Design Task 1

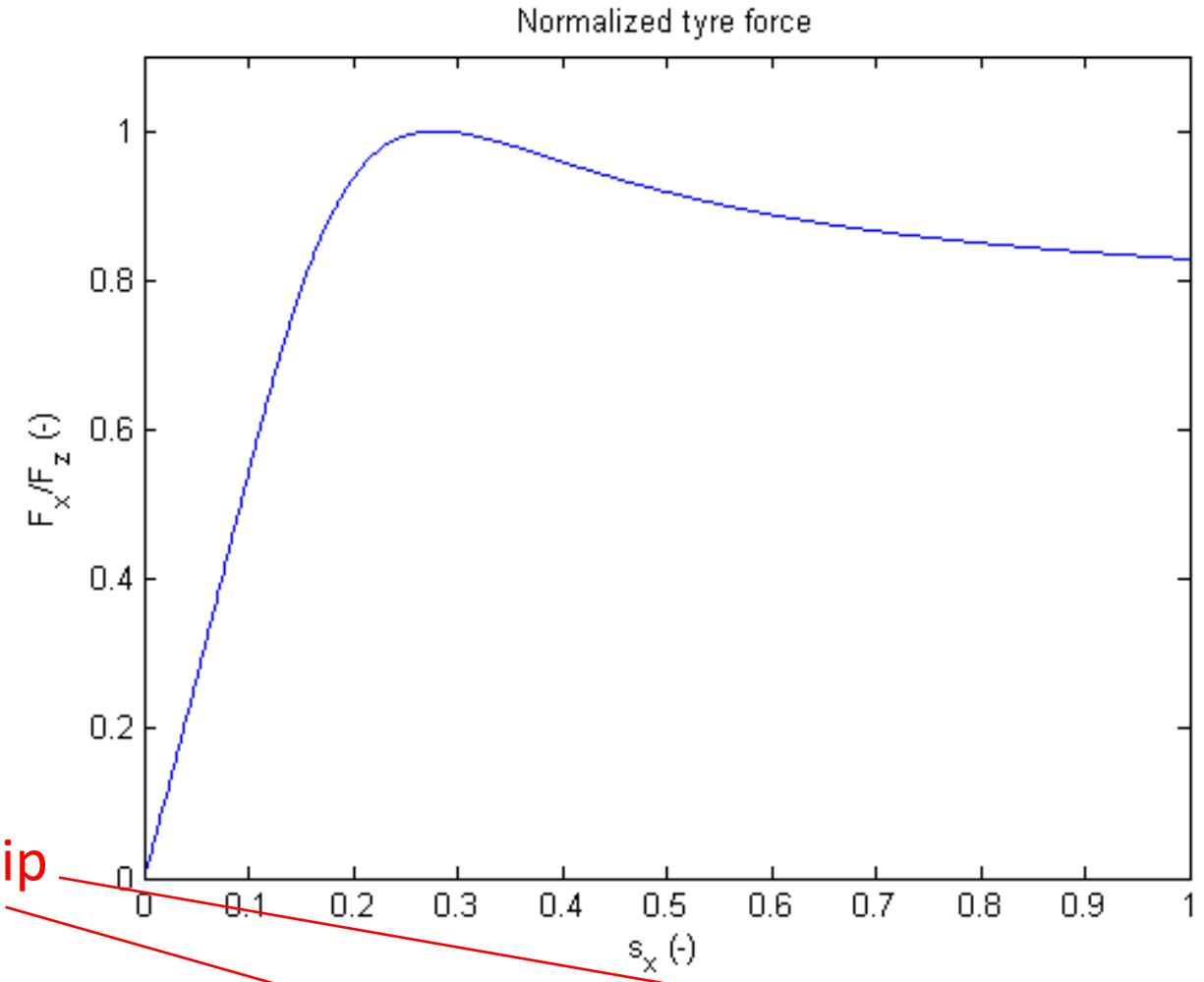
Longitudinal dynamics

Design task objectives

- Model tyres and road surface conditions using a slip model.
- Model longitudinal vehicle dynamics using load transfer and resistive forces.
- Learn how to work with ordinary differential equations numerically.

