Lab 3 «Simulation of mechanical systems»

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Objective and Goals

Objective: to study the basic principles of building mathematical models, modelling and analysis of electromechanical systems on the example of DC motor **with two-mass load with elastic joints**.

Goals:

- Build the dynamic models of the DC motor with **two-mass load with elastic joints** in different forms: Simscape block, block diagram, transfer function, state space representation;
- Draw bode plots.
- Get data-driven model of DC motor with **two-mass load with elastic joints by** experimental frequency response function

Initial data

Initial data

R_a - armature resistance

L_a - armature inductance

Ψ_{rated} - rated flux

U_{rated} - rated voltage

J_M - inertia of the shaft

k - torsional stiffness coefficient

b - damping coefficient

J_L - inertia of the load

Task 1

a) Build the model of the DC-motor **with two-mass load with elastic joints** using:

- Simscape library
- block diagram
- transfer functions: $W_1(s) = \dfrac{\omega_M(s)}{U(s)}$

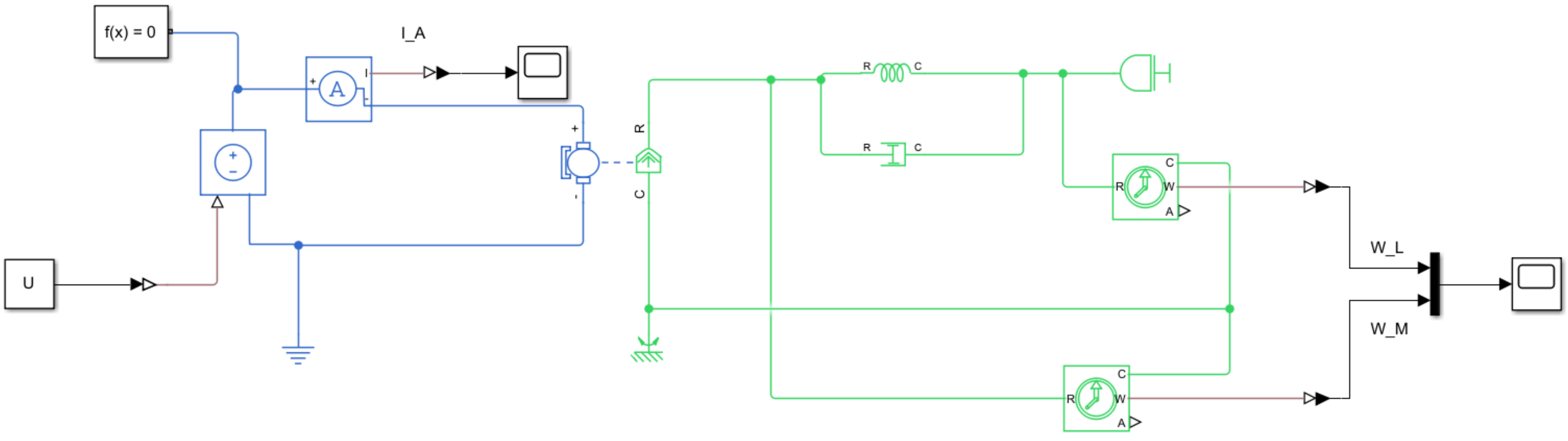
  $W_2(s) = \dfrac{\omega_L(s)}{U(s)}$
- state space model

$$
\begin{cases}
L_a \cdot \dfrac{di_a}{dt} = U - R_a \cdot i_a - \Psi \cdot \omega_M \\
J_M \cdot \dfrac{d\omega_M}{dt} = \Psi \cdot i_a - T_S - b\left(\omega_M - \omega_L\right) \\
J_L \cdot \dfrac{d\omega_L}{dt} = T_S + b\left(\omega_M - \omega_L\right) \\
\dfrac{dT_S}{dt} = k\left(\omega_M - \omega_L\right)
\end{cases}
$$

