

Midterm Assignment

Course: **Vehicle Dynamics**

Instructor: **Dr. Pillapakkam**

Student: **Jakob Werle**

Submission Date: **2024-04-01**

# Contents

[Contents 2](#_Toc162888912)

[Assignment Description 2](#_Toc162888913)

[Part 1: 2](#_Toc162888914)

[Part 2: 3](#_Toc162888915)

[Questions 3](#_Toc162888916)

[Question 1: 3](#_Toc162888917)

[Question 2: 3](#_Toc162888918)

[Question 3: 3](#_Toc162888919)

[Question 4: 4](#_Toc162888920)

[Question 5: 4](#_Toc162888921)

[Question 6: 4](#_Toc162888922)

[Question 7: 4](#_Toc162888923)

[Question 8: 4](#_Toc162888924)

[Question 9: 4](#_Toc162888925)

[Question 10: 5](#_Toc162888926)

[Question 11: 5](#_Toc162888927)

[Question 12: 5](#_Toc162888928)

[Question 13: 6](#_Toc162888929)

[Question 14: 6](#_Toc162888930)

[Question 15: 6](#_Toc162888931)

[References 7](#_Toc162888932)

# Assignment Description

## Part 1:

Theoretical response to the questions posed. Much of this was solved in  
class, so the challenge here is not so much to replicate it, but to read beyond what  
was presented in the class and in doing so, gain a better understanding and develop  
the ability summarize the concepts in words in addition to symbolic derivations.

## Part 2:

This part of the assignment is shorter in terms of page count, it is the  
more research-intensive part of the assignment. Read widely about your response  
to each question from at least 3 peer-reviewed articles, book chapters or engineering  
standards. Then you are responsible for adding footnotes to your response in Part  
1. The notes should be a mixture of 1) definitions of terms or words you are unfamiliar with 2) fundamentals concepts from physics or math that would help a reader  
understand the context 3) critical interpretations or implications of results. Please  
include a minimum of 3 notes per each question. Include citations with each note  
where relevant. This part must contain a properly formatted bibliography in APA  
format. Use of database such as Google Scholar for formatting the bibliography is  
encouraged.

# Questions

## Question 1:

Prove that under acceleration, load is transferred to the rear axle. What is tractive  
force? Using the expression for Wf and Wr, obtain an expression for maximum  
tractive force.

## Question 2:

Prove that under braking, load is transferred to the front axle. What is ideal braking  
force? What is the maximum deceleration and minimum braking distance that can  
be achieved?

## Question 3:

Describe the principle behind Gough’s testing machine. What are the observations  
from Gough’s tests?

In the early 1950’s, Gough developed a testing apparatus to characterize the behavior of tires as a function of lateral loading and tire slip. Simply put, the machine imposed a lateral load onto a thin rolling tire while its deflection was recorded by printing the tire contact patch onto paper. The main take away from Gough’s test was that the perpendicular force calculated from the stress distribution along the tire print matched the lateral force placed on the wheel’s axle (Milliken & Milliken, 1995). Milliken & Milliken also describe four other observations from Gough’s tests:

1. *Pneumatic Trail* defines the distance aft of the print centerline, at which the tire’s lateral force is centralized. This distance works to create an *aligning torque* when multiplied by the lateral force.
2. Lateral slippage of the tire happens towards the back of the print and is dependent on sliding velocity and slip angle.
3. By photographing the test at high speed through a glass plane, the low speed testing results were generally confirmed to be accurate.
4. The lateral force characteristics of tires in the elastic range are largely independent of rolling speed, which confirms the usage of low speed testing.

## Question 4:

Describe the relationship between (i) Lateral force and slip angle (ii) Aligning torque  
and slip angle.

## Question 5:

Define longitudinal stiffness.

## Question 6:

What is a tire friction ellipse? Explain the key feature of a friction ellipse.

## Question 7:

Why are tire models necessary? Interpret one of the foremost tire models used  
extensively - the Magic Formula tire model.

## Question 8:

Define slip, grip and rolling resistance.

## Question 9:

Define the following suspension components with a help of a sketch: (i) axle (ii) Ball  
joint (rod end) (iii) Steering axis or kingpin axis (iv) Knuckle or upright (v) Scrub  
radius (vi) Kingpin offset (vii) Steering-axis inclination angle (Kingpin inclination  
angle).A diagram of a line drawing

Description automatically generated with medium confidence

Figure 1 - Suspension Component Diagram

1. Axle – the axis that the wheel and tire spin around
2. Ball joint – also defined as “pick-up points”, these are the theoretical end points of control arms and tie-rods at which they articulate
3. Kingpin axis – the axis defined by the upper and lower outboard pick-up points, which the upright and wheel turns about
4. Upright – the component that houses outboard pick-up points and attaches the wheel/tire to the vehicle
5. Scrub radius – the distance between the tire contact patch and intersection between the kingpin axis and ground plane, which creates a moment arm when coupled with the tire forces
6. Kingpin inclination angle – the angle created by the kingpin axis and the vertical plane when looking at the car’s front view

## Question 10:

Obtain an expression for and explain the forces and moment at the contact patch  
that create total moment about the kingpin axis.

## Question 11:

Define the following: (i) Eulerian viewpoint (ii) Lagrangian viewpoint (iii) Material  
derivative

## Question 12:

Derive the conservation of mass and momentum equations for a fluid.

## Question 13:

Derive the dimensionless version of Navier-Stokes equation. Define and interpret  
Reynolds number.

## Question 14:

Define lift and drag force. Define the dimensionless lift and drag coefficients and the  
characteristic area used in its calculation.

## Question 15:

What is no-slip boundary condition? For an external flow past an object, (i) Define  
boundary layer (ii) With the help of a sketch, describe how the thickness of the  
boundary layer changes with Reynolds number.

# References

Milliken, W. F., & Milliken, D. L. (1995). *Race car vehicle dynamics*. SAE International.