Task 1

Tyre characteristics for different road conditions (1 p)



Semi-empirical magic tyre formula

Normalized traction force (utilized μ)

Longitudinal slip

$$\frac{F_x}{F_z} = D \cdot \sin\left(C \cdot \arctan\left(B \cdot s_x - E \cdot (B \cdot s_x - \arctan(B \cdot s_x))\right)\right)$$

Task 1a, 1b

A. Plot the normalized traction force for the full slip range

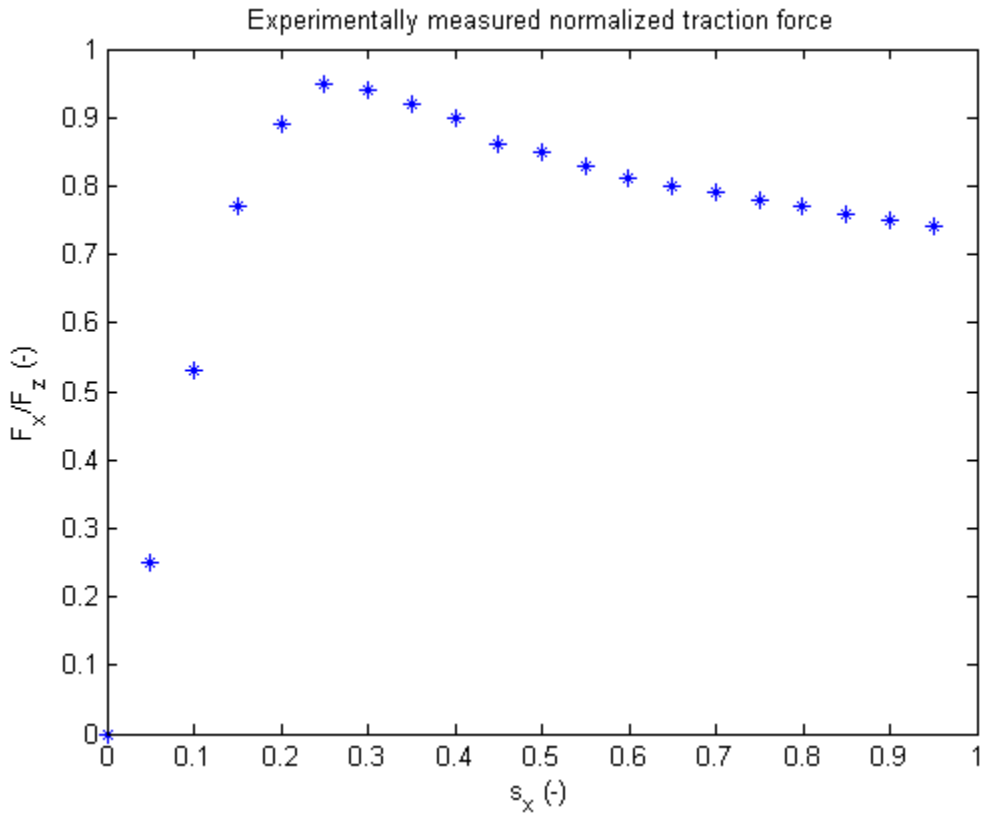
	D	C	E
Dry asphalt	1.00	1.45	-4.00
Wet asphalt	0.60	1.35	-0.20
Ice	0.10	1.50	0.80