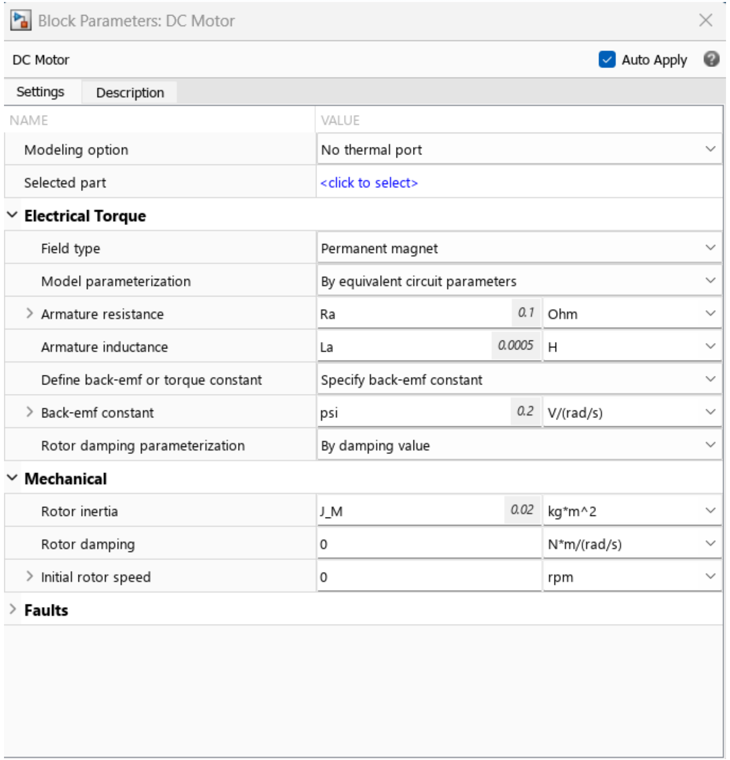
Assume load torques equal to zero.

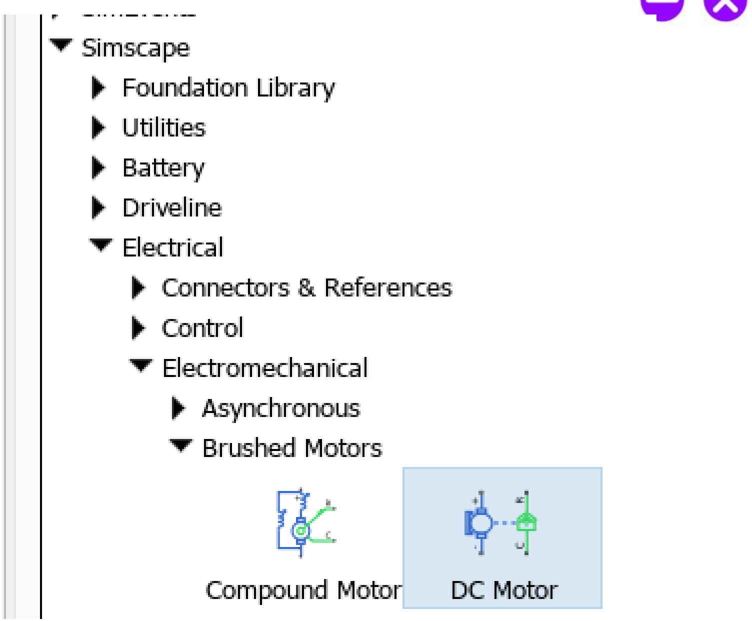
Simulate the models with the rated voltage. Draw graphs of the armature current, motor velocity, load velocity.

