

**Course: ELEC-E8103 Modelling, Estimation, and Dynamic Systems**

# EXAMINATION 21.03.2016

**The examination will start from 21.03.2016 12:00 to 21:00. Please submit your solutions to the exam section of the course page in [mycourses.aalto.fi](https://mycourses.aalto.fi) before the deadline. The exam will be carried out in student's own computer at home. The exam should be done individually, and **NO discussion is allowed**.**

## **Submission of the exam papers**

You should submit your solutions to the Exam section of the Aalto University Mycourses page: <https://mycourses.aalto.fi/course/view.php?id=5231&section=4>. Your submission should include a single zip file named as "surname\_studentNumber\_Exam.zip", consisting of a pdf file named "surname\_studentNumber\_Exam.pdf", and the following MATLAB files: "problem1.m", "problem1.mdl", "parameters.m", "problem2.m", and "sys01.sid", "sys02.sid", "sys03.sid", "sys04.sid", and "sys05.sid" for problem 3.

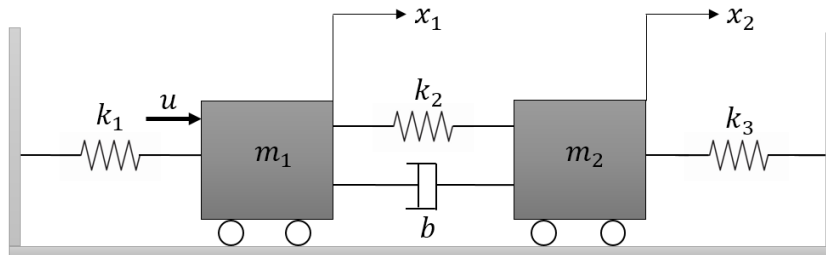
**The hard deadline for submission of the exam solutions is 21.03.2016 at 21:00.**

## **Hints**

The physical laws in the exam are already discussed in the exercise sessions of the course, especially sessions 2 and 6.

**Exam Questions:****1. (15 points)**

Figure 1 shows a mechanical system consisting of: two masses  $m_1$  and  $m_2$ ; three springs  $k_1$ ,  $k_2$ , and  $k_3$ ; and a damper  $b$ . The input  $u$  is the force applying to the system.  $x_1$  and  $x_2$  correspond to the positions of masses  $m_1$  and  $m_2$ . Assume the contact surfaces frictionless.



**Figure 1 – Mechanical system**

- Derive the dynamic model of the system in the form of differential equations.  
(2 points)
- Obtain the transfer functions  $X_1(s)/U(s)$  and  $X_2(s)/U(s)$  of the mechanical system.  
(3 points)
- Write the equations of motion (derived in part “1-a”) in the state-space form. Use the following vector  $X$  as the state vector.

$$X = [x_1 \quad \dot{x}_1 \quad x_2 \quad \dot{x}_2]^T$$

(3 points)

- Write a MATLAB script named “problem1.m”. Plot the positions of the masses ( $x_1$  and  $x_2$ ) after a unit step force ( $u$ ) is applied to the system. Assume the following values for the system parameters.

$$m_1 = 0.2 \text{ kg}$$

$$m_2 = 0.4 \text{ kg}$$

$$k_1 = 20 \text{ N/m}$$

$$k_2 = 10 \text{ N/m}$$

$$k_3 = 25 \text{ N/m}$$

$$b = 4 \text{ N.s/m}$$

(2 points)