B. Fit the MTF to experimental data

Task 1a, 1b

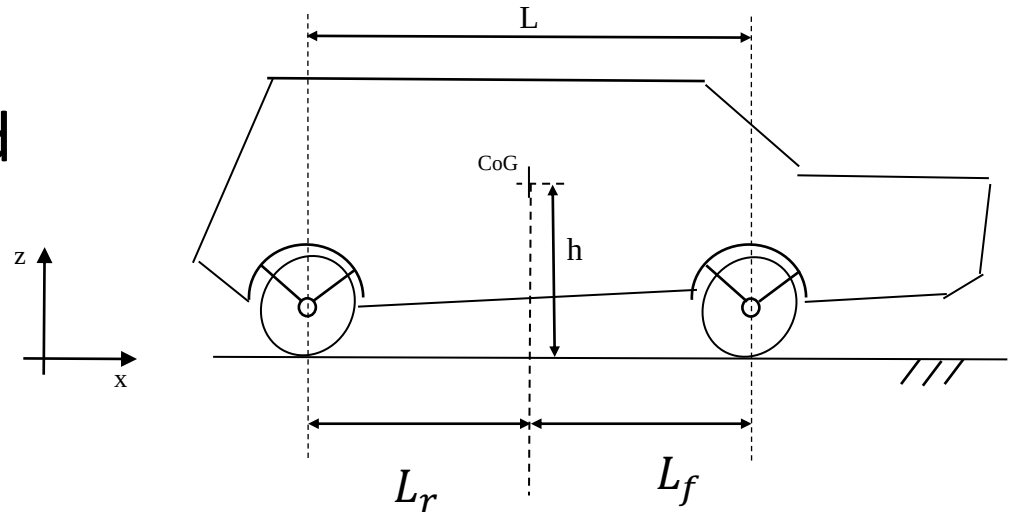
s_x	F_x/F_z
0.00	0.0
0.05	0.25
0.10	0.53
0.15	0.77
0.20	0.89
0.25	0.95
0.30	0.94
0.35	0.92
0.40	0.90
0.45	0.86

s_x	F_x/F_z
0.50	0.85
0.55	0.83
0.60	0.81
0.65	0.80
0.70	0.79
0.75	0.78
0.80	0.77
0.85	0.76
0.90	0.75
0.95	0.74



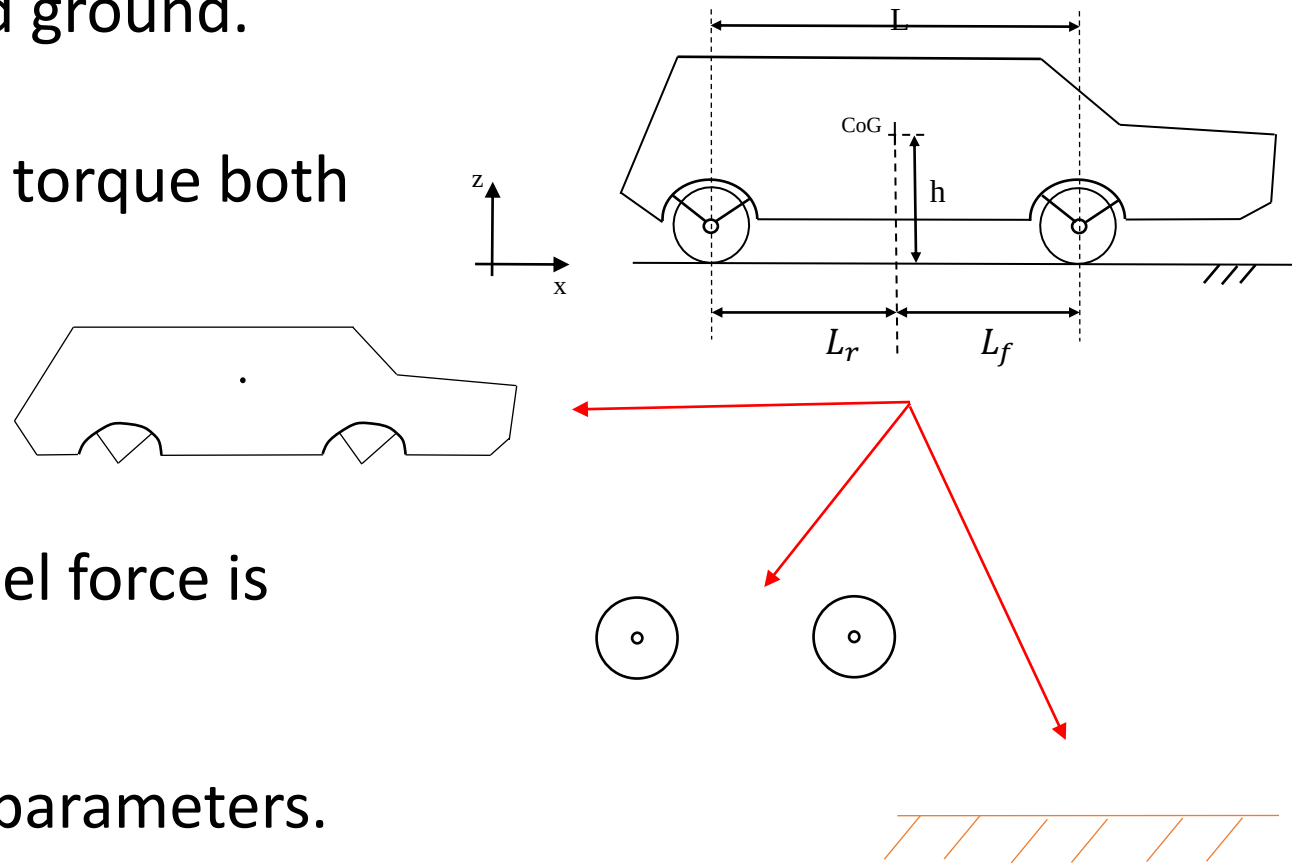
Vehicle model (5 p)

