1. **(max. 5 points)**
   Figure 1 shows a simplified quarter-car suspension system. k_s and b are the spring and damper coefficients of the suspension system, respectively. k_w represents the spring coefficient of the wheel. m_2 represents the so-called sprung mass of the car, and m_1 represents the so-called unsprung mass of the car. z_2 and z_1 represent the displacement of the sprung and unsprung mass, respectively. d is the displacement of the road with respect to a reference (that can also be called the measure of unevenness of the road's surface). To design a convenient suspension system, we are interested in the position of the sprung mass of the car (z_2) with respect to the unevenness of the road (d).

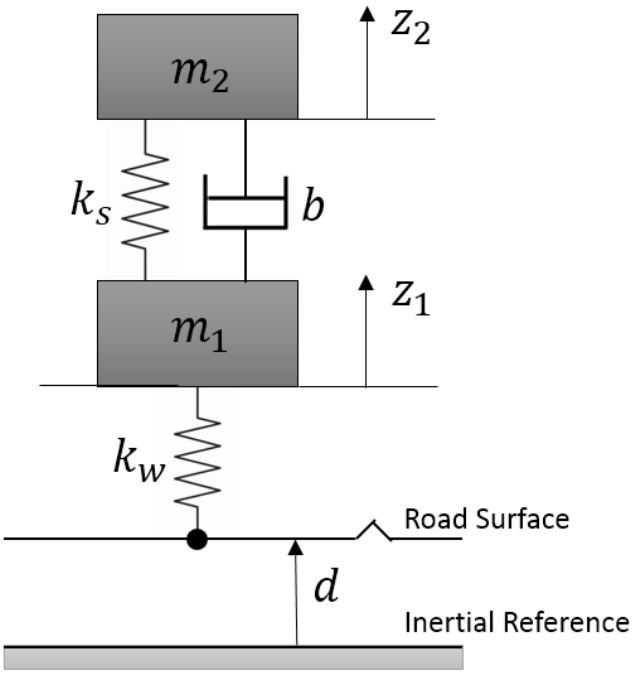

Figure 1 – Suspension system.

a) Based on the description of the system, structure the problem. You are supposed to answer these questions: What signal(s) are the output(s) of the system? What signal(s) are the input(s) of the system? What are the constants of the system? What are the internal time-varying variables of the system? **(0.5 points)**

b) Set up the basic equations of the system. You are supposed to derive the underlying differential equations of the system using first principles. **(1 point)**

c) In this part, your task is to solve the differential equations using MATLAB ODE solvers (e.g., ode45). First, create a MATLAB script named "SuspenseSystemODE.m". Constant initialization and plotting should be done in this script. In addition, SuspenseSystemODE.m" should call a function named "rhs.m", in which the right-hand side of the equations is defined. Plot the response of the system (z_1 and z_2) to the following function representing a bump on the road for 10 seconds:

$$d(t) = e^{-t}\sin(t)$$

Assume that initially the system is at rest. Use the parameters given in Table 1 below. **(1.75 points)**

Symbol	Value	Unit	Description
m_1	10	kg	Unsprung mass
m_2	350	kg	Sprung mass
k_w	500 000	N/m	Wheel spring coefficient
k_s	10 000	N/m	Suspension system spring coefficient
b	500	N · s/m	Damper coefficient

Table 1 – System parameters.

Note: The goal in this part is to solve the ODEs directly without using state-space or transfer function formulation!

d) Simulate the system in Simulink for 10 seconds. Save the Simulink model as "SuspenseSystem.mdl". Plot the response of the system (z_1 and z_2) to the input $d(t)$ given in (c). You should include all the constants used in the Simulink model in a separate file named "constants1.m". After executing this file, all the constants should be stored in MATLAB workspace. Save "constants1.m" for submission. **(1.75 points)**

2. (max. 5 points)
Consider the cruise control system with the throttle input u and the vehicle speed v as the output described in the file "CruiseControlSystem.pdf" in the Assignment 2 section in MyCourses.

a) Simulate the cruise control system in Simulink. Save the model as "cruiseSym.mdl". You should include all the constants used in the Simulink model in a separate file named "constants2.m". After executing this file, all the constants should be stored in MATLAB workspace. Save "constants2.m" for submission. **(2.5 points)**

b) For the gear ratio α_3, mass $m = 800$ kg and throttle input $u = 0.7$, what is the steady state value of the speed v, assuming that the road surface is flat? **(1 point)**
Tip: Steady state can be defined as the actual output as time tends to infinity.

c) Show the effect of a 5-degrees uphill ramp on the speed. What should the value of the throttle input be in order to have the same speed as on a flat road? Is there a need to change the gear ratio? **(1.5 points)**

What to return?

You are supposed to submit your assignment to the related link for Assignment 2 in MyCourses. Your submission should include one zip file "Assign02_student number.zip", consisting of a PDF file "Assign02_student number.pdf" and four MATLAB scripts, "SuspenseSystemODE.m", "rhs.m", "constants1.m", "constants2.m", and two Simulink models, "SuspenseSystem.mdl" and "cruiseSym.mdl".

The hard deadline for submission of this assignment is 6.10.2019 at 23:59.