Actuators

Modelling of mechanics of the actuators

LAB1

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LAB #1 Modelling of mechanics of the actuators

Task to be completed

LAB#1 Modelling of mechanics of the actuators

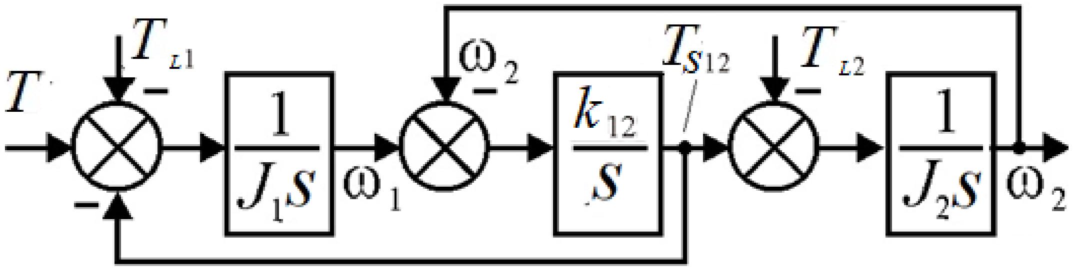
- LAB#1 is aimed at checking the theoretical data and relationships presented in theory materials (Lectures 1, Practice 1 of course “Actuators”)
- LAB#1 is performed in MATLAB / Simulink
- LAB#1 consists two parts:

Part1 . Mathematical modelling of two-mass mechanism

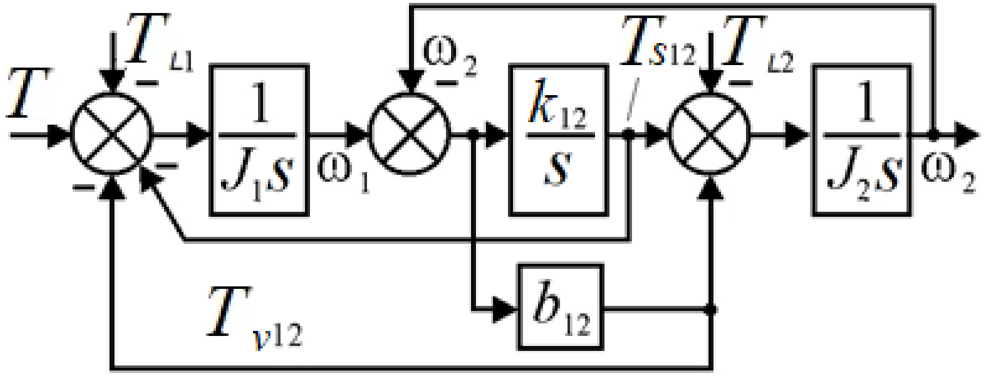
Part2. Mathematical modelling of DC-motor with two-mass mechanism

Schemes under consideration

Part 1. Mathematical modelling of two-mass mechanism

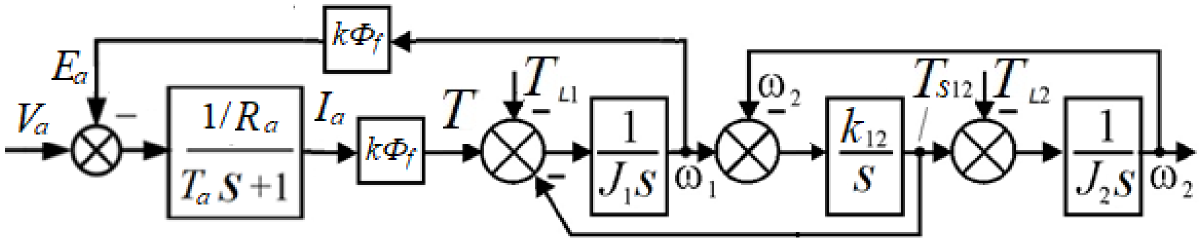


a)



b)

Part 2. Mathematical modelling of DC-motor with two-mass mechanism (***not necessary – this is additional option***)



c)

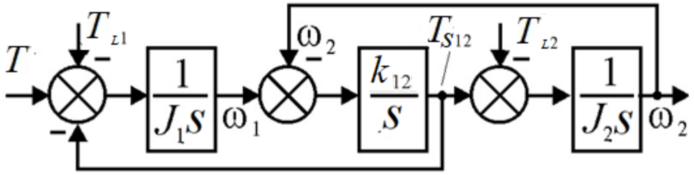
Table 1 –The data for the LAB

Two-mass mechanism					DC-motor				
N	J_1 kgm2	J_2 kgm2	k_{12} Nm/rad	$\Delta\phi$ rad	Va V	Ra Ohm	Ta s	$k\Phi_f$	Trated
One option for all	0.183	0.055	3800	0,39	400	21,45	0,004	12	*47,7*

Tasks for part 1 (modelling of two-mass mechanism)

Part 1. Mathematical modelling of two-mass mechanism

Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions).



1. Show on plot transient response of ω_1(t), ω_2(t), T_{s12}(t) by the step reference signal T with value $0.1T_{rated}$ (at T_{L1}=0, T_{L2}=0). Please put $\omega_1(t)$, $\omega_2(t)$ on one plot and make sure that the speed of the first and second masses change in antiphase with the same value of acceleration

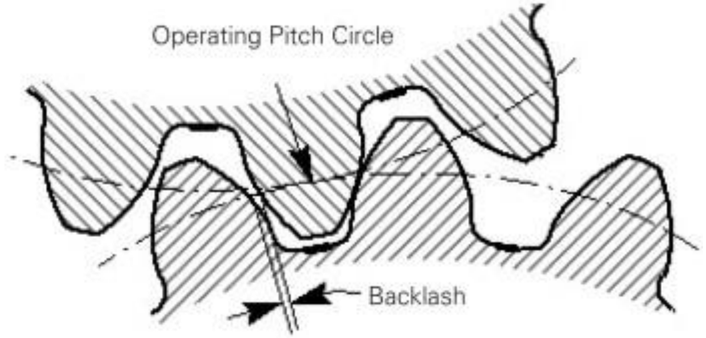
2. Plot the Bode diagram of the two-mass mechanism and determine resonance frequency.

