Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	VEHICLE DYNAMICS
COURSE CODE	:	BNG 32003
PROGRAMME CODE	:	BNG
EXAMINATION DATE	:	JULY 2024
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

Q1 Vehicle dynamics is a part of automotive development method that focuses on studying the behavior and performance of a vehicle while it is in motion. It involves analyzing various characteristics to ensure that the vehicle meets the desired performance standards

(a) List **FOUR (4)** vehicle motion and its behavior which define vehicle dynamic.

(4 marks)

(b) Explain **THREE (3)** classification of fundamental approach to vehicle dynamics.

(6 marks)

(c) Brakes are critical in vehicle dynamics, ensuring safety and performance. Engineers analyze braking principles, types, forces, and efficiency factors to enhance systems. Factors like brake design, tire traction, and road conditions influence efficiency.

(i) A car has a total weight of 1300 kg and is traveling at a speed of 80 kilometer per hour. If the brakes can apply a force of 50,000 Newton per square meter and the brake piston has an area of 0.02 square meter for one brake. Each brake consists of one brake piston. Calculate the kinetic energy, *KE* require to fully stop the car and estimate force is being applied to each brake pads when the brakes are fully applied.

(5 marks)

(ii) Explain the effects of tire adhesion and hysteresis during tire contact with the road in terms of vehicle dynamics.

(4 marks)

(iii) A vehicle is traveling at a speed of 72 km/h and comes to a stop after skidding for several meters (time taken to 0 km/h is 5 seconds). The vehicle's mass is 1200 kg. Determine the coefficient of friction between the tires and the road surface and the braking stopping distance.

(6 marks)

Q2 Aerodynamics and related resistances are integral components of vehicle dynamics, influencing how vehicles move and perform. Resistances, including drag and rolling resistance, impact acceleration, braking, and overall energy consumption.

(a) Bernoulli's principle explain that vehicle shape can achieve lift because of the shape of its body. Based on Bernoulli's principle, define downforce and drag force by using an aid of diagram.

(4 marks)

(b) Aerodynamic drag is a force which the oncoming air applies on a moving body. Based on aerodynamics concept, describe and draw the effect of flow separation in point of view of automotive application.

(3 marks)

(c) A sports car is moving at 126 km/h on a racetrack. The car's spoiler is designed to increase the speed of the airflow over the top surface, thereby reducing the air pressure and creating downforce that helps keep the car stable on the track. After installation of the speed sensor, the speed of the airflow is 180 km/h and 108 km/h for bottom and top of the spoiler respectively. Calculate the aerodynamic downforce created by the airflow over the vehicle's body using Bernoulli's principle. Given Air density (ρ) is 1.225 kg/m^3, Spoiler top surface area (A) is 2.0 m^2, atmospheric pressure (P_{atm}) is 101325 Pa.

(6 marks)

(d) Aerodynamics is critical in EV design, enhancing energy efficiency and range by reducing drag and optimizing airflow. Let say you are designing an electric vehicle (EV) for a university project. The vehicle has a mass (m) of 1000 kg and a drag coefficient (C_d) of 0.3. The frontal area (A) of the vehicle is 2.5 square meters. The density of air (ρ) is 1.2 kg/m^3.

(i) Calculate the drag force (D_A) acting on the EV when it is moving at a speed of 25 m/s.

(3 marks)

(ii) If the EV is also experiencing a rolling resistance force (F_{rr}) of 500 N, calculate the total resistive force acting on the EV.

(3 marks)

(iii) Use the total resistive force to determine the acceleration (a) of the EV.

(3 marks)

(e) Explain the concept of rolling resistance in vehicle dynamics and provide the relevant equation.

(3 marks)

Q3 Vehicle dynamics involves understanding how vehicles move and respond to different conditions. The vehicle model predicts these behaviors, while steady-state cornering examines a vehicle's balance during a turn, including forces like lateral acceleration and tire traction, essential for stable handling.

(a) The quarter car model suspension system is a well-known and valuable tool for studying vehicle comfort and vertical motion within the context of vehicle dynamics. With appropriate diagram, derive quarter car suspension system model which represent sprung acceleration, $\ddot{x}_1$ and unsprung acceleration, $\ddot{x}_2$.

(6 marks)

(b) Tire slip angle is a part of important parameter which to improved vehicle handling. Define slip side angle of the tire with drawing aid and explain the effect on lateral force and slip angle.

(4 marks)

(c) Heavy vehicles were found to be easily roll-over during an event of high-speed cornering. High roll moment distribution is one of the causes. List **THREE (3)** parameters or methods which can reduce vehicle roll moment.

(3 marks)

(d) Lateral forces arise when a vehicle turns or changes direction, exerting a force perpendicular to the direction of motion. Let's say a car is driving along a circular track of radius 100 meters at a constant speed of 72 km/h. However, the track is banked at an angle of 10 degrees. If the coefficient of friction between the car's tires and the track is 0.5. Calculate is the maximum safe speed that the car can maintain without slipping off the track. Assume the car's weight is 1500 kg.

(12 marks)

Q4 Steering is crucial in vehicle dynamics, allowing drivers to control direction via the steering wheel. Suspension, integral to vehicle dynamics, supports the vehicle's weight, absorbs road shocks, and maintains tire contact for stability and comfort. Together, these systems play a vital role in ride and handling performance.

(a) The solid axle, or beam axle, is a robust rod that is a crucial component in a vehicle's suspension system. It connects the wheels on the same side of the vehicle and helps maintain stability and control during driving.

(i) Describe the purpose of dependent suspension in vehicles and provide an example of a vehicle that uses dependent suspension.

(3 marks)

(ii) With an aid of diagram, differentiate the differences between **TWO (2)** types of independent suspensions.

(6 marks)

(b) Passive, semi-active, and active suspensions each has its own set of advantages and disadvantages. By using table, differentiate between semi active and active vehicle suspension.

(4 marks)

(c) The vehicle dynamics are influenced by longitudinal tire forces, aerodynamic drag forces, rolling resistance forces and gravitational forces. Based on simple vehicle model:

(i) Draw forces and related dimension acting on the simple vehicle model.

(4 marks)

(ii) Derive vertical forces acting on front tire, F_{z1} and rear tire F_{z2}.

(8 marks)

- END OF QUESTIONS -

APPENDIX A

$$\eta_b = \frac{D_{act}}{\mu_p}$$

$$\mu_p = \frac{F_{f@r}}{W_{f@r}}$$

$$D_A = \frac{1}{2}\rho v^2 C_D A$$

$$L_A = \frac{1}{2}\rho v^2 C_L A$$

$$S_A = \frac{1}{2}\rho v^2 C_s A$$

$$PM = \frac{1}{2}\rho v^2 C_{PM} AL$$

$$YM = \frac{1}{2}\rho v^2 C_{YM} AL$$

$$RM = \frac{1}{2}\rho v^2 C_{RM} AL$$

$$\delta = \frac{L}{R}$$