- Find the equations of motion using Newtonian mechanics
  - Use a bicycle vehicle model
  - Rigid suspension: no rotation around the y-axis (pitch)
- Solve the system of equations
- Integrate the system using Euler method



Task 2a: Free body diagram

- Separate into chassis, wheel and ground.
- Assume that there is propulsion torque both on front and rear axle.
- Wheel mass negligible.
- Horizontal offset of vertical wheel force is small compared to wheel base.
- Show all relevant variables and parameters.



Task 2b: Derive the equations of motion

- Using the free body diagram, derive the equations.
  - Are any additional equations needed?

- Unknowns
  - Traction force on front axle F_{fx}
  - Traction force on rear axle F_{rx}
  - Normal force on front axle F_{fz}
  - Normal force on rear axle F_{rz}
  - Front wheel rotational acceleration $\dot{\omega}_f$
  - Rear wheel rotational acceleration $\dot{\omega}_r$
  - Vehicle linear acceleration $\dot{v}$

Task 2c, 2d

C. Account for road grade by rotating the coordinate system
   - Which equations change?

D. Solve the equations of motion to get explicit expressions
   - Either algebraically: manually or with MATLAB symbolic tool
   - Or numerically: “A\b”

$$A \cdot Y = b$$

$$A = \begin{bmatrix} & \cdots & \\ \vdots & \ddots & \vdots \\ & \cdots & \end{bmatrix}_{7\times 7} \qquad Y = \begin{bmatrix} F_{fx} \\ F_{rx} \\ F_{fz} \\ F_{rz} \\ \dot{\omega}_f \\ \dot{\omega}_r \\ \dot{v} \end{bmatrix} \qquad b = \begin{bmatrix} . \\ . \\ . \\ . \\ . \\ . \\ \end{bmatrix}_{7\times 1}$$