3. Compare calculated parameters of transient and parameters got by simulation

4. Change the parameters of the two-mass bodies' system: mass inertia ratio ((3 values J_2 to get γ from 1 to 2) , link stiffnesses koeff (3 values: k12min, k12medium, k12max). Draw a conclusion about the comparison of the processes

Part 1. Mathematical modelling of two-mass mechanism

Task 1.2. Add backlash in a model of the two-mass mechanism



1. Show on plot transient response of $\omega_1(t)$, $\omega_2(t)$, $T_{s12}(t)$ by the step reference signal T with value $0.1T_{rated}$ (at T_{L1}=0, T_{L2}=0). Please put $\omega_1(t)$, $\omega_2(t)$ on one plot and make sure that the speed of the first and second masses change in antiphase with the same value of acceleration but with deadzones

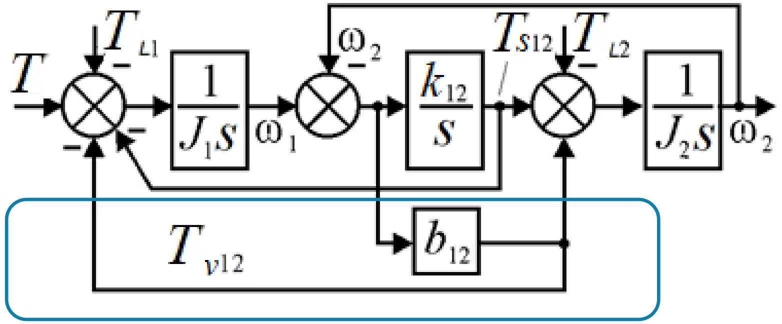
2. Compare $T_{s12}(t)$ in mechanism without and with backlash in gearbox

3. Draw conclusions

Task 1.3. Add torque of viscous friction in a model of the two-mass mechanism.

1. The viscous damping coefficient b should be chosen considering that the oscillation damp in 5 periods.

2. Get results. Draw conclusions



LAB #1 Modelling of mechanics of the actuators

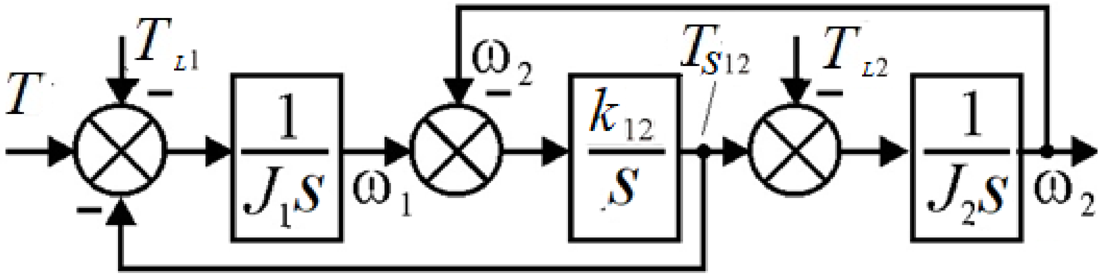
Execution steps

Tasks for part 1 (modelling of two-mass mechanism)

<u>Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)</u>

Mathematic model of two-mass mechanism

$$\begin{cases} XXX \\ XXX \\ XXX \end{cases} \qquad \textit{Please fill in by yourself} \qquad (1)$$



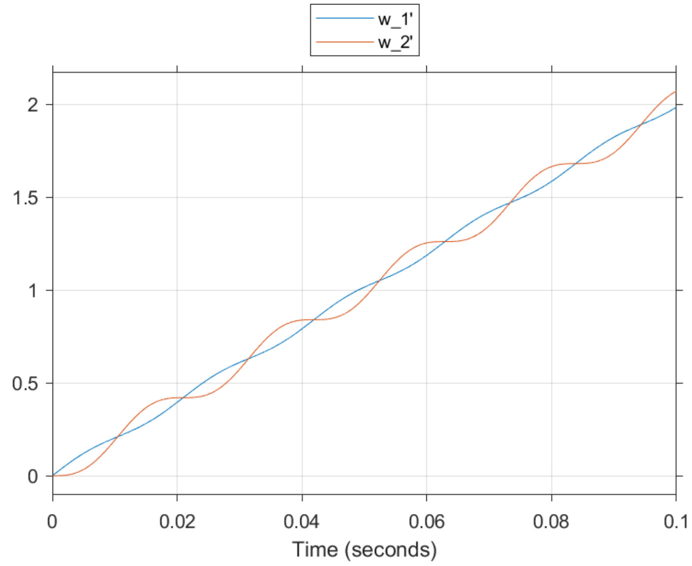
Scheme of the system (Fig.)

Please, design it by yourself

Figure : Math model of the two-mass mechanism in Simulink

<u>Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)</u>

1. Show transient response of $\omega_1(t)$, $\omega_2(t)$, $T_{s12}(t)$ by the step reference signal T with value $0.1T_{rated}$ (T_{L1}=0, T_{L2}=0).



