AuE/ME 4600/6600: Dynamic Performance of Vehicles

Fall 2022 – Final Exam
Take-Home Part (70 pts.)

<u>DUE:</u> 12/13/2022 – 12:00pm (noon) – NO EXTENSIONS

<u>Problem 1:</u> Stability Derivatives (15 points)

Consider a bicycle model vehicle with the following parameters ***(SAE)***:

- 40% front weight
- 10 ft wheelbase
- The vehicle is known to be neutral steer.

The vehicle is driven in a steady-state fashion with the following conditions:

  - Velocity = 66 ft/s
  - Steer angle = - 40 deg at the steering wheel
  - Steering ratio = 16
  - Stabilizing yaw moment (including static and dynamic contributions) = 3200 lb.-ft
  - Yaw rate = -12 deg/sec

Determine the following

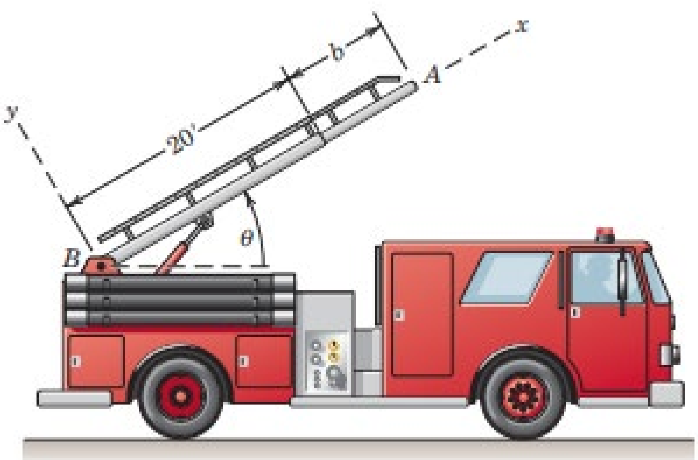
1. Static stability derivative
2. Control moment derivative
3. Yaw damping derivative
4. Front and rear cornering stiffnesses
5. Path radius

Problem 2: Transport theorem (10 points)

A fire truck is moving forward at a speed of 35 miles/hour and is decelerating at the rate of 10 ft/sec^2. Simultaneously, the ladder is being raised and extended. At the instant considered below, the angle of the ladder is 30º and is increasing at the constant rate of 10 deg/sec. Furthermore, at this instant shown, the ladder extension b is 5 ft, with $\dot{b} = 2\ ft/s$ and $\ddot{b} = -1\ ft/sec^2$.

For this instant, determine the acceleration of the end A of the ladder

a. With respect to the truck and
b. With respect to the ground.

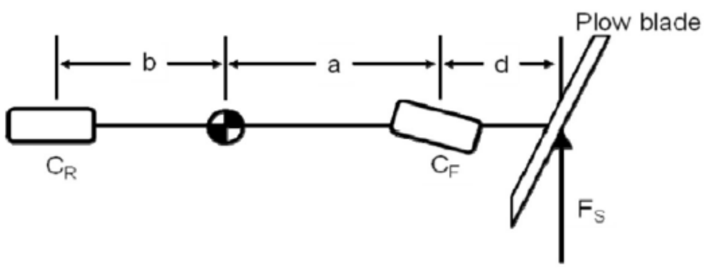


Fire truck with a ladder

Problem 3: 2DoF Bicycle Model with load transfer (20 points)

A (linear) Bicycle Model of a snowplow is shown below, with a sketch of the real vehicle at the right. The snow is applying a constant lateral force F_s to the vehicle.
Here are the vehicle parameters:

- Weight = 40,000 lbs.
- Weight distribution: 40% front
- Roll distribution: 45% front
- Wheelbase: 15 fts
- Speed: 50 mph
- Distance d: 4 fts
- Snow Force, F_s: 1000 lbs.
- Height of CG: 4.7 ft.
- Trackwidth: 9 ft.



