

# Automotive Mechanics in EVs

## *Syllabus and Question Bank*

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### **Fundamentals of Vehicle and Tire Dynamics**

Introduction to Vehicle Dynamics - Basic principles and concepts, Importance in overall vehicle performance - Tire Dynamics - Suspension Systems - Vehicle Load Transfer - Steering Mechanisms - Impact on Vehicle Dynamics - Influence of steering system design on handling characteristics - Steering response and feedback - Simulation and Modeling - Tools for simulating vehicle and tire dynamics - Case Studies - Analysis of real-world vehicle dynamics scenarios.

### **Vehicle Components and Mechanics**

Chassis and Frame Design - Structural design considerations, Impact on vehicle dynamics and safety - Brake Systems - Dynamics of braking and brake force distribution, Advanced braking technologies (ABS, EBD) - Powertrain Layouts - Different powertrain configurations (FWD, RWD, AWD) - Systems engineering approach to vehicle design - Practical Exercises - Hands-on projects to analyze and improve vehicle mechanics

### **Vehicle Stability Control and Aerodynamics**

Introduction to Vehicle Stability Control - Principles of stability control systems, Importance for safety and performance - Dynamic Stability Control Systems - Electronic Stability Control (ESC) and Traction Control Systems (TCS) - Basics of wind tunnel testing, Analyzing and optimizing aerodynamic performance - Case Studies - Examples of aerodynamic optimization in modern EVs, Lessons learned from industry leaders

### **Dynamics of Electric and Hybrid Vehicles**

Electric and Hybrid Powertrain Dynamics - Differences between ICE and electric/hybrid powertrains, Dynamics of electric motors and regenerative braking - Energy Management in EVs - Strategies for efficient energy use, Impact on vehicle dynamics and performance - Hybrid Vehicle Dynamics - Interaction of electric and ICE components, Control strategies for optimal performance - Thermal Management Systems - Practical exercises using advanced simulation tools - Case Studies - Analysis of successful electric and hybrid vehicle designs, Insights from industry applications

### **Handling, Ride Quality, and Stability Analysis**

Handling Characteristics of EVs - Factors influencing vehicle handling, Techniques for improving handling performance - Ride Quality Analysis - Importance of ride comfort in EVs, Methods for evaluating and enhancing ride quality - Vehicle Stability Analysis - Techniques for assessing vehicle stability - Tools and techniques for dynamic optimization, Practical exercises in vehicle dynamics optimization - Case Studies - Real-world examples of handling, ride quality, and stability improvements.

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1. What is the role of vehicle dynamics, and why is it important for Electric Vehicles (EVs)?
2. Explain how Tesla's torque vectoring system enhances vehicle agility.
3. What is the effect of aerodynamic drag on a vehicle? Explain the influence of frontal area and skin effect.
4. Describe the concept of torsional rigidity in a vehicle chassis.
5. What is the importance of the ride quality of the vehicle?
6. Explain how chassis stiffness influences handling and NVH.
7. What is the importance of the motor in an EV?
8. How do you relate vehicle speed and steering ratio in terms of vehicle stability? Briefly explain the interaction.
9. Explain the importance of the aerodynamic center in the vehicle dynamics.
10. Explain how simulation models are used to forecast the likelihood of a vehicle flipping over

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11. Discuss the energy management strategies employed in hybrid vehicles to optimize fuel efficiency.
12. Explain the working principles of an Anti-lock Braking System (ABS) and its impact on braking performance.
13. What is the difference between sprung mass and unsprung mass?
14. Explain how varying road surface conditions (e.g.,  $\mu$ -split) affect vehicle stability.
15. Examine how braking behaviour impacts the safety of electric vehicles
16. What is the function of the suspension system?
17. Explain the importance of the braking system in the vehicle.
18. Describe how ESC systems mitigate oversteer and understeer.
19. Explain the role of the yaw rate sensor in an Electronic Stability Control (ESC) system.

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20. Discuss the advantages and disadvantages of different drivetrain configurations (FWD, RWD, AWD) in EVs.
21. What is the purpose of the traction control system?
22. Analyze the factors that influence a tire's relaxation length and discuss its significance in transient handling maneuvers.
23. What is the relationship between slip and the coefficient of friction in the context of ABS and TCS control ranges? Explain with a plot.
24. Review industrial examples to assess the performance of Electronic Stability Control.
25. What are the critical factors that affect a vehicle's handling characteristics?
26. Discuss successful EV designs focusing on energy management.
27. Critically analyse handling improvements in modern EVs.
28. Explain how regenerative braking influences the dynamics of EVs.

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29. Explain how Porsche's PDCC system minimizes body roll during cornering.
30. How will you Calculate the aerodynamic drag force and power required for an EV?
31. Compare and contrast the torque delivery characteristics of electric motors and ICEs.
32. What is meant by "one pedal control" in EVs, and which Original Equipment Manufacturer (OEM) initiated it?
33. Explain the continuous and peak operating points of torque and speed through a graph. How do these points relate to a drive cycle?
34. What are the various tires used in vehicles? Is any special compounding required for EV tires?
35. Explain how regenerative braking works in an electric vehicle?
36. Derive the load distribution expressions along the front and rear axles of a vehicle on a ramp inclined to the road.
37. Discuss the importance of accurate tire modeling in vehicle dynamics simulations.