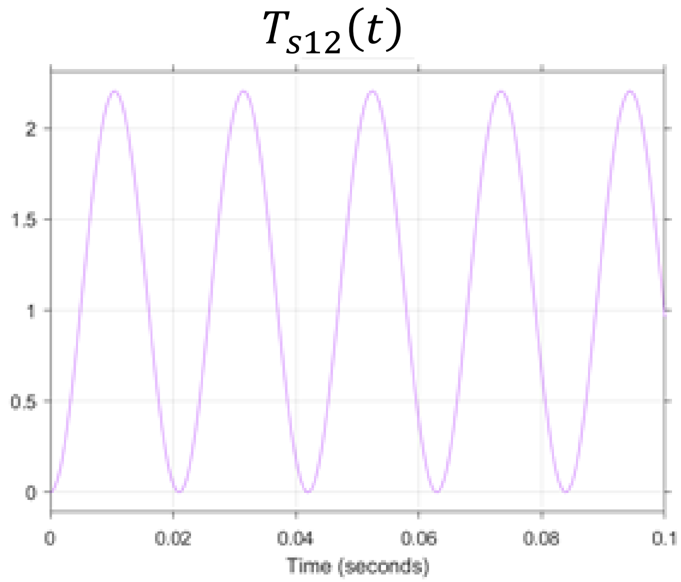


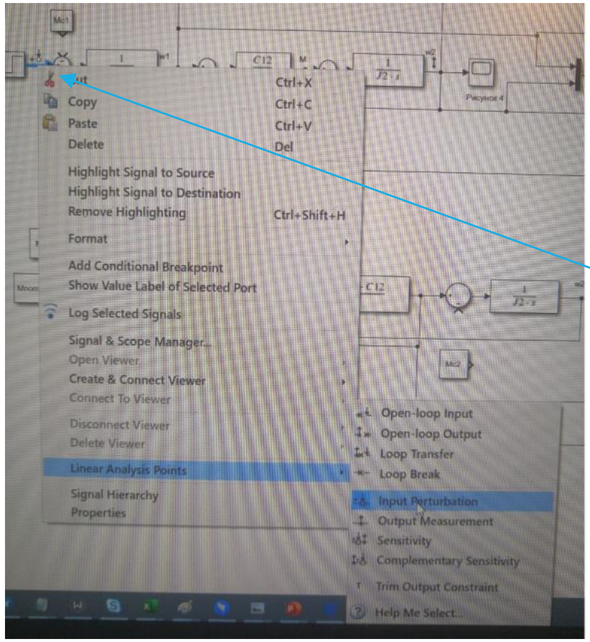
Figure : transient response of $\omega_1(t)$, $\omega_2(t)$ (a), $T_{s12}(t)$ (b)

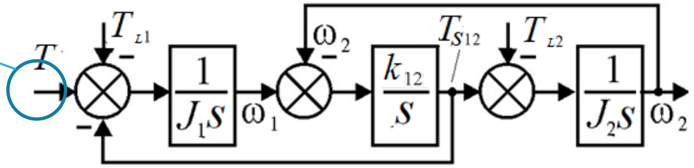
Please show $\omega_1(t)$, $\omega_2(t)$ on one plot and make sure that the speed of the first and second masses change in antiphase with the same value of acceleration

Tasks for part 1 (modelling of two-mass mechanism)

Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)

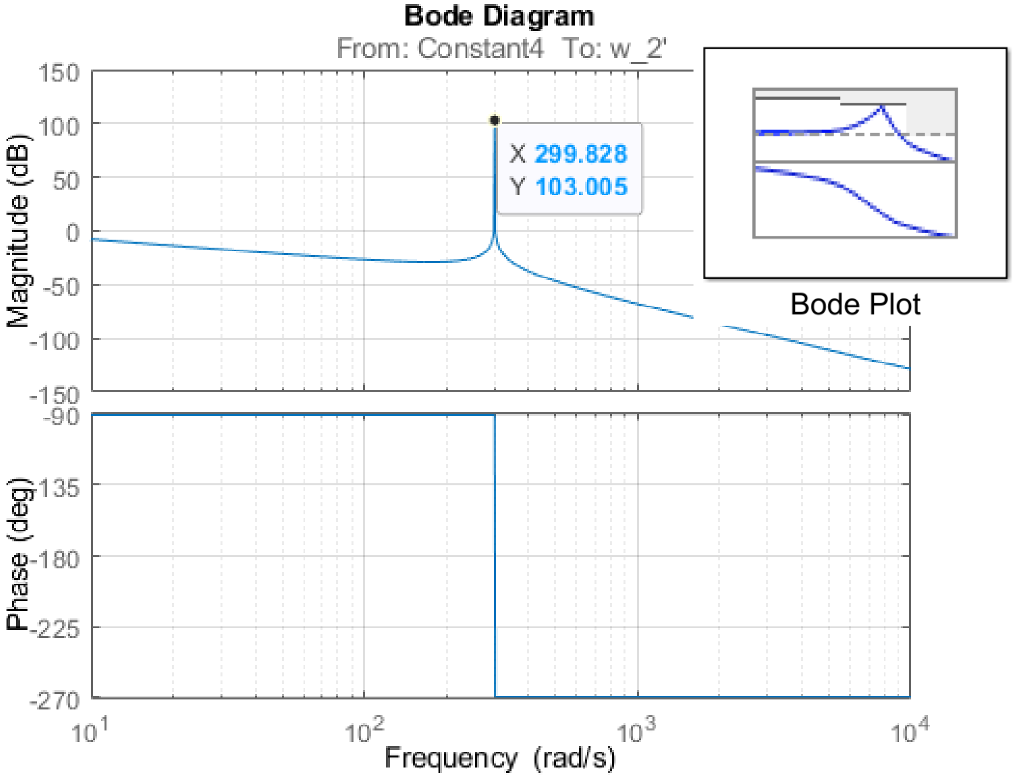
2.Plot the Bode diagram of the two-mass mechanism





In Simulink Library Browser:

Simulink Control Design/Linear Analysis Plots/Bode Plot.