This vehicle is traveling at steady state in a circular motion with a radius of 500 ft. Determine the equations of motion for this system.

Part A:

For this part, ignore the lateral load transfer completely and determine:

A. Ackermann Steer Angle
B. Lateral Acceleration
C. Yaw Rate
D. Front Lateral Force
E. Rear Lateral Force
F. Front Slip Angle
G. Rear Slip Angle
H. Total Yaw Moment
I. Vehicle Sideslip Angle
J. Steer Angle

The relationship between cornering stiffness and normal load of the tires is given as follows:

$$C_\alpha = a * F_z - b * {F_z}^2$$
$$a = 0.2196; b = 7.35 \times 10^{-6}$$
F_z in lb and C in lb/deg

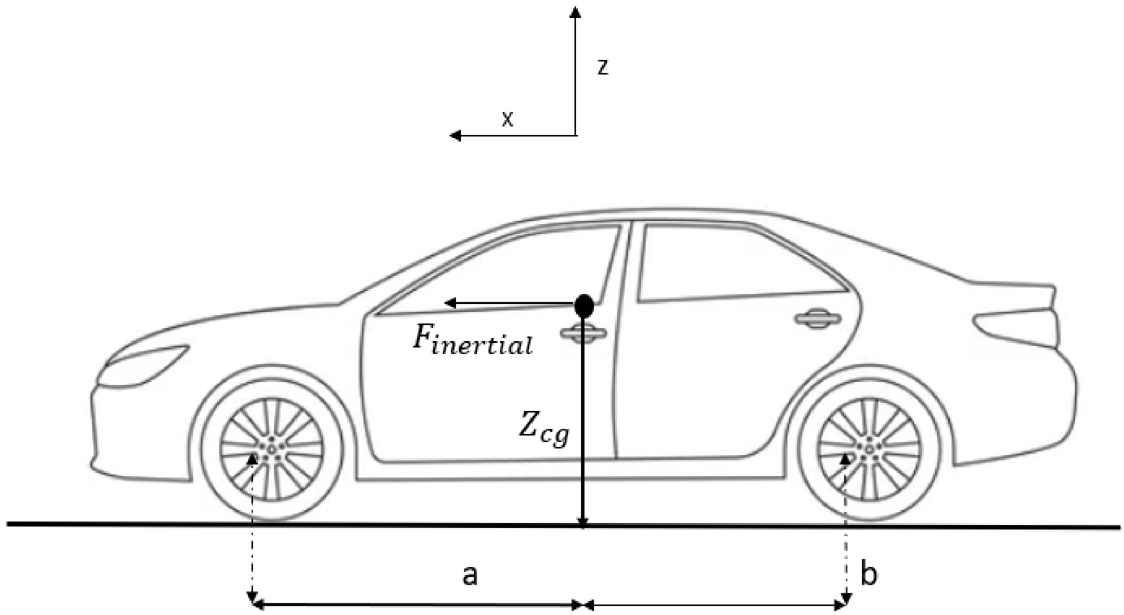
Part B:

Consider the effects of lateral load transfer on normal load of tire with given roll distribution. Repeat Part A.

Compare the results of Part A and Part B and comment on it.

<u>Problem 4:</u> Longitudinal Load Transfer and Simulation (25 points)

Part A (Rigid body load transfer):



