

## AUPC3004 VEHICLE DYNAMICS (3-0-0)

### Course Objectives:

1. To provide a comprehensive understanding of the dynamic behavior of road vehicles.
2. To analyze and model longitudinal, vertical, and lateral vehicle responses.
3. To explore the influence of suspension, tyres, and steering systems on vehicle ride and handling.
4. To introduce computational tools (e.g., MATLAB) for vehicle dynamics simulation.

### Module - I: Introduction to Vehicle Dynamics (06 Hours)

Coordinate systems: sprung and unsprung mass reference frames. Modes of vehicle dynamics: longitudinal, lateral, vertical. Dynamic axle load transfer in braking, acceleration, and cornering. Aerodynamic forces acting on a vehicle: lift, drag, side force. Rolling resistance, aerodynamic drag reduction strategies. Ground effect and its implications on handling and high-speed stability.

### Module - II: Performance Mode (Longitudinal Dynamics) (08 Hours)

Tractive effort and resistance forces (aerodynamic, rolling, grade resistance). Force and power requirements for acceleration and cruising. Calculation of acceleration time, maximum speed, and gradeability. Braking performance analysis: braking force distribution, weight transfer. Stopping distance calculations and emergency braking scenarios. Anti-lock braking system (ABS) behavior and performance comparison.

### Module - III: Ride Mode (Vertical Dynamics) (10 Hours)

Types of vibrations: free, forced, damped. Basic vibration analysis of single-degree and two-degree freedom systems. Quarter car and half car models for vertical dynamics. Road profile and excitation modelling. Pitch and bounce motion equations and frequency response. Transmissibility and resonance conditions. Role of vibration absorbers and dampers. MATLAB modeling of quarter car suspension dynamics.

### Module - IV: Suspension System and Tyres (10 Hours)

Concept of sprung and unsprung mass dynamics. Suspension parameters: stiffness, damping, travel limits. Suspension types: passive, semi-active, and active systems. Wheel hop and bounce phenomena. Tyre properties: cornering stiffness, slip angle, longitudinal slip. Tyre models: empirical vs analytical – Magic Formula (Pacejka's model). Tyre force generation and aligning torque. Vehicle rollover and tip-over stability on slopes and curves.

### Module - V: Handling Mode (Lateral Dynamics) (09 Hours)

Steering system geometry: toe, camber, caster, kingpin inclination. Understeer, neutral steer, and oversteer conditions. Steady-state and transient cornering characteristics. Yaw rate, lateral acceleration, and sideslip angle. Yaw velocity gain and characteristic speed. Roll steer and compliance steer effects on directional control. Vehicle handling evaluation metrics. MATLAB simulation of lateral dynamics and handling behaviour.

### Course Outcomes (COs):

Upon successful completion of this course, students will be able to:

- CO1: Apply coordinate systems and force analysis to vehicle dynamics.  
CO2: Evaluate performance characteristics such as acceleration, braking, and gradability. CO3: Analyze ride quality using vibration models and interpret vehicle response.  
CO4: Investigate the role of tyres and suspension in handling and stability.  
CO5: Predict vehicle handling characteristics using steering geometry and computational models.

### Textbooks:

1. Thomas D. Gillespie – Fundamentals of Vehicle Dynamics, SAE International
2. J.Y. Wong – Theory of Ground Vehicles, Wiley
3. Rajesh Rajamani – Vehicle Dynamics and Control, Springer

### Reference Books:

1. Reza N. Jazar – Vehicle Dynamics: Theory and Application, Springer
2. Hans B. Pacejka – Tire and Vehicle Dynamics, Butterworth-Heinemann
3. William F. Milliken and Douglas L. Milliken – Race Car Vehicle Dynamics, SAE