Bode Plot

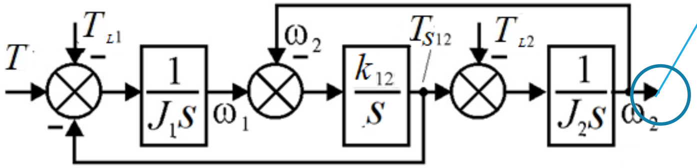
Point – Right mouse button $\rightarrow$ Linear Analysis Points $\rightarrow$ Input Perturbation

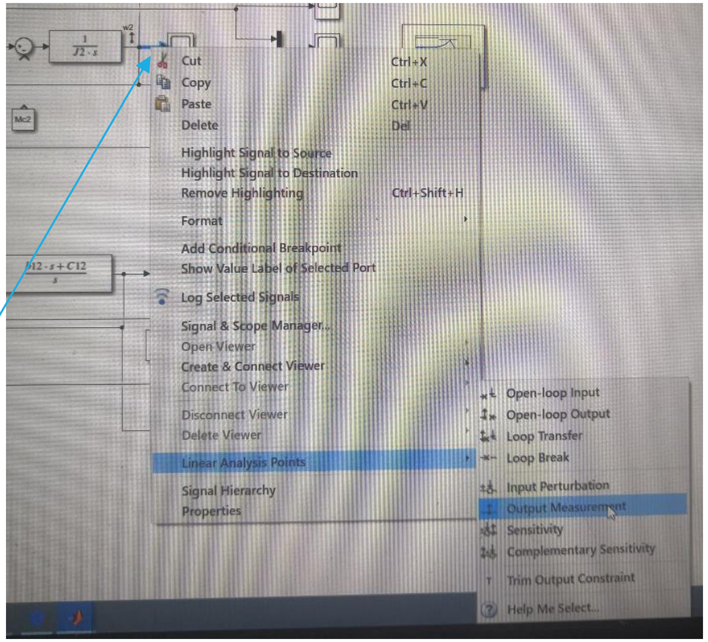
Tasks for part 1 (modelling of two-mass mechanism)

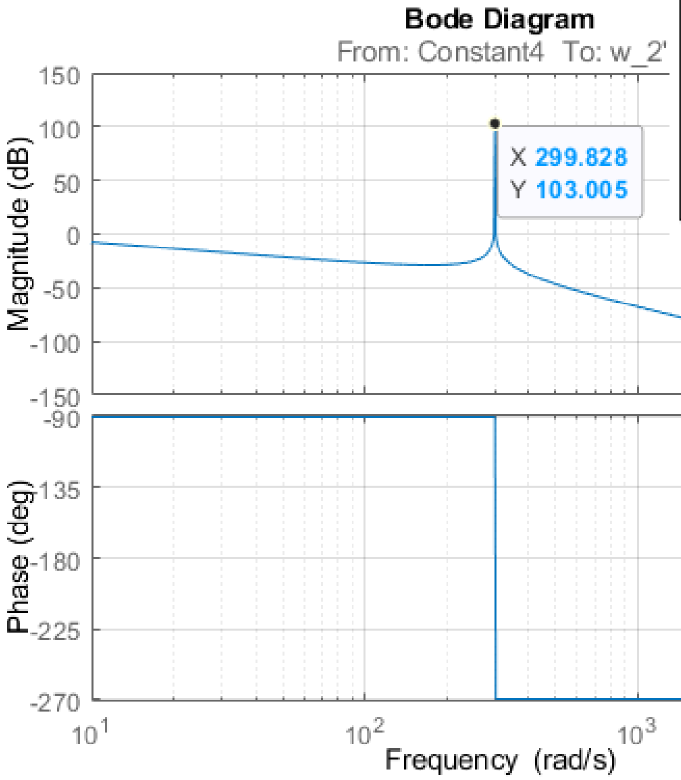
Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)

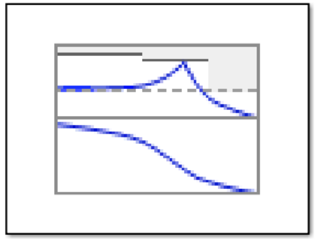
2.Plot the Bode diagram of the two-mass mechanism

Simulink Control Design/Linear Analysis Plots/Bode Plot.







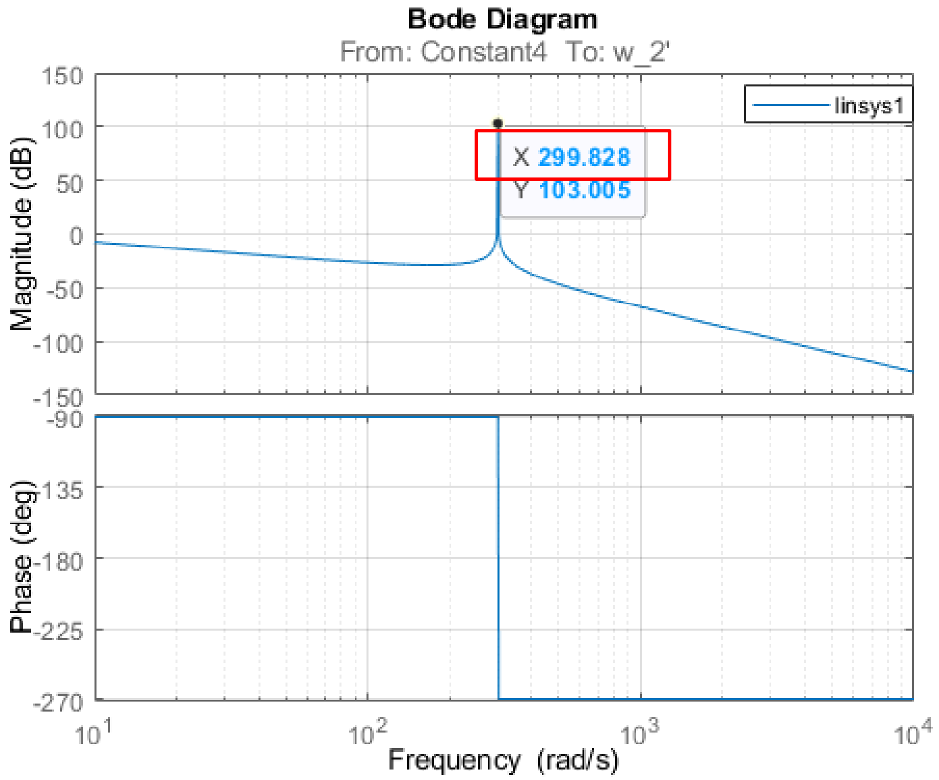

Bode Plot

Point – Right mouse button → Linear Analysis Points → Output Measurement

Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)

