Abstract: Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems serve a dual purpose — contributing to the vehicle's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations, etc. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

I. INTRODUCTION
Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems serve a dual purpose — contributing to the vehicle's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations etc. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

II. OBJECTIVES
- To provide good ride and handling performance
- Vertical compliance providing chassis isolation ensuring that the wheels follow the road profile very little tire load fluctuation
- To ensure that steering control is maintained during maneuvering wheels to be maintained in the proper position wrt road surface
- To ensure that the vehicle responds favorably to control forces produced by the tires during longitudinal braking accelerating forces, lateral cornering forces and braking and accelerating torques. This requires the suspension geometry to be designed to resist squat, dive and roll of the vehicle body
- To provide isolation from high frequency vibration from tire excitation requires appropriate isolation in the suspension joints Prevent transmission of 'road noise' to the vehicle body

III. VEHICLE AXIS SYSTEM
A. Un-sprung mass:
- Right-hand orthogonal axis system fixed in a vehicle
- x-axis is substantially horizontal, points forward, and is in the longitudinal plane of symmetry.
- y-axis points to driver's right and
- z-axis points downward.
B. Rotations:
- A yaw rotation about z-axis.
- A pitch rotation about y-axis.
- A roll rotation about x-axis

IV. TIRE TERMINOLOGY – BASIC
A. Camber angle:
- angle between the wheel plane and the vertical
taken to be positive when the wheel leans outwards from the vehicle
- Swivel pin (kingpin) inclination
- angle between the swivel pin axis and the vertical
- Swivel pin (kingpin) offset
• distance between the centre of the tire contact patch and
• intersection of the swivel pin axis and the ground plane

B. Castor angle
• inclination of the swivel pin axis projected into the fore–aft plane through the wheel centre
• positive in the direction shown.

V. ANALYSIS OF SUSPENSION MECHANISMS
A. 3D mechanisms:
• Compliant bushes create variable link lengths
• 2D approximations used for analysis
• Requirement
• Guide the wheel along a vertical path
• Without change in camber
• Suspension mechanism has various SDOF mechanisms

B. The mobility of suspension mechanisms
Guide motion of each wheel along (unique) vertical path relative to the vehicle body without significant change in camber. Mobility (DOF) analysis is useful for checking for the appropriate number of degrees of freedom, does not help in synthesis to provide the desired motion.
Two-dimensional kinematics of common suspension mechanisms

VI. SUSPENSION TYPES –DEPENDENT
Motion of a wheel on one side of the vehicle is dependent on the motion of its partner on the other side
Rarely used in modern passenger cars
- Can not give good ride
- Can not control high braking and accelerating torques
Used in commercial and off-highway vehicles

VII. KINEMATIC ANALYSIS –GRAPHICAL
The suspension ratio R (the rate of change of vertical movement at D as a function of spring compression) the bump to scrub rate for the given position of the mechanism.

A. Kinematic Analysis – Sample calculation
Double wish bone
Determine camber angle α, and suspension ratio R (as defined in the previous example)
For suspension movement described by —q varying from 80° to 100°
Given that in the static laden position —q = 90°.

AC = 331 mm
BC = 567 mm
BD = 173 mm

Simplified suspension model
Positions are provided Two non-linear equations solved for positions described interval 1

Data: \( c_1 = 203 \), \( c_2 = 102 \), \( c_3 = 127 \), \( c_4 = 152 \), \( c_5 = 127 \), \( c_7 = 267 \), \( c_8 = 102 \), \( c_9 = 51 \), \( c_{10} = 110 \), \( C = 96^\circ \), \( t = 292 \)

Constants \( c_{12} = c_1 + c_2 \), \( c_{34} = c_3 + c_4 \), \( k_d = \frac{\pi}{180} \)

Solution estimates: \( A = -10 \), \( B = 10 \)

Given

\[ c_{12} \sin (q \cdot k_d) - c_{34} \sin (A \cdot k_d) - c_t \cos (B \cdot k_d) - c_q = 0 \]
\[ c_{12} \cos (q \cdot k_d) - c_{34} \cos (A \cdot k_d) - c_t \sin (B \cdot k_d) + c_t = 0 \]

\( F(q) \) := Find(A, B)

\( q := 80 \text{.}100 \quad i := 0 \text{.}20 \)

\( A_1 := F(80 + i_1) \quad B_1 := F(80 + i_1) \quad q_i := 80 + i \)

The second part of the solution begins by expressing the length of the suspension spring in terms of the primary variable and then proceeds to determine the velocity coefficients

\[ K_{IP} (q) = \frac{dY}{dq} \quad \text{and} \quad K_L (q) = \frac{dL}{dq} \]

These allow the suspension ratio \( R = \frac{K_{IP}}{K_L} \)

to be determined.

Length of suspension spring

\[ L_i = \sqrt{(c_1 \cdot \sin(q_i)) - c_3}^2 + (c_t + c_1 \cdot \cos(q_i)) - c_3 \]

Mean position of suspension spring \( L_{01} := L_{01} \quad L_0 = 238.447 \text{ mm} \)

Deflection from mean position \( u_i := L_0 - L_i \)

Velocity coefficients

\[ K_{A1} = \frac{c_{12} \cdot \cos(q_i) + B_1}{c_{34} \cdot \cos(A_1 + B_i)} \]
\[ K_{Y1} = c_{12} \cdot \sin(q_i) + K_{A1} \cdot c_3 \cdot \sin(A_1) - c_{10} \cdot \cos(A_1) + t \cdot \sin(q_i) \]
\[ K_{L1} = \frac{c_1 \cdot c_9 \cdot \sin(q_i) - c_7 \cdot c_1 \cdot \sin(q_i) - c_1 \cdot c_8 \cdot \cos(q_i)}{\sqrt{(c_1 \cdot \sin(q_i)) - c_3}^2 + (c_t + c_1 \cdot \cos(q_i)) - c_3}^2 \]

Suspension ratio \( R_{i} = \frac{K_{Y1}}{K_{L1}} \quad R_{10} = 1.607 \text{ at static ride height} \)

**B. Kinematic Analysis - Results**

![Graph of suspension ratio vs wheel travel]

**REFERENCE**