$$Y = A\backslash b$$

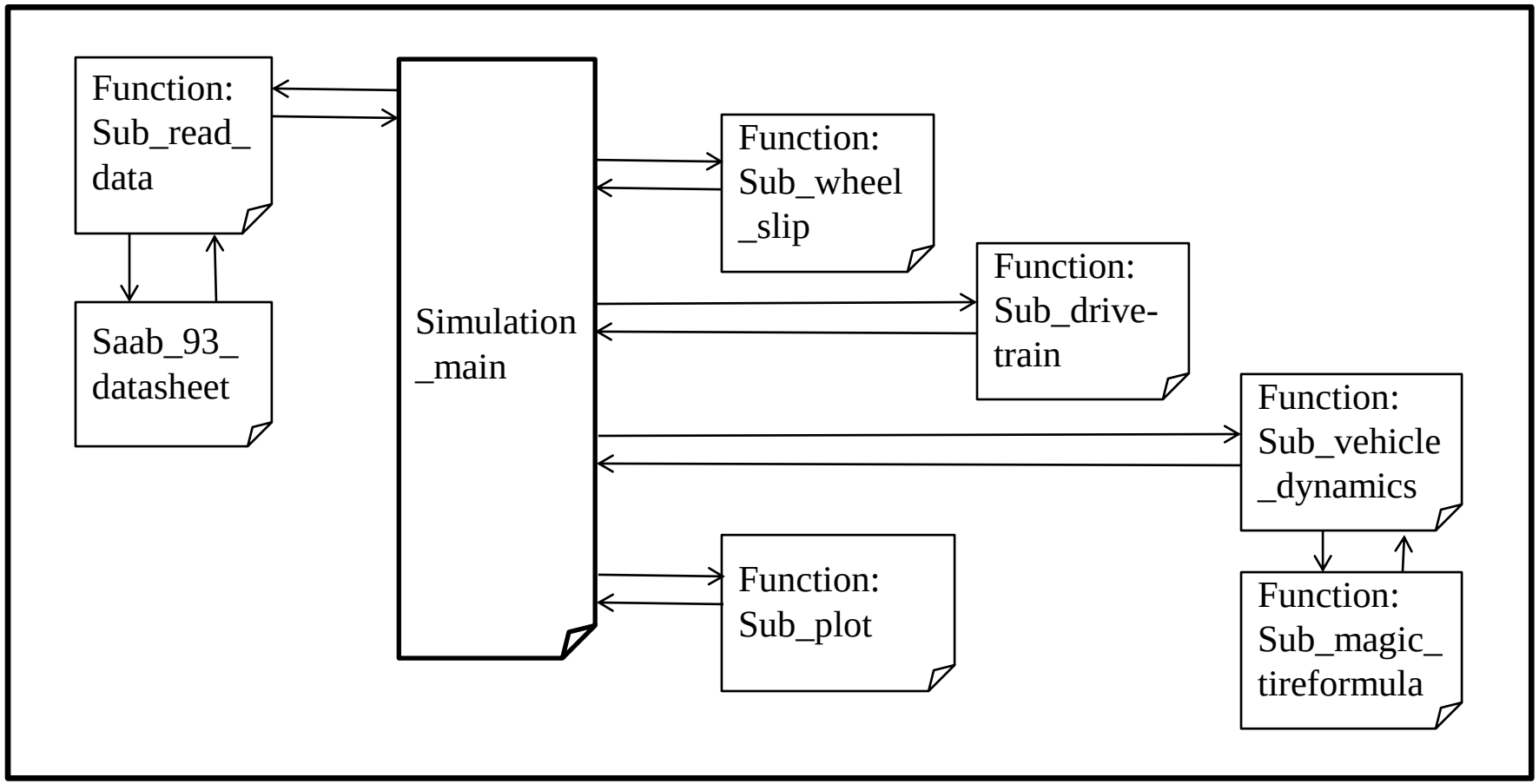
Task 2e,

- Implement the slip definition in one of the handed-out m-files.

Simulation of longitudinal dynamics (3 p)

- You are the chief engineer of a dragracing team (using a Saab 93)
- Find the best vehicle configuration
  - Possible to configure as either front wheel drive or rear wheel drive
- Investigate the influence of road friction

Vehicle model layout



Task 3a: Implement model and test run

- Go through the entire model
- Write your equations of motion in the file “Sub_vehicle_dynamics.m”
- Test it, play around!
- Present and evaluate the results in some scenario.

Task 3b: Choose best vehicle configuration

- The racing track is 100 m long and has an uphill slope of 8^{o}
- Naturally, you want to finish the tracks as quickly as possible
- Before the race you may change configuration between front wheel drive and rear wheel drive
- Weather forecasts predict that there might be rain: prepare for this too

What to hand in

- Design task report
  - Only formal requirements: specific front page and abstract
- Explain what you do
  - Are relevant equations included? Sketches? Tables? Graphs? Other pictures?
- Answer the RIGHT question
- Submit report as a pdf file together with code in a zip file on Canvas

  Name it: “Lastname1_firstname1_and_lastname2_firstname2”
- Hand in of .pdf-file
  - Name it: “Lastname1_firstname1_and_lastname2_firstname2”

General info

- Assistants:
  - Yansong Huang
  - Fredrik Bruzelius

- Maximum 10 points
  - Pass ≥ 4 points
- Work in pairs
- Due date: 17 Nov 2022, 23:59