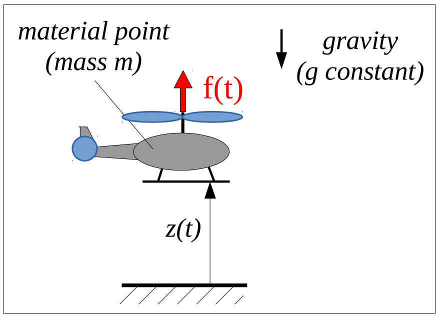
# Theory of Machines and Automatic Control - project class

**The Faculty of Automotive and Construction Machinery Engineering**

Winter 2019/2020

**<u>Project no. 3  (teacher: S. Korczak)</u>**




## 1. MODELING

a) Obtain equation ,of motion of the presented system using Lagrange equations of the second kind. Choose copter altitude $z(t)$ as a generalized coordinate. Assume vertical movement with air resistance linearly dependent to velocity with $c$ constant.

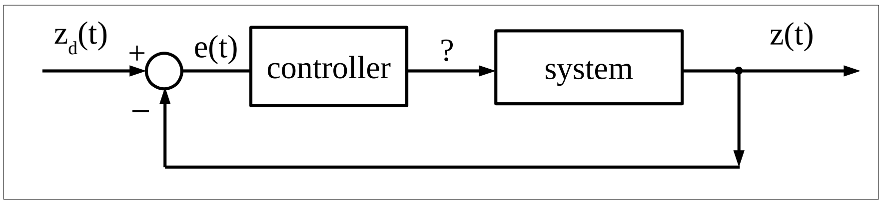
b) Obtain transfer function of the system where $z(t)$ is an output. Can we use rotor force $f(t)$ as an input?

c) Draw step response, Nyquist Plot and Bode Plot of the system using parameters from the table below.

| Student number / group | m [kg] | c [Ns/m] |
|---|---|---|
| 297572 / 102 | 1000 | 20 |
| 297579 / 102 | 2000 | 18 |
| 297581 / 102 | 1800 | 22 |
| 302474 / 102 | 1600 | 26 |
| 302561 / 102 | 500 | 10 |
| 300603 / 102 | 300 | 7 |
| 309398 / 102 | 450 | 11 |
| 302475 / 103 | 1300 | 13 |
| 302521 / 103 | 1500 | 15 |
| 301096 / 103 | 1900 | 19 |
| | 1400 | 14 |
| | 1100 | 12 |

| Student number / group | m [kg] | c [Ns/m] |
|---|---|---|
| 302490 / 103 | 1000 | 11 |
| 300594 / 103 | 2000 | 13 |
| 297574 / 103 | 1800 | 15 |
| 297577 / 103 | 1600 | 19 |
| 302615 / 103 | 700 | 9 |
| 295517 / 103 | 900 | 7 |
| 297580 / 103 | 1300 | 12 |
| K-5618 / 103 | 1500 | 16 |
| K-5619 / 103 | 1900 | 12 |
| K-5620 / 103 | 1400 | 15 |
| K-5766 / 103 | 1100 | 10 |
| | 1300 | 12 |

## 2. CONTROL




For system's transfer function obtained in 1b, calculate reduced transfer function of control system, where input $z_d(t)$ is a desired copter altitude and output $z(t)$ is a real altitude, for: a) P controller, b) PI controller.

## 3. STABILITY

a) Check stability of the system described <u>in point 1b</u> using general stability criterion.

b) Find out values of proportional and derivative constants that give us stability of the control systems from <u>points 2a and 2b</u>. Use Hurwitz criterion.

c) Draw step responses and Bode Plots for exemplary proportional and derivative constants that satisfies stability criterion from point 3b.

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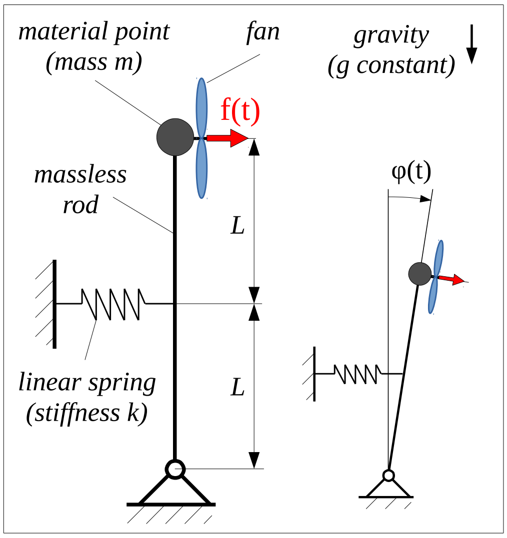



**<u>Project no. 3 (teacher: P. Wawrzyniak)</u>**

1. MODELING

a) Obtain equation of motion of the presented system using Lagrange equations of the second kind. Choose $\varphi(t)$ angle as a generalized coordinate. Assume, that the $\varphi(t)$ is very small.