Simscape model

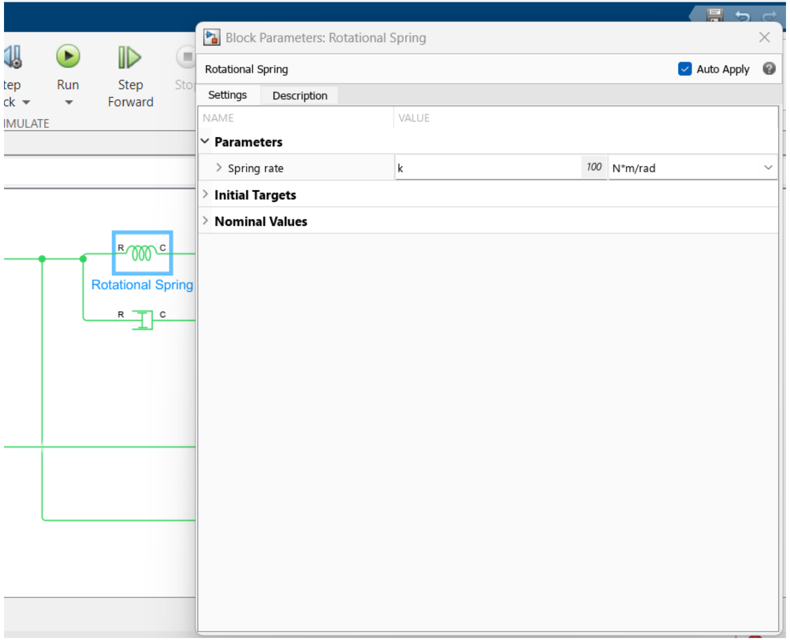


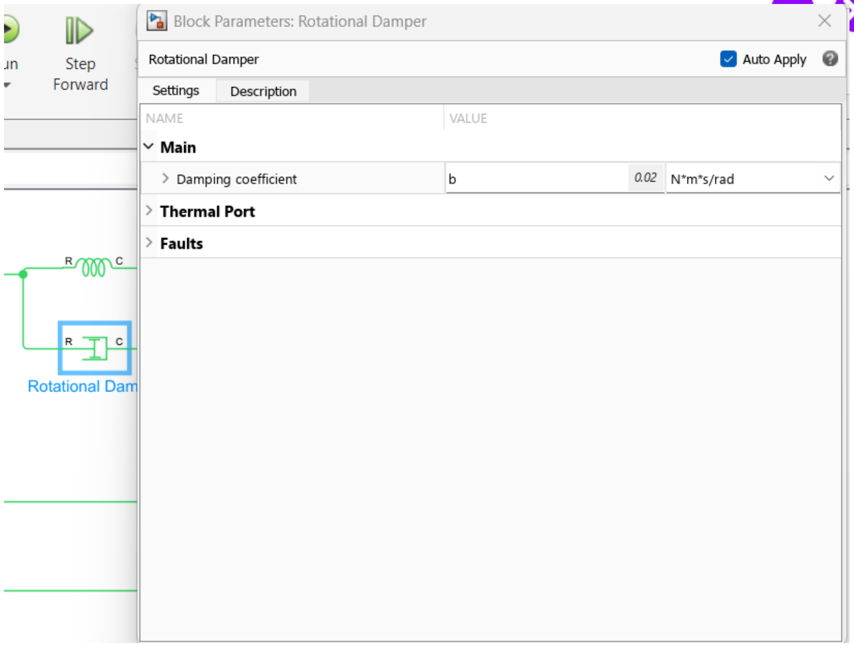
Simscape model



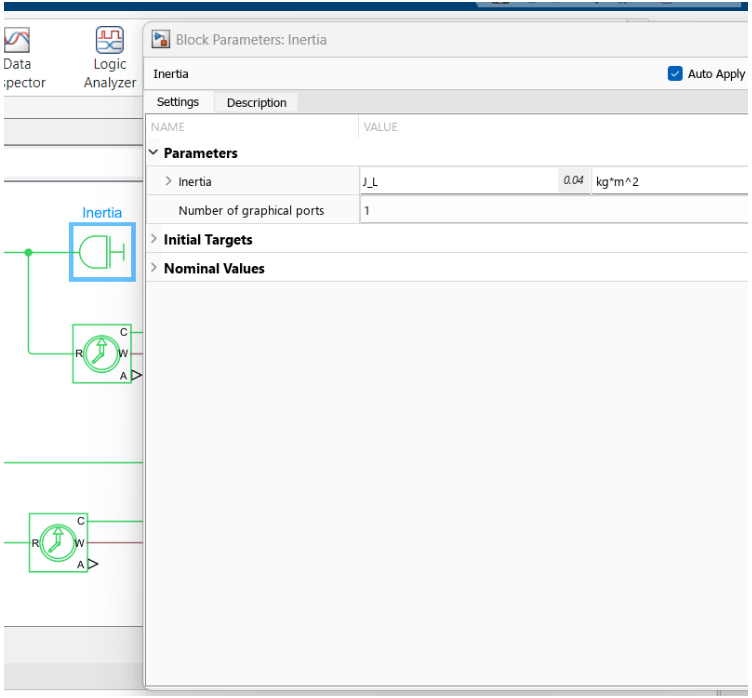


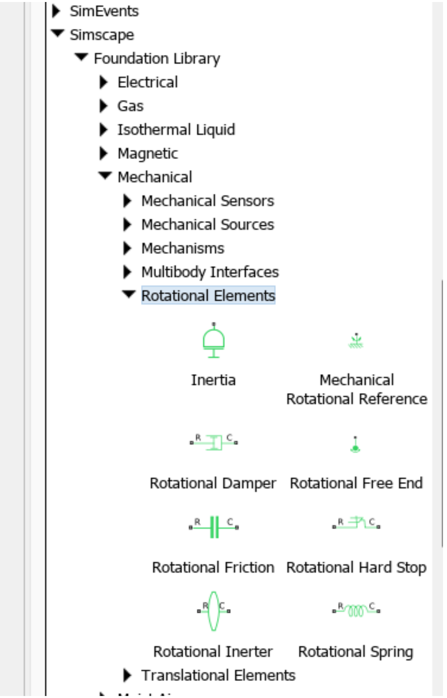
Simscape model





Simscape model





Task 2

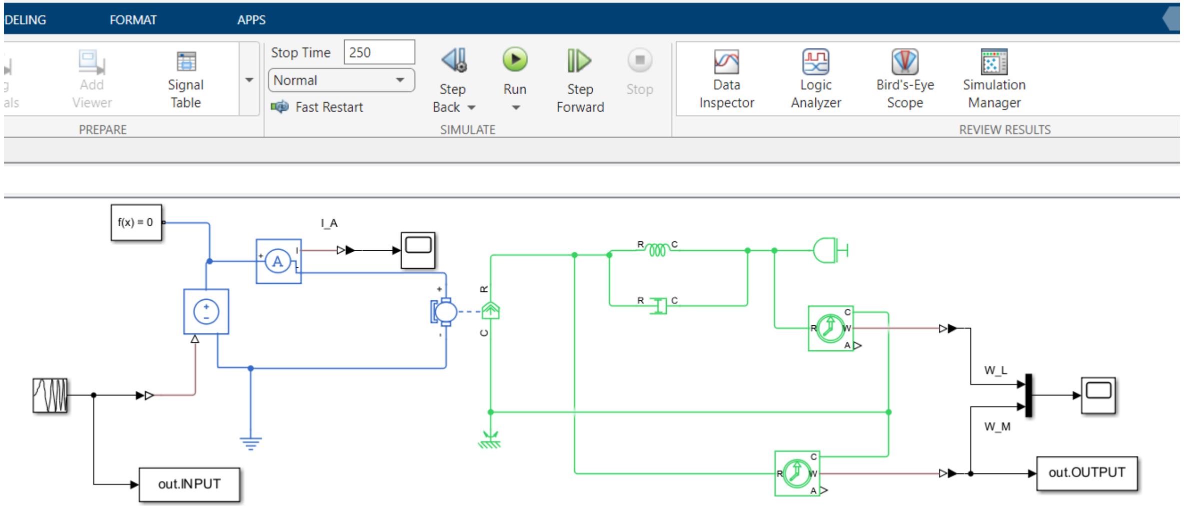
Draw bode plots for 2 transfer functions:

