**ANSWER 1A:**

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| --- | --- |
| **Maneuver 1** | **Maneuver 2** |
|  |  |

We can observe that the step input results in a straight-circle-straight maneuver and fishhook maneuver results in a straight-spiral-straight motion where the radius of spiral keeps decreasing.

**ANSWER 1B:**

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| --- | --- |
| **Maneuver 1** | **Maneuver 2** |
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|  |  |

From the tabular data, the values of coefficients are, a = 25.6349 rad-1 and b = -0.0016178 rad-1N-1

We can observe that when we account for load transfer, the understeering behavior of the vehicle increases, resulting in corner with increased radius. However, we can see that since we are still using a linear tire model, this can lead to numerical instabilities in cases where the lateral acceleration is too high.

**NOTE:** If we look at lateral acceleration vs. time plots for both maneuvers, we can observe that for 1st maneuver, the maximum lateral acceleration achieved is slightly greater than 1g. However, for 2nd maneuver, the lateral acceleration becomes about -2.25e265 m/s2 (which is due to numerical instability and not practical).

Chart, line chart

Description automatically generated

If we closely observe, for the 2nd maneuver (refer to plot above) without load transfer, we can see that the maneuver demands a peak lateral acceleration of more than 5g, which is high, but can still be handled by linear tire model (since we are not accounting for lateral acceleration anywhere in the linear steady state model). However, when we plug in the load transfer equations, as ay keeps increasing there comes a point where the Fz for left (inner) tires becomes negative! This causes the cornering stiffness values to become negative, which in turn cause the state variables to become negative and ultimately makes ay negative in next iteration. This continues until values blow up to NaN and as a result, the simulation stops without completion of maneuver.

**ANSWER 2A:**

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| **Maneuver 1** | **Maneuver 2** |
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|  |  |
| Chart, histogram, box and whisker chart  Description automatically generated | Chart  Description automatically generated |

**NOTE:** The above plots were generated using the non-linear tire model while accounting load transfer assuming roll stiffness distribution of 60% front and 40% rear.

We can clearly observe that when we account for load transfer and use non-linear tire model, the understeering behavior of the vehicle increases further, resulting in corner with further increased radius.

**ANSWER 2B-1:**

UG for Maneuver 1 with Non-Linear Tire Model is 0.003700 rad sec2 m-1

UG for Maneuver 2 with Non-Linear Tire Model is 0.002029 rad sec2 m-1

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| --- | --- | --- |
| Maneuver 1 | Chart  Description automatically generated | Chart  Description automatically generated |
| Chart, bubble chart  Description automatically generated |  |
| Maneuver 2 | Chart  Description automatically generated | Chart, line chart  Description automatically generated |
| Chart, line chart  Description automatically generated | Chart, line chart  Description automatically generated |

**NOTE:** The above plots were generated assuming roll stiffness distribution of 60% front and 40% rear. We can see that when we disregard load transfer but use non-linear tire model, the radius of the corner increases as compared to 1A.

**ANSWER 2B-2:**

UG for Maneuver 2 with Non-Linear Tire Model and Load Transfer (with roll stiffness distribution of 60% front and 40% rear) is 0.002719 rad sec2 m-1

Looking at variation of lateral force vs. slip angle plots for front & rear tires (with load transfer), and assuming same tire quality (i.e., same breakaway slip angle), we can observe that since the slope of the lateral force vs. slip angle plot in the linear region (i.e., cornering stiffness) of rear tire is less than that of the front tire, it will saturate (reach maximum lateral force) before the front tire, indicating that the vehicle will be limit oversteer.

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Since roll stiffness and load distribution are same, more (magnitude) load transfer will be resisted by more (magnitude) roll stiffness and hence we see expected behavior of increased understeering gradient (larger corner radius) as compared to 2B-1.

**ANSWER 2B-3:**

UG for Maneuver 2 with Non-Linear Tire Model and Load Transfer (with roll stiffness distribution of 30% front and 70% rear) is 0.000938 rad sec2 m-1

Looking at variation of lateral force vs. slip angle plots for front & rear tires (with load transfer), and assuming same tire quality (i.e., same breakaway slip angle), we can observe that since the slope of the lateral force vs. slip angle plot in the linear region (i.e., cornering stiffness) of rear tire is less than that of the front tire, it will saturate (reach maximum lateral force) before the front tire, indicating that the vehicle will be limit oversteer.

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Since roll stiffness and load distributions are not same, rather the roll stiffness is less where there is more load and vice versa, more (magnitude) load transfer will be resisted by less (magnitude) roll stiffness and hence we see somewhat unstable vehicle motion.