- The resonance frequency:

$$\omega_{R1} = \sqrt{k_{12}\frac{J_1 + J_2}{J_1 J_2}} = \boxed{299{,}75c^{-1}}$$

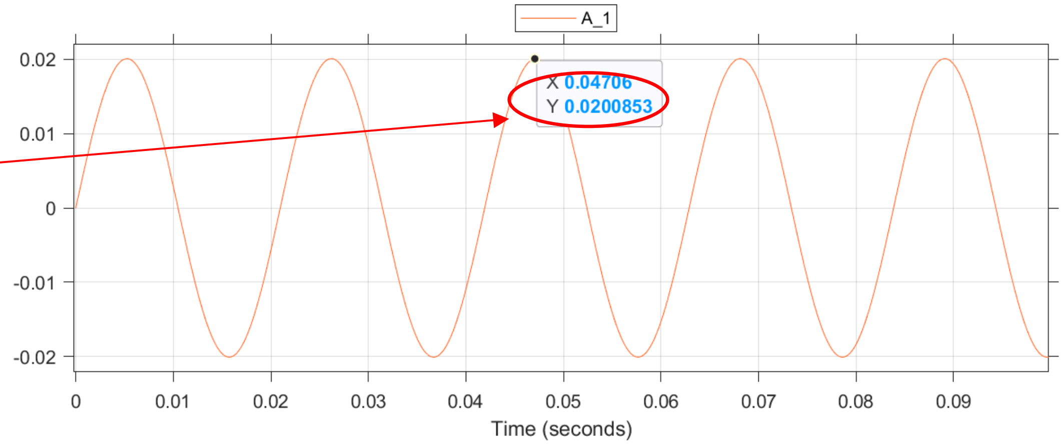


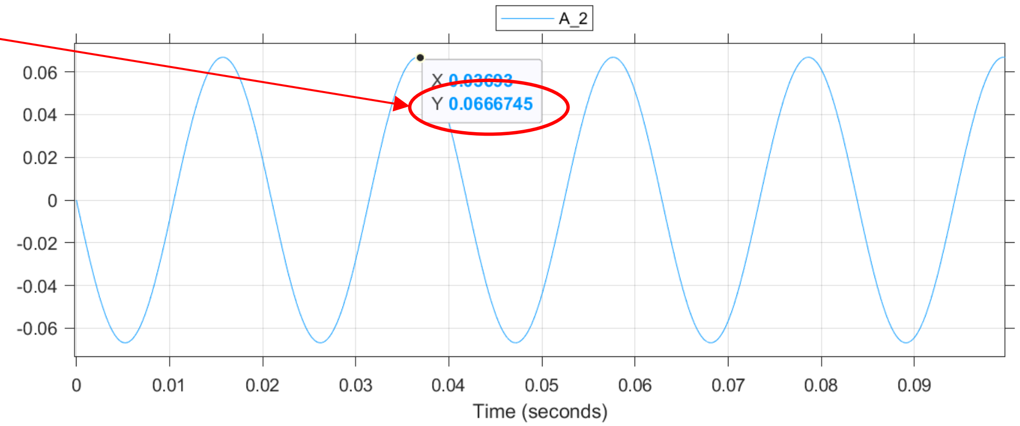
<u>Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)</u>

- The magnitudes of bodies fluctuation:

$$A_1 = \frac{J_2 \varepsilon_{av}}{J_1 \omega_{R1}} = 0{,}0201 \text{ rad/s}$$

$$A_2 = \frac{\varepsilon_{av}}{\omega_{R1}} = 0{,}0669 \text{ rad/s}$$





- Exclude the average angular acceleration:

$$\varepsilon_{av} = \frac{T}{J_1 + J_2} = \frac{0.1 \times T_{rated}}{J_1 + J_2} = 20 \text{ rad/s}^2$$

Tasks for part 1 (modelling of two-mass mechanism)

Task 1.1. Design a model of the two-mass mechanism without any disturbances (load torques, frictions)

1. Changing the parameters of the two-mass motor-mechanism system

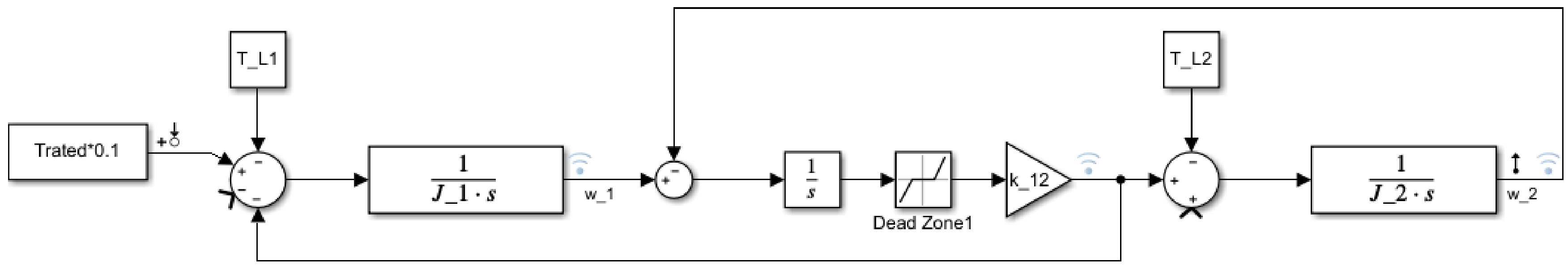
a) Show transient process in a two-mass load at various values of mass inertia ratio $\gamma = \frac{J_1+J_2}{J_1}$ (3 values J_2 to get γ from 1 to 2)

