VEHICLE DYNAMICS

ENAM 412

Lecture : 3 **Year : IV**
Tutorial : 0 **Part : I**
Practical : 3/2

Course Objectives:
The objective of this course is to provide concepts of vehicle longitudinal, lateral and vertical dynamics, including the mechanics of tractive effort, aerodynamic forces and braking stability. The course enables students to analyze and model vehicle performance through mathematical equations and computational simulations.

1 Introduction (5 hours)

1.1 Types of force acting on vehicle
1.2 Tractive forces on the driving wheel
1.3 Transmission efficiency
1.4 Traction characteristics of a motor vehicle
1.5 Road, rolling and air resistance on a motor vehicle
1.6 Equation of motion of a motor vehicle
1.7 Powertrain Modeling: Engine torque-speed curve, gear ratio effect

2 Traction Dynamics of Motor Vehicle (5 hours)

2.1 Force and power balance
2.2 Dynamic axle loads
2.3 Load transfer during acceleration, braking, constant velocity motion, condition of traction
2.4 Layout analysis as per engine placement; Front and rear engine, front and rear wheel drive
2.5 Slip mechanics: Longitudinal and lateral slip

3 Aerodynamics of a Motor Vehicle (4 hours)

3.1 Mechanics of airflow and pressure distribution on a motor vehicle
3.2 Aerodynamics force and drag component
3.3 Aerodynamics aids
3.4 Drag side force and lift force
3.5 Pitch, yawing and rolling moment
3.6 Crosswind sensitivity

4 Dynamic Performance of Motor Vehicle (5 hours)

4.1 Power-limited acceleration based on; Engine, power train, final drive ratio and automatic transmission
4.2 Traction-limited acceleration (Transverse weight shift due to drive torque, traction limits)
4.3 Acceleration due to traction force
4.4 Gradient climbing, coasting, overtaking
4.5 EV acceleration characteristics

5 Braking Dynamics of a Motor Vehicle (8 hours)

5.1 Introduction to braking dynamics
5.2 Basic equations of motion of a motor vehicle; Constant deceleration with wind resistance
5.3 Braking properties of a motor vehicle braking forces on wheels
5.4 Equation of a motor vehicle during braking
5.5 Characteristics of a motor vehicle braking dynamics: Braking deceleration, braking time and braking distance
5.6 Braking force distribution between the wheels
5.7 Requirement of braking performance, braking proportioning, rear wheel lock up, regenerative braking
5.8 Braking methods, braking efficiency on ABS, mechanical and hydraulic braking system
5.9 Slip during braking

6 Stability of a Motor Vehicle (6 hours)

6.1 Steering geometry
6.2 Steady-state handling characteristics of a two-axle vehicle: Neutral steer, understeer, oversteer
6.3 Steady-state response to steering input: Yaw velocity response, lateral acceleration response, curvature response
6.4 Lateral dynamics model: Bicycle model (2 DOF)
6.5 Testing of handling characteristics: Constant radius test, constant speed test, constant steer angle test
6.6 Directional stability, electronic stability control

7 Steerability of a Motor Vehicle (4 hours)

7.1 Steerability characteristics, force analysis during steering
7.2 Wheel lateral slip and ability of a motor vehicle to turn
7.3 Four-wheel steer: Low-speed turning, high-speed cornering
7.4 Ackermann steering geometry (With derivation)
7.5 Steering effort and self-aligning torque

8 Suspension System in Motor Vehicle (8 hours)

8.1 Suspension types
8.2 Design and analysis of passive, semi-active and active suspension using quarter car, bicycle model, half car and full car model
8.3 Natural frequency and damping ratio, ride comfort criteria
8.4 Influence of suspension stiffness, suspension damping and tire stiffness
8.5 Roll axis
8.6 Roll center analysis for various suspensions

Practical (22.5 hours)

1. Simulation of vehicle using CarSim or MATLAB/Simulink (Vehicle dynamics toolbox) or Dynacar
2. Simulation of longitudinal vehicle dynamics under various road conditions
3. Analysis of acceleration performance of a motor vehicle
4. Evaluation of braking distance and stopping time under different road friction conditions
5. Anti-lock braking system (ABS) performance using simulation
6. Design and analysis of brake force distribution between front and rear axles
7. Simulation of quarter car suspension model for ride comfort analysis
8. Estimation of aerodynamic drag force and its effect on vehicle performance
9. Case study on vehicle dynamics performance of a selected vehicle

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	5	6
2	5	6
3	4	6
4	5	8
5	8	10
6	6	*8*
7	4	*6*
8	8	10
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Chhikara, A. (2014). Automobile engineering: Automobile chassis and systems (Vol. 2). Satya Prakashan.
2. Crouse, W. H. & Anglin, D. L. (2017). Automotive mechanics (10th ed.). McGraw Hill Education.

3. Gillespie, T. D. (2021). Fundamentals of vehicle dynamics (Revised ed.). SAE International.
4. Giri, N. K. (2015). Automobile mechanics (10th ed.). Khanna Publishers.
5. Jazar, R. N. (2025). Vehicle dynamics: Theory and application (5th ed.). Springer.
6. Rajamani, R. (2012). Vehicle dynamics and control (2nd ed.). Springer.
7. Wong, J. Y. (2022). Theory of ground vehicles (5th ed.). John Wiley & Sons.