$$W_1(s) = \frac{\omega_M(s)}{U(s)} \qquad W_2(s) = \frac{\omega_L(s)}{U(s)}$$

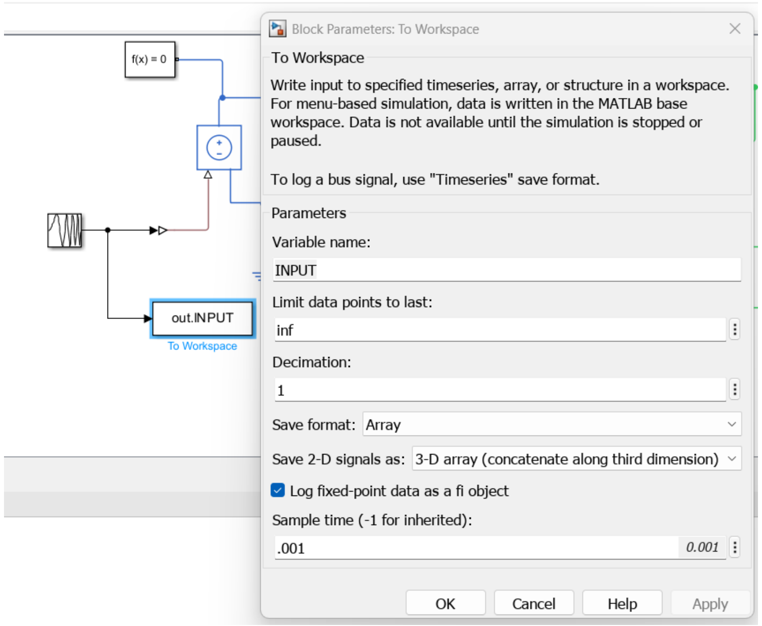
Find the resonant frequency of the mechanical subsystem from bode plot

Task 3

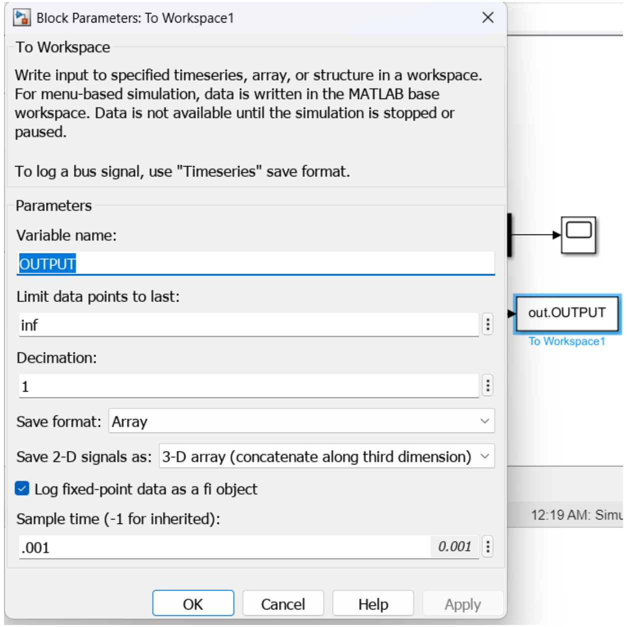
a) Simulate the DC motor with 2-mass load with multi-harmonic input signal. Save the input data and velocity of the motor ω_M. Simulation time: 250 s



Task 3

