Controllability and Observability of Dynamic Systems (CO)

Entrance examination

376.051, LU, Mechatronic Systems Laboratory
Summer Semester, 2017

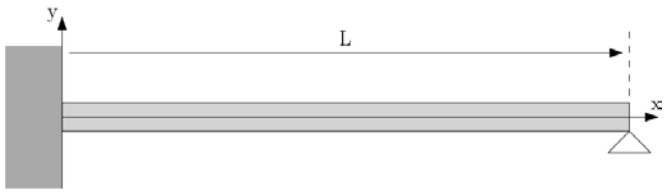

Figure 1

1. The mode shapes of the shown beam are expressed by the following equation:

$$Y_n(x) = A_n \sin(\beta_n x) + B_n \cos(\beta_n x) + C_n \sinh(\beta_n x) + D_n \cosh(\beta_n x).$$

The boundary conditions are:

$$(I): Y_n(0) = 0, \qquad (II): \left.\frac{dY_n(x)}{dx}\right|_{x=0} = 0, \qquad (III): Y_n(L) = 0, \qquad (IV): \left.\frac{d^2Y_n(x)}{dx^2}\right|_{x=L} = 0.$$

Use boundary conditions *(I)*, *(II)* and *(III)* to determine the expression of all mode shapes of the cantilever as a function of A_n, β_n and L. [1 point]

Hint 1:
$\frac{d}{dx}\sinh x = \cosh x, \qquad \frac{d}{dx}\cosh x = \sinh x$

2. Use boundary conditions *(III)* and *(IV)* to derive the transcendental equation to derive $\beta_n L$. Refer to Figure 2 to approximately determine the first two eigenvalues. [1 point]

Hint 2:
Sum and subtract the equations obtained from (III) and (IV) to obtain the solution.

3. Refer to Figure 3 to determine the position of the nodes and antinodes of the second and fourth mode shape. [0.5 points]

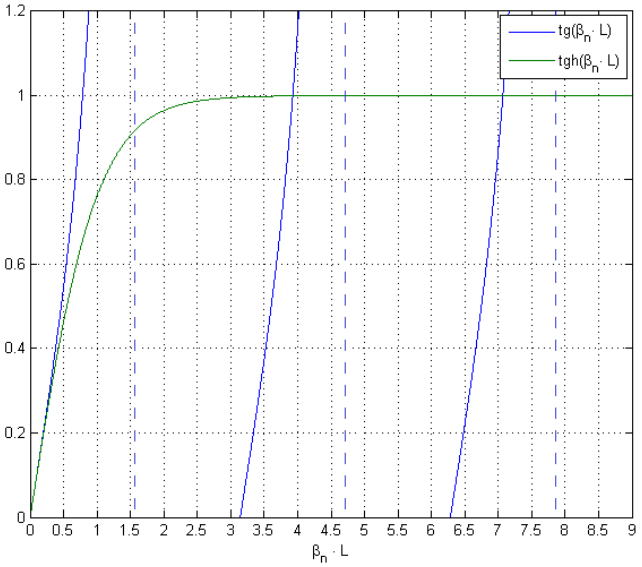

Figure 2

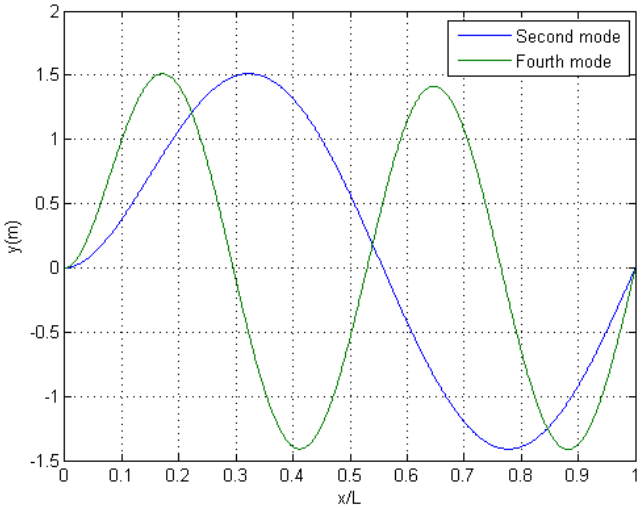

Figure 3

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Entrance examination for Optical System (OS) and Sensor Principles (SP)

376.051, LU, Mechatronic systems laboratory
Summer Semester, 2017

1. Consider a laser spot on quadrant photodetectors as shown in Figure 1. Explain the principle of a quadrant photodetector and draw equations for the calculation of the beam position [1 point].