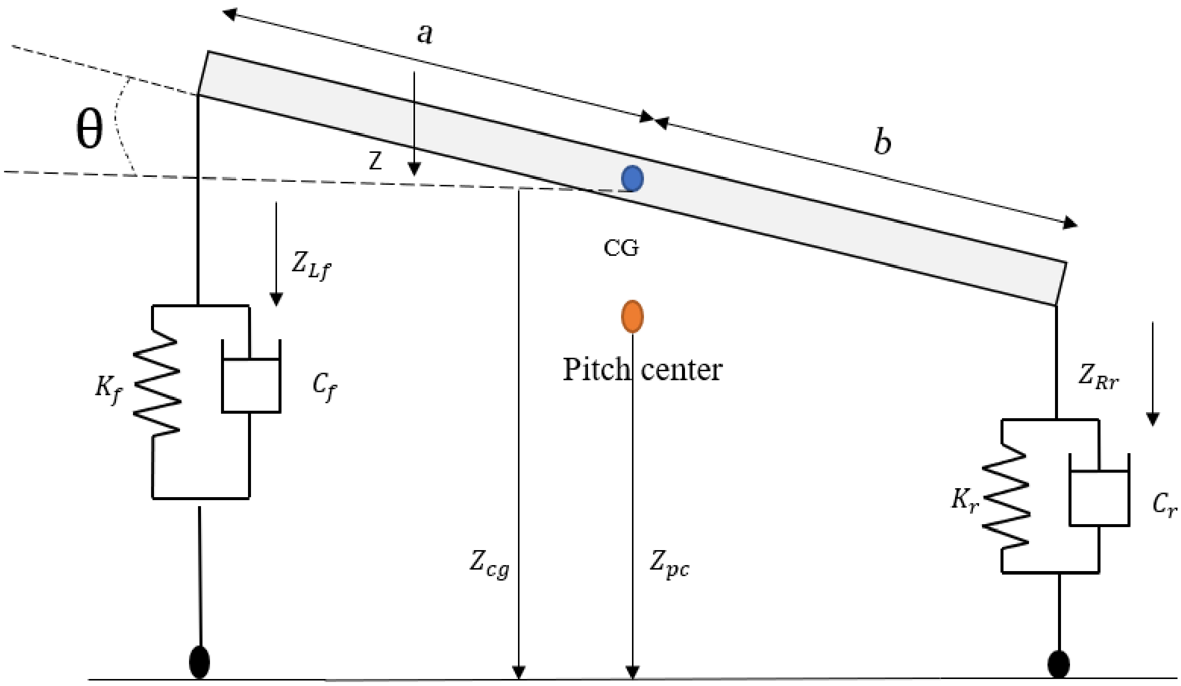
Schematic diagram of car

A. Determine the four static wheel loads for a car with the following parameters: mass: 143 slugs, front weight: 54 %, left weight: 52%, diagonal weight: 500 N
B. Given the vehicle configuration in the figure, derive an expression for the total rigid body load transfer while braking.
C. With the above parameters and a CG height of 2.3 ft, front, and rear track width of 5.25 ft, wheelbase 9.45 ft, Determine the total amount of load transferred from the rear tires to the front tires when the vehicle is braking at 0.5g!
D. At what longitudinal acceleration will all the load be transferred to the front wheels in a straight-line motion?

Part B (Pitch Dynamics):

Derive the equations of motion for a 1 Degree of Freedom (DoF) pitch model. Use the following figure as a reference to develop the equations and apply small angle approximations (linear model).

(Hint: Take inspiration form the model developed for body roll)



1-DoF pitch model

Part C (Simulation):

Parameters:

- Pitch center height from ground = 1.5 ft.
- I_{yy} = approximately 40 % of a rectangular block's (L x W) mass moment of inertia about a transversal axis
- Suspension stiffness
    - Rear: 52 kN/m
    - Front: 45 kN/m
- Initial damping: 0
- Consider the data provided from .mat file which consists of the following information
    - time – seconds
    - acceleration – measured at the CG of vehicle (m/s^2)
    - ride height sensor – placed on top of the suspension strut (m), front and rear
    - velocity – measured in (m/s)

A. Perform a simulation of the derived model and plot the states of the system for step input for an acceleration of – 2 m/s^2.
B. Now, determine the damping coefficient by simulating your above model with the measured acceleration from the data file as an input. Tune the value of damping coefficient manually until you have 'good' agreement between measured and simulated data (start with a reasonable value and calculate the coefficient of damper for left and right (assuming they are equal) such that system's states settle down).