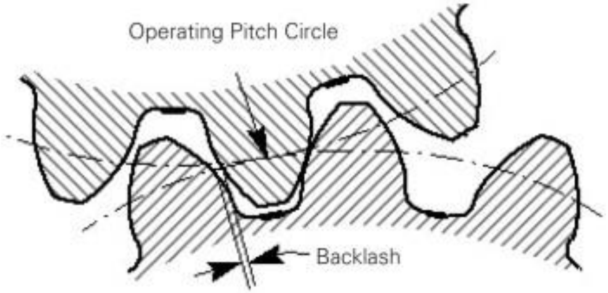
b) Show transient process in a two-mass load at various values of link stiffnesses (3 values: k12min, k12medium, k12max)

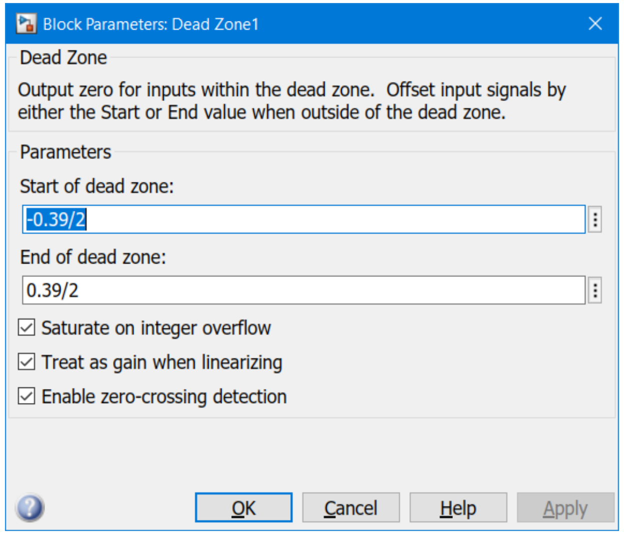
Draw a conclusion about the comparison of the processes in one-mass and two-mass systems.

Tasks for part 1 (modelling of two-mass mechanism)

Task 1.2. Add backlash in a model of the two-mass mechanism



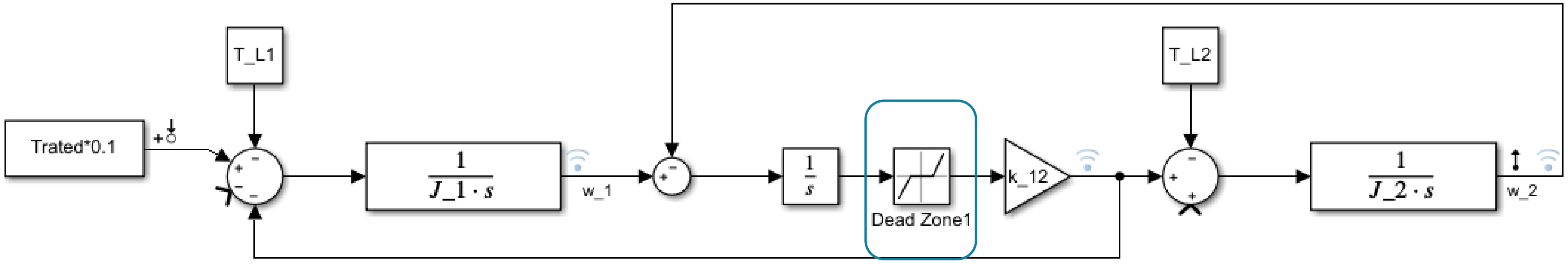


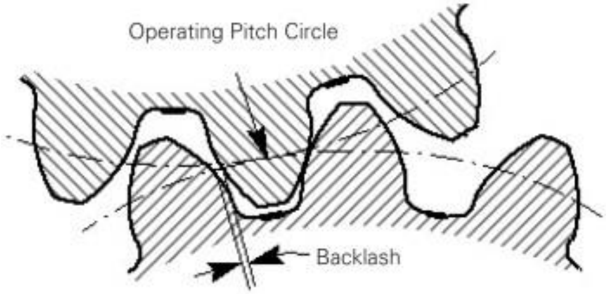


$$\begin{cases} T - T_{L1} - T_{s12} = J_1\, s w_1 \\ T_{s12} - T_{L2} = J_2\, s w_2 \\ T_{s12} = k_{12}(\varphi_1 - \varphi_2 \pm \Delta\,\varphi/2), |\varphi_1 - \varphi_2| > \Delta\,\varphi/2 \\ T_{s12} = 0, |\varphi_1 - \varphi_2| \le \Delta\,\varphi/2 \end{cases}$$

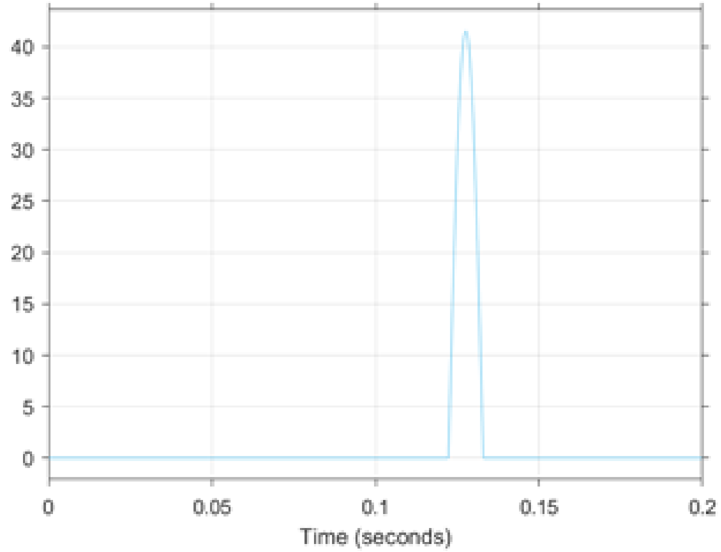
Tasks for part 1 (modelling of two-mass mechanism)

