechanical friction. This dynamic design provides the driver with tactile "road feel," communicating traction limits and changing road surfaces through the steering wheel.
- **Power Steering Calibration**: Controls the precise torque assist delivered by hydraulic pumps or electric motors. Dynamic sensors measure the driver's input force and vehicle speed to offer heavy, stable steering at high speeds and light, effortless steering during parking.
- **Electronic Stability Control (ESC)**: Analyzes dynamic data from wheel speed sensors, steering wheel angle sensors, and yaw rate sensors. If the vehicle begins to slide (understeer or oversteer), the system selectively applies individual brakes to pull the vehicle back into the intended path of travel