2. Draw a circuit that provides the beam position x and y as the voltage outputs based on the equation above. Discuss noise and bandwidth of the circuit and draw a modification that improves the noise by sacrificing bandwidth.
[1.5 points]

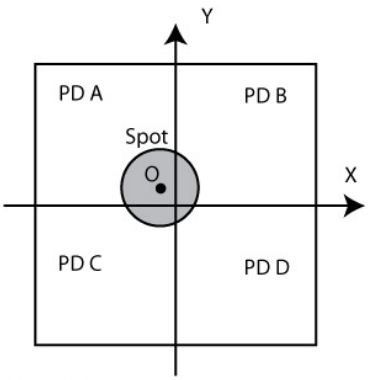

Figure 1: Laser spot position on a system of four photo detectors

Filter implementation (FI)

Entrance examination

376.051, LU, Mechatronic Systems Laboratory,
Summer Semester, 2017

1. Figure 1 shows an integration circuit of a PID controller. Derive an equation to obtain the input to output ratio (i.e. V_o/V_i) in the case that resistor R_2 is connected and disconnected, respectively. [1 points]

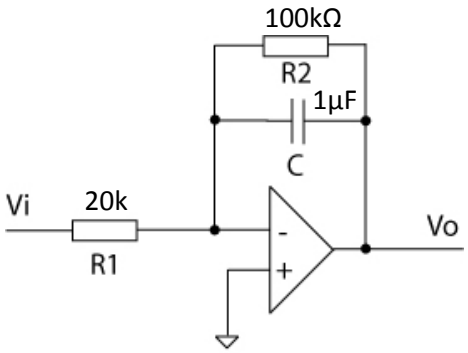

Figure 1: OP Amp Circuit

2. Using results obtained above, draw a Bode plot and discuss the effect of resistor R_2 in the circuit. [1.5 points]

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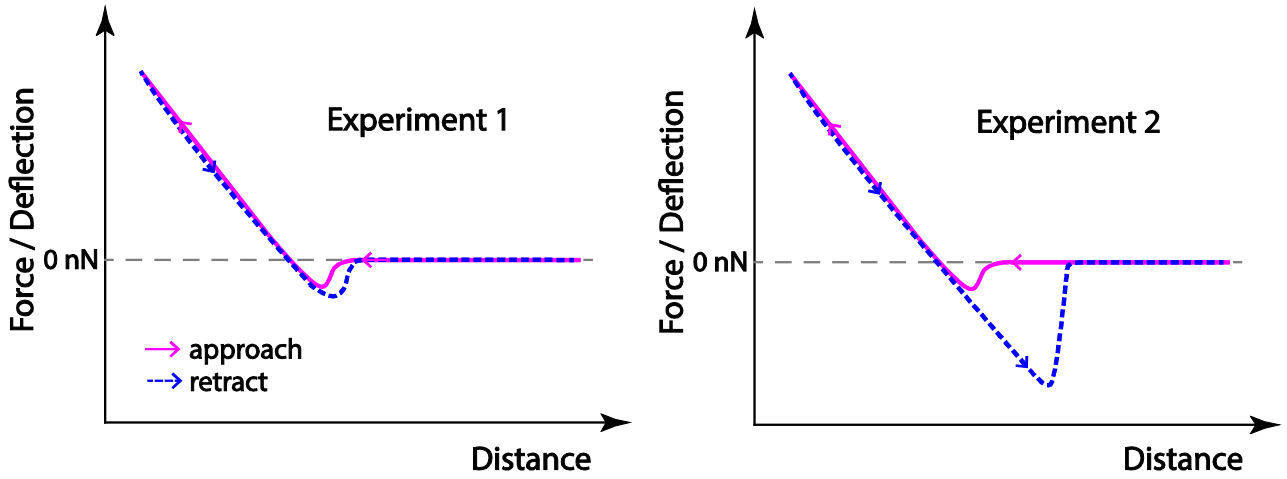
Principles of Atomic Force Microscopy (AFM)

Entrance examination

376.051, LU, Mechatronic Systems Laboratory,
Summer semester, 2017

Answer the following questions:

1. Following drawings are the force curves in two experiments. Explain what kind of force is acting in each regime and draw how the cantilever deflects in each case. Then guess the samples and/or the measurement conditions of both cases that result in these differences. For both experiments, the same cantilever is used
   [1.5 points]



2. What are main advantages of tapping mode compared to contact mode? Draw the operation region of tapping mode in the force curve above.
   [1 point]

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Entrance examination for CD player (CD)

Mechatronic systems laboratory,
March 2017

1. A voice coil motor has a back EMF constant of 1 V/(m/s) and a motor constant of 1 N/A, as well as a coil resistance of 2 Ω. Derive the maximum force that can be generated by the motor. Assume that its amplifier's output voltage is up to 1 V.
   [1.5 points]

2. In modeling of a voice coil motor for CD players, its back EMF is neglected in many cases. Discuss why it is reasonable or unreasonable.
   [1.5 points]

3. Fig. 1 shows an inverting amplifier. Derive the offset that can be seen in the output voltage V_o due to the input offset voltage of the amplifier V_{os}.
   [2 points]

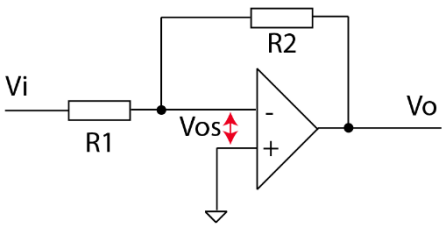

Fig. 1: OP Amp with offset voltage

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