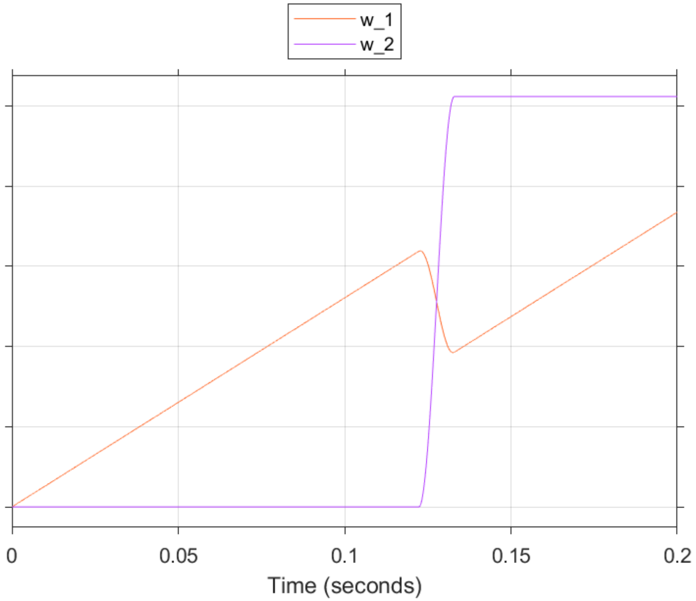
Task 1.2. Add backlash in a model of the two-mass mechanism



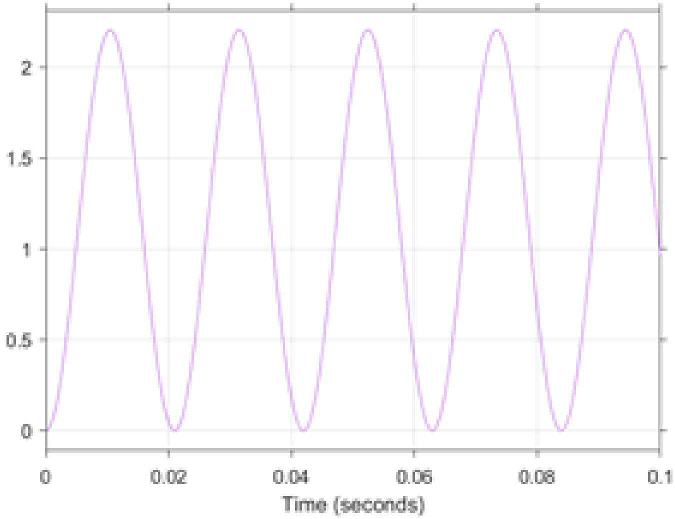


$T_{s12}(t)$



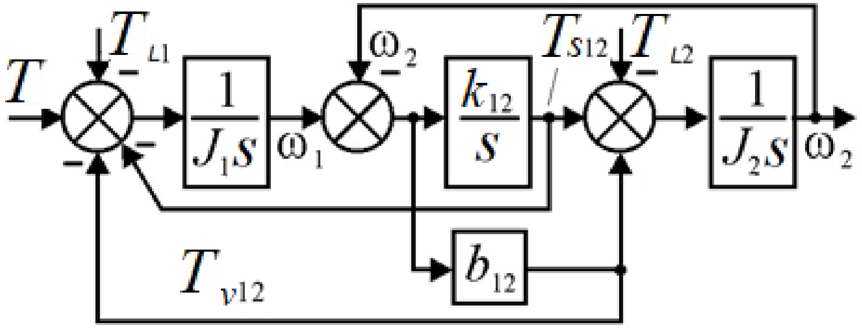


$T_{s12}(t)$



$T_{s12}(t)$ in the mechanism without backlash

<u>Task 1.3 Design a model of the two-mass mechanism with viscous frictions</u>



$$b_{12} = \frac{2a_v J_1 J_2}{J_1+J_2} = \frac{6\omega_{R1} J_1 J_2}{10\pi(J_1+J_2)} = = 2{,}4211$$

where $a_v \approx \frac{3\lambda_v \cdot \omega_{R1}}{2\pi} = \frac{3\omega_{R1}}{10\pi}$