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38. Explain the concept of energy absorption in a vehicle structure and how it applies to the vehicle chassis.
39. Explain how a low centre of gravity contributes to improved handling in EVs.
40. What is the significance of oversteering and understeering in vehicle dynamics? Explain with simple sketches and how EVs adjust them automatically.
41. Analyse the principles of aerodynamic downforce generation and its effect on vehicle stability.
42. What are the different types of light-weighting materials used in EVs?
43. Explain the difference between series, parallel and combined hybrid vehicle.
44. Explain the working principles of Electronic Brakeforce Distribution (EBD) and its benefits over traditional braking systems.
45. How would you assess ride quality in a vehicle? Provide a detailed analysis.

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46. Discuss the role of suspension tuning in optimizing the balance between handling and ride comfort.
47. What is the importance of steering geometry parameters in achieving better vehicle manoeuvrability? Illustrate and explain three key parameters.
48. Explain how the aerodynamic drag is distributed across various regions of the vehicle body.
49. What is the role of King Pin Inclination in vehicles, and why is it important?
50. What is a drive cycle? Provide examples of internationally recognized drive cycles.
51. How does the Hotchkiss drive impact vehicle dynamics and its importance in vehicle design?
52. How does regenerative braking contribute to the energy efficiency of EVs?
53. Analyze the impact of regenerative braking on the longitudinal dynamics and energy efficiency of EVs.

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54. Describe the factors that contribute to the subjective perception of "ride quality."
55. Analyze the key parameters used to quantify and assess vehicle stability.
56. Discuss the challenges and innovations in integrating multiple vehicle subsystems to achieve optimal overall vehicle dynamics performance in modern EVs.
57. Derive the equation for lateral load transfer during steadystate cornering.
58. What is meant by slip? How does the slip angle affect vehicle dynamics? Discuss the forces associated with the slip angle.
59. Discuss the role of Phase Change Materials (PCMs) in ride comfort.
60. Explain the importance of ergonomic design in EVs, and its relevance to operation and ride comfort.
61. Describe the importance of Hotchkiss drive in vehicles.
62. Discuss the structural parameters that give Electric Vehicles an advantage over Internal Combustion Engine (ICE) vehicles.

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63. Provide a brief explanation of the relationship between vehicle speed and steering ratio, including how they interact to influence vehicle stability.
64. List the key factors influencing vehicle handling.
65. In the context of vehicle dynamics, explain the significance of the "Magic formula" using the characteristic curve.
66. Discuss the role of simulation tools in analysing tire dynamics with suitable examples
67. With simple sketches, illustrate and explain any three steering geometry parameters and their effect on vehicle manoeuvrability.
68. How does regenerative braking work in an electric vehicle?
69. How do structural parameters in electric vehicles offer distinct advantages over traditional ICE vehicles?
70. What is the Energy Management System in EVs? Provide a brief explanation.
71. Explain the dynamics of an EV motor.

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72. What is regenerative braking in EVs, and how is energy management carried out during the braking process?
73. How is manoeuvrability related to handling quality in vehicles?
74. What are the different sensors used in modern EVs to enhance ride comfort?
75. What is the importance of thermal management systems in EVs? Explain in detail.
76. With a block diagram, explain the required modules in an ECU to ensure vehicle stability.
77. Explain the thermal management system used in EVs and how it helps in maintaining optimal performance.
78. What is a battery cooling system in EVs? Provide a circuit diagram to explain its functioning.
79. Discuss the aerodynamic drag influenced by the frontal area and skin effect in detail.
80. Explain in detail the "Magic Formula" used in analysing tire behavior.

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81. What is the significance of camber angles and toe-in/toe-out in steering? Illustrate with simple sketches.
82. What are the methods adopted to reduce NVH (Noise, Vibration, and Harshness) in vehicles?
83. How is vehicle stability achieved in modern EVs? Explain the technologies used.
84. Describe the role of height adjustment in modern vehicles and explain with a simple sketch.
85. What is a battery charging system in EVs, and what types of wireless charging are used?
86. With a simple diagram, explain the Visco-Elastic nature of tires and its impact on rolling resistance.
87. What are the powertrain configurations used in EVs? Provide examples.
88. Explain the fundamental difference between longitudinal and lateral load transfer in a vehicle.
89. Describe the "friction ellipse" concept and its implications for tire behavior during combined braking and cornering.

