AuE-ME 4600-6600 (Fall 2022) – Homework
Assignment #6

Reference:	Lecture 11/12/13 & Lecture 18/19
Due Date:	11/10/22, at midnight

Vehicle Parameters:

Mass:	1637 kg
Yaw inertia:	3326 $kg - m2$
Wheelbase:	2.736 m
Trackwidth:	1.7 m
Weight distribution:	60% to front
Front cornering stiffness:	1500 N/deg per tire (static load)
Rear cornering stiffness:	1146 N/deg per tire (static load)
Steering ratio:	15: 1 (15 degree at the steering wheel = 1 degree at the front wheel)
CG height:	2.4 ft

Maneuver Description:

In this assignment, you are required to simulate the bicycle model for 2 different maneuvers that are described below. Based on the description, for each maneuver, you should create a vector of inputs for the simulation

1) The roadwheel steering angle is the input to your bicycle model. In the first maneuver, provide a step input for this steering angle. The vehicle is first being driven down a straight line at 74 mph for 7 seconds after which the driver holds the handwheel position constant at 45 degrees for 60 seconds. The handwheel position is then returned to 0 degrees and the maneuver is terminated

2) The second maneuver is called the "fishhook maneuver" where you need to gradually increase the steering angle. To begin this maneuver, the vehicle is first driven in a straight line at 50mph. The driver must attempt to maintain this speed for 5 seconds. After that, the handwheel position is linearly increased from 0 to 270 degrees at a rate of 14.5 degrees per second. The handwheel position is held constant at 270 degrees for 4 seconds, after which the maneuver is concluded. The handwheel is then returned to 0 as a convenience to the driver.

Problem 1 Simulation (pts)

Part A:

Now let's revisit the HW 5 problem 3, extend the bicycle model developed in HW5 problem 3 to determine the position of the CG as well as the direction of the velocity vector in the world (inertial) coordinate frame. For each maneuver, provide a plot for the trajectory of the vehicle. Clearly indicate the location of CG and the velocity vector, at an interval of 1 second, for the complete maneuver. (2 plots in total)

Assume that the CG is laterally in the middle of the vehicle, i.e., the static load is equally distributed to the left and to the right.

Part B:

Now it is time to include the effects of Lateral load transfer on cornering stiffnesses of front and rear axle, perform the simulation. Assume that the roll stiffness distribution is the same as the weight distribution

The relationship between cornering stiffness and normal load is given as

$$C_\alpha = a * F_Z + b * F_z{}^2$$

$$F_z = normal\ load\ in\ N$$

$$C_\alpha = cornering\ stiffness\ in\ {}^{N}\!/_{deg}$$

The following tabular data can be used to find the coefficients *'a'* and *'b'*.

Cornering Stiffness (N/deg)	Normal load (N)	Cornering Stiffness (N/deg)	Normal load (N)
848	2200	1461	4600
972	2600	1531	5000
1088	3000	1593	5400
1195	3400	1645	5800
1292	3800	1689	6200
1381	4200	1723	6600
		1748	7000

Problem 2

In problem 1, the bicycle model was simulated assuming a linear tire model for a given load (of course, it is nonlinear model with respect to F_z). For this part, a non-linear tire model (nonlintire.m) is being provided to you. This tire model accepts an argument in the format (α, F_z, v) where α is the slip angle, F_z is the normal load, and v is the longitudinal velocity of the wheel center, and returns a lateral force, Fy.

The given nonlinear tire model produces forces according to the non-adapted ISO system, i.e., assuming negative cornering stiffness. However, our models are derived assuming positive cornering stiffness, i.e., positive slip angles correspond to positive forces. Therefore, you have to make the tire model compliant with your model.

Part A:

Using this non-linear tire model, for each maneuver, simulate the states of the bicycle model and determine the position of CG as well as the direction of the velocity vector in the inertial coordinate frame. Provide plots for the states as well as the trajectory of CG and direction of velocity vector – i.e., total 6 plots

Part B:

1. Calculate the Understeer Gradient (UG) of fishhook maneuver and step input without load transfer

2. From the Fishhook maneuver, determine the sublimit Understeer Gradient (UG) with load transfer. Comment on the limit behavior.

3. Now assume a roll stiffness distribution of 70% rear 30% front and perform the same analysis as in section 2 of Part B. Comment on the results.

NOTE: In your report, clearly mention your approach, the equations used, and your observations along with the plots of your result. Attach your MATLAB code in the appendix of the report for reference