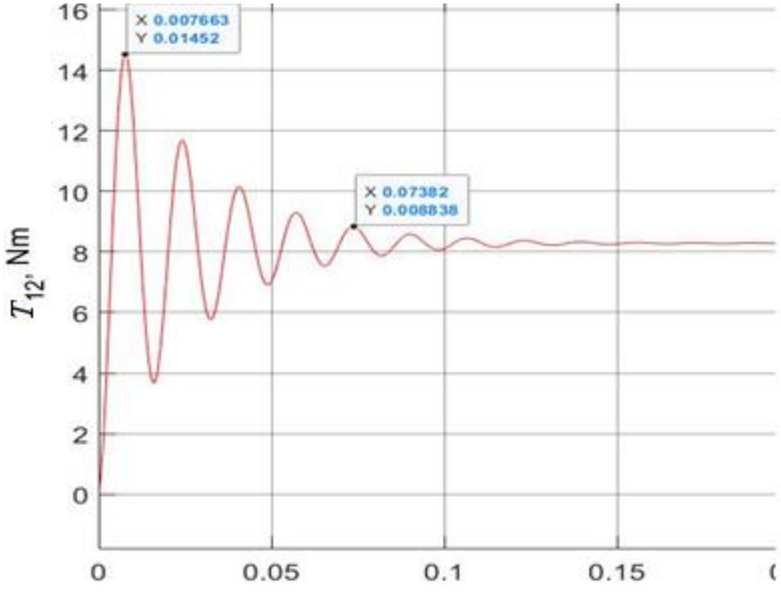
λ_v - logarithmic decrement

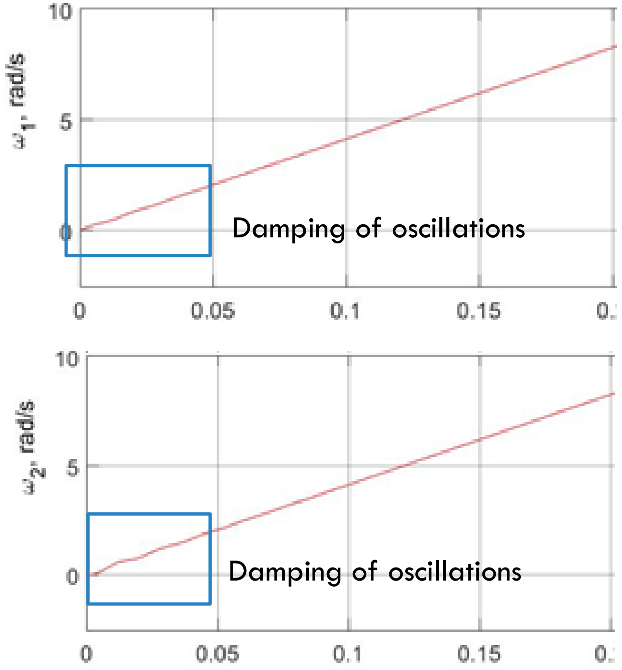
a_v - attenuation coefficient

$$\lambda_v = avT = \frac{T}{\tau} = \frac{1}{n}$$

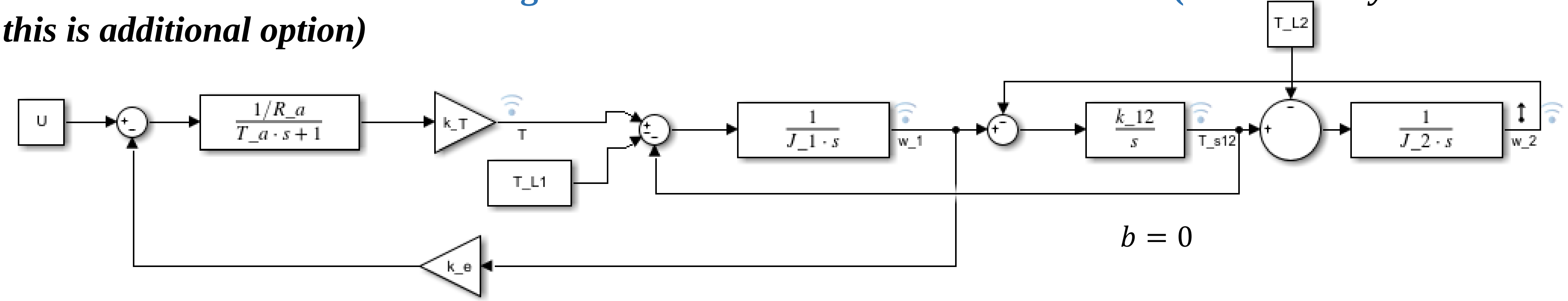
n - number of harmonic oscillations during relaxation τ (the amplitude decreases e times)

$A_0 e^{-a_v t}$ ⇨ $t_{res} = 3\frac{1}{a_v} = nT$=5T time response





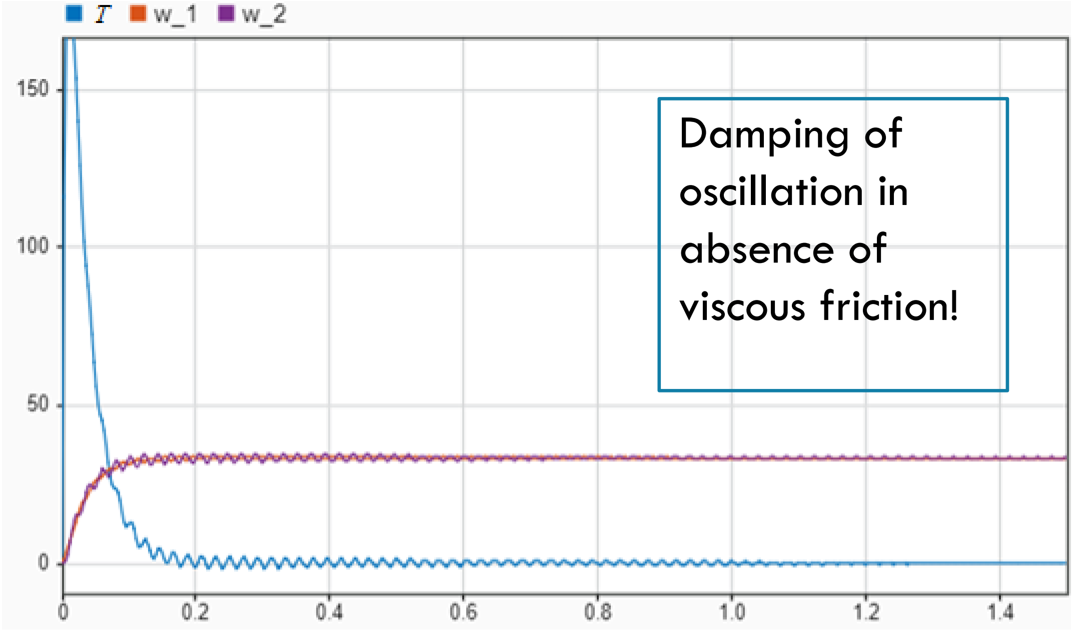
Part 2. Mathematical modelling of DC-motor with two-mass mechanism (*not necessary – this is additional option)*



<u>Task 2.1 Modelling of the DC-motor with two-mass mechanism.</u>

<u>1</u>. Design a model of the DC-motor with two-body mechanism.

2. Show plots $T(t)$, $T_{s12}(t)$, $\omega_1(t)$, $\omega_2(t)$



Tasks for part 2 (modelling of motor with two-mass load) - ***not necessary***

Task 2.2 Modelling of the DC-motor with two-body mechanism with another parameters

1. Changing the parameters of the two-mass motor-mechanism system

a) Show transient process of start mode of a motor with a linear torque-speed curve with a two-mass load at various values of mass inertia ratio $\gamma = \frac{J_1 + J_2}{J_1}$ (3 values J_2 to get γ from 1 to 2)

b) Show transient process of start mode of a motor with a linear torque-speed curve with a two-mass load at various values of link stiffnesses (3 values: k12min, k12medium, k12max)

Draw a conclusion about the comparison of the processes in one-mass and two-mass systems.

Thank you for your attention