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90. What is the aerodynamic drag?
91. Explain the importance of the aerodynamic center in the vehicle dynamics.
92. Compare and contrast the torque delivery characteristics of electric motors and ICEs.
93. Explain how regenerative braking influences the dynamics of EVs.
94. Analyse the challenges and strategies involved in thermal management for EV battery packs.
95. How does a hybrid vehicle work?
96. Discuss the energy management strategies employed in hybrid vehicles to optimize fuel efficiency.
97. Explain the influence of battery pack placement on the overall dynamics of an EV.
98. What is the importance of the motor in an EV?
99. Explain the difference between series, parallel and combined hybrid vehicle.

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100. Explain how a low centre of gravity contributes to improved handling in EVs.
101. Describe the factors that contribute to the subjective perception of "ride quality."
102. Analyze the key parameters used to quantify and assess vehicle stability.
103. What is the importance of the ride quality of the vehicle?
104. Discuss the role of suspension tuning in optimizing the balance between handling and ride comfort.
105. Explain the concept of "limit handling" and its importance in vehicle dynamics testing.
106. What is the importance of the handling performance of the vehicle?
107. Explain the role of the stability analysis of the vehicle.
108. Derive the equation for lateral load transfer during SteadyState cornering.

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109. Explain how tire cornering stiffness ( $C_\alpha$ ) affects a vehicle's understeer/oversteer gradient.
110. Describe how the natural frequency of a suspension system influences ride comfort.
111. Analyse the factors that determine a vehicle's stopping distance during emergency braking, including relevant equations.
112. Explain how Tesla's torque vectoring system enhances vehicle agility.
113. Discuss the design considerations for optimizing aerodynamic efficiency in EVs, including the trade-off between drag and downforce.
114. Explain how Porsche's PDCC system minimizes body roll during cornering.
115. Analyse the impact of regenerative braking on the longitudinal dynamics and energy efficiency of EVs.

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116. Compare and contrast the chassis design philosophies of two different OEMs (e.g., BMW vs. Toyota) and their effects on vehicle handling.
117. Discuss the challenges and innovations in integrating multiple vehicle subsystems to achieve optimal overall vehicle dynamics performance in modern EVs.
118. Define "slip angle" and "slip ratio" in the context of tire dynamics.
119. Explain how varying road surface conditions (e.g.,  $\mu$ -split) affect vehicle stability.
120. Discuss the importance of accurate tire modeling in vehicle dynamics simulations.
121. What is the role of the steering system in the vehicle dynamics?
122. Explain the impact of the steering ratio on the handling of the vehicle.
123. Analyze the working principles of Electronic Brakeforce Distribution (EBD) and its benefits over traditional braking systems.

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124. Explain the systems engineering approach to vehicle design and its relevance to achieving optimal vehicle dynamics.
125. Describe how ESC systems mitigate oversteer and understeer.
126. Discuss the importance of minimizing aerodynamic drag in EVs to enhance range.
127. What is the aerodynamic drag?
128. Analyze the challenges and strategies involved in thermal management for EV battery packs.
129. How does a hybrid vehicle work?
130. Discuss the energy management strategies employed in hybrid vehicles to optimize fuel efficiency.
131. Explain the influence of battery pack placement on the overall dynamics of an EV.
132. What is the importance of the motor in an EV?
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152. Define "slip angle" and "slip ratio" in the context of tire dynamics.
153. Explain how varying road surface conditions (e.g.,  $\mu$ -split) affect vehicle stability.
154. Discuss the importance of accurate tire modeling in vehicle dynamics simulations.
155. What is the role of the steering system in the vehicle dynamics?
156. Explain the impact of the steering ratio on the handling of the vehicle.

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157. Calculate the initial kinetic energy, the recovered energy, and the total charge stored in the battery during regenerative braking for a vehicle of 1,800 kg traveling at 90 km/h.
158. If an electric vehicle has a frontal area of 2.3 m<sup>2</sup>, a drag coefficient of 0.27, and air density of 1.225 kg/m<sup>3</sup>, calculate the aerodynamic drag force when the vehicle is traveling at 90 km/h. Also, calculate the power required to overcome this drag, assuming the motor efficiency is 90%.
159. Perform the needed Thermal management calculations the EV, Tesla Model 3 (Standard Range Plus) with the following specifications:
  - Battery capacity = 60 kWh
  - Voltage = 350V
  - Current during discharge = 200A
  - Internal resistance = 0.004 Ω
  - Battery efficiency = 92% (0.92)
  - Time = 1 hour (3600s)
  - Coolant: Water-Glycol mixture
  - Target temperature rise in coolant = 8°C

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- Air cooling system area =  $2.5 \text{ m}^2$
- Air heat transfer coefficient =  $45 \text{ W/m}^2\cdot\text{K}$

154. Write briefly on Crash analysis and the related software.

155. Evaluate the role of aerodynamics in improving EV efficiency with industry case studies.

156. Critically analyse methods to improve handling in EVs with real-world examples.

157. Discuss a real-world case study where poor steering feedback led to safety issues.

158. Discuss stability optimization techniques using simulation tools.

159. Evaluate the role of systems engineering in integrating vehicle components.

160. Discuss lessons learned from the aerodynamic optimization in Tesla EVs