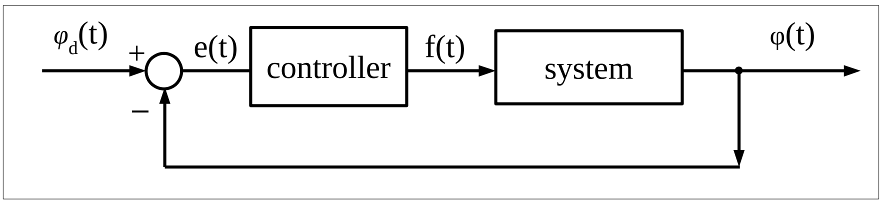
b) Obtain transfer function of the system with Laplace transform. Force $F(t)$ is an input, angle $\varphi(t)$ is an output.

c) Draw step response, Nyquist Plot and Bode Plot of the system using parameters from the table below.

| Student number | L | m | k |
|---|---|---|---|
| | [m] | [kg] | [N/m] |
| 295546 | 0,2 | 1 | 50 |
| 297590 | 0,25 | 2 | 40 |
| 302369 | 0,15 | 2,2 | 44 |
| 302370 | 0,19 | 1,2 | 80 |
| 302292 | 0,22 | 1,5 | 72 |
| 297584 | 0,21 | 1,1 | 60 |
| 302476 | 0,18 | 1,3 | 55 |
| 297606 | 0,19 | 1,8 | 70 |
| K-5811 | 0,2 | 1,5 | 75 |
| K-5781 | 0,22 | 1,9 | 49 |
| 295514 | 0,21 | 1,1 | 68 |
| 281081 | 0,25 | 1,5 | 38 |

| Student number | L | m | k |
|---|---|---|---|
| | [m] | [kg] | [N/m] |
| 297602 | 0,19 | 1 | 100 |
| 302368 | 0,22 | 0,9 | 80 |
| 297604 | 0,21 | 2 | 150 |
| 302620 | 0,18 | 2 | 120 |
| 297605 | 0,19 | 3 | 140 |
| 297608 | 0,21 | 2 | 110 |
| 273464 | 0,22 | 1,5 | 90 |
| K-5775 | 0,21 | 2 | 150 |
| K-5780 | 0,2 | 1,8 | 120 |
| | 0,22 | 1,7 | 130 |
| | 0,21 | 1,6 | 80 |
| | 0,25 | 2 | 90 |

2. CONTROL




For system's transfer function obtained in 1b, calculate reduced transfer function of control system, where input $\varphi_d(t)$ is a desired angle (setpoint) and output $\varphi(t)$ is a real pendulum angle, for: a) P controller, b) PD controller.

3. STABILITY

a) Check stability of the system described <u>in point 1b</u> using general stability criterion.

b) Find out values of proportional and derivative constants that give us stability of the control systems from <u>points 2a and 2b</u>. Use Hurwitz criterion.

c) Draw step responses and Bode Plots for exemplary proportional and derivative constants that satisfies stability criterion from point 3b.

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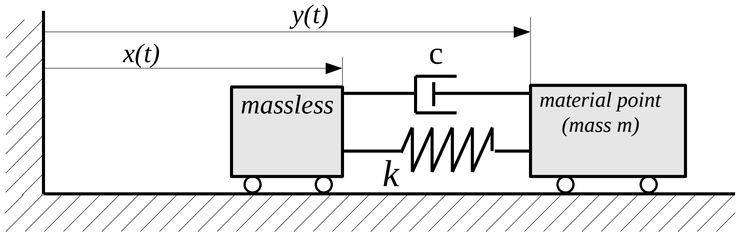
**<u>Project no. 3 (teacher: M. Parafiniak)</u>**

1. MODELING

a) Obtain equation of motion of the presented system using Lagrange equations of the second kind. Choose $x(t)$ as a generalized coordinate. Assume there is no friction, spring and damper have linear characteristics. Spring free length is $L_0$.



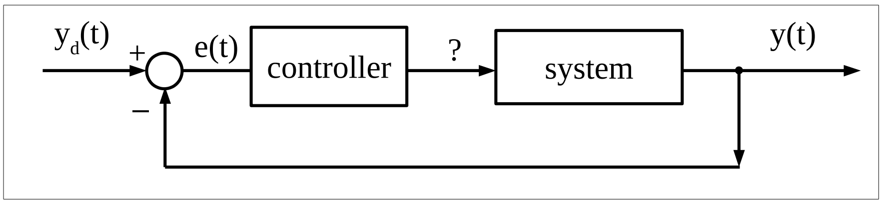

b) Obtain transfer function of the system where displacement $y(t)$ is an output. Can we use displacement $x(t)$ as an input?

c) Draw: step response, the Nyquist Plot and the Bode Plot of the system using values:

| Student number | m [kg] | k [N/m] | c [Ns/m] |
|---|---|---|---|
| 202889 | 1 | 5 | 1 |
| 302656 | 1 | 10 | 1 |
| 297611 | 1 | 3 | 5 |
| 302367 | 2 | 7 | 5 |
| 301398 | 2 | 5 | 3 |
| 286181 | 2 | 2 | 3 |
| 302293 | 2 | 8 | 5 |
| 297613 | 2 | 10 | 5 |
| 302294 | 3 | 2 | 2 |
| 302491 | 3 | 5 | 2 |
| 297614 | 3 | 8 | 2 |
| K-5801 | 1 | 2 | 1 |
| K-5520 | 2 | 5 | 2 |
| K-5519 | 3 | 3 | 1 |

2. CONTROL

For system's transfer function obtained in 1b calculate reduced transfer function of control system, where input $y_d(t)$ is a desired object position and output $y(t)$ is a real position, for: a) P controller, b) PI controller.




3. STABILITY

a) Check stability of the system described in <u>point 1b</u> by using general stability criterion.

b) Find out what values of proportional and integral constants give us stability of control systems from <u>points 2a and 2b</u>. Use Hurwitz criterion.

For exemplary proportional and integral constants that satisfies stability criterion from point 3b, draw step responses and Bode Plots.