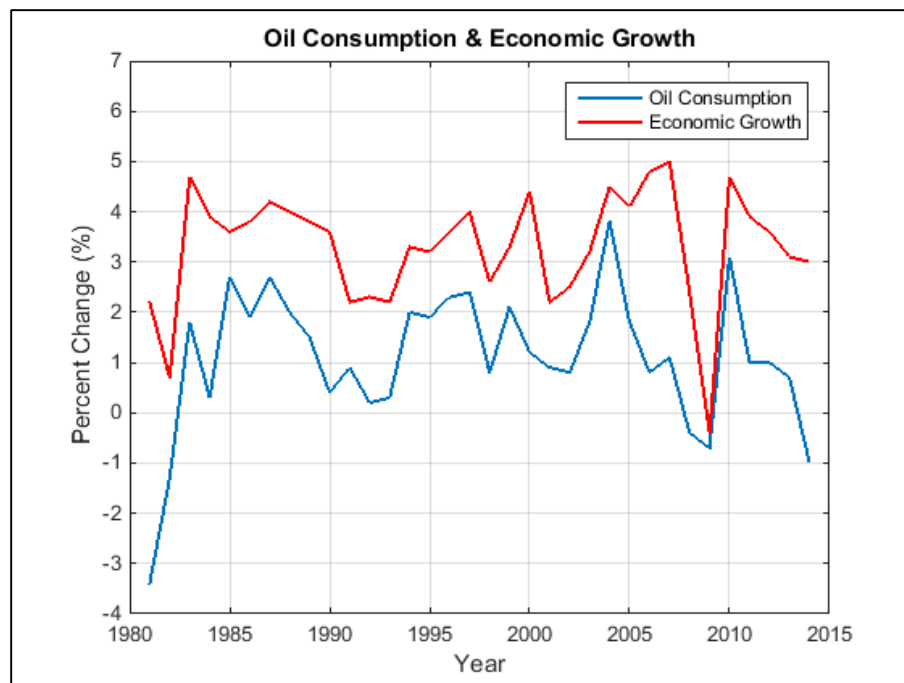
- e) Simulate the system in Simulink. Save the Simulink model as “problem1.mdl”. Plot the positions of the masses ( $x_1$  and  $x_2$ ) after a unit step force ( $u$ ) is applied to the system.

You should include all the used parameters in the Simulink model in a separate file. After executing this file, all needed parameters should be stored to MATLAB workspace. Save the mentioned script -including the parameters for your simulation- as “parameters.m”.

(5 points)

2. (10 points)

Figure 2 illustrates the percentage change in oil consumption and economic growth in US from 1981 to 2014. Load the data file “data2.mat”. The first, second, and third column of data correspond to year, oil consumption, and economic growth, respectively.



Write a script called “problem2.m”. The script should perform the following tasks:

- a) Analyze the relationship between oil consumption and economic growth **quantitatively**. Do you consider these parameters correlated or not? Discuss the method that you used in your analysis. Provide the required computations in your MATLAB script.

(5 points)

b) Estimate a polynomial model for predicting economic growth from oil consumption in US using MATLAB polynomial estimation functions, “polyfit” and “polyval”. What polynomial order do you choose for the given data? Why? (Tip: You may divide the given data to training and validation sets)

(3 points)

c) Plot the estimated function for year  $\epsilon [1981,2014]$  on the same scatter plot of data. Predict the economic growth in year 2015 assuming that the oil consumption percentage change was -0.5%.

(2 points)

### 3. (25 points)

**Copy the files “runExam.m”, and “modeldata.mat” in your MATLAB current folder. Run the “runExam.m” script.**

The following text should appear in your command window.

```
>> runExam
```

**Please Enter the numeric part of your student number!:**

Now, you should type your student number and press *Enter*. If your student number ends with an alphabetical letter, you should just type the numerical part of your student number, e.g. if your student number is 12345W, you should type 12345.

Then your data will be stored to MATLAB workspace. Data has been collected from five different dynamic systems. Input-output datasets are  $(u_1, y_1)$ ,  $(u_2, y_2)$ ,  $(u_3, y_3)$ ,  $(u_4, y_4)$ , and  $(u_5, y_5)$ .

Identify polynomial models of the mentioned systems using MATLAB System Identification Toolbox. You should explicitly select a model as your final answer for each input-output dataset.

You should explain the identification path in your final document. The identification path includes the following issues:

- What were the reason(s) for rejection of a specific model structure in your path?
- What were the reason(s) for selection of a specific model structure in your path?
- What are the alternative model(s) for the data if you think there are any?

You should validate your answers to the above-mentioned questions using required plots. You should include all validation test results for your final selected model for each system in your document.

Save the final identification session for each dynamic system as “sys01.sid” for  $(u_1, y_1)$ , “sys02.sid” for  $(u_2, y_2)$ , “sys03.sid” for  $(u_3, y_3)$ , “sys04.sid” for  $(u_4, y_4)$ , and “sys05.sid” for  $(u_5, y_5)$ .

The points will be given based on the resulted model structures and their orders, as well as the justification of the identification path.

(5 points for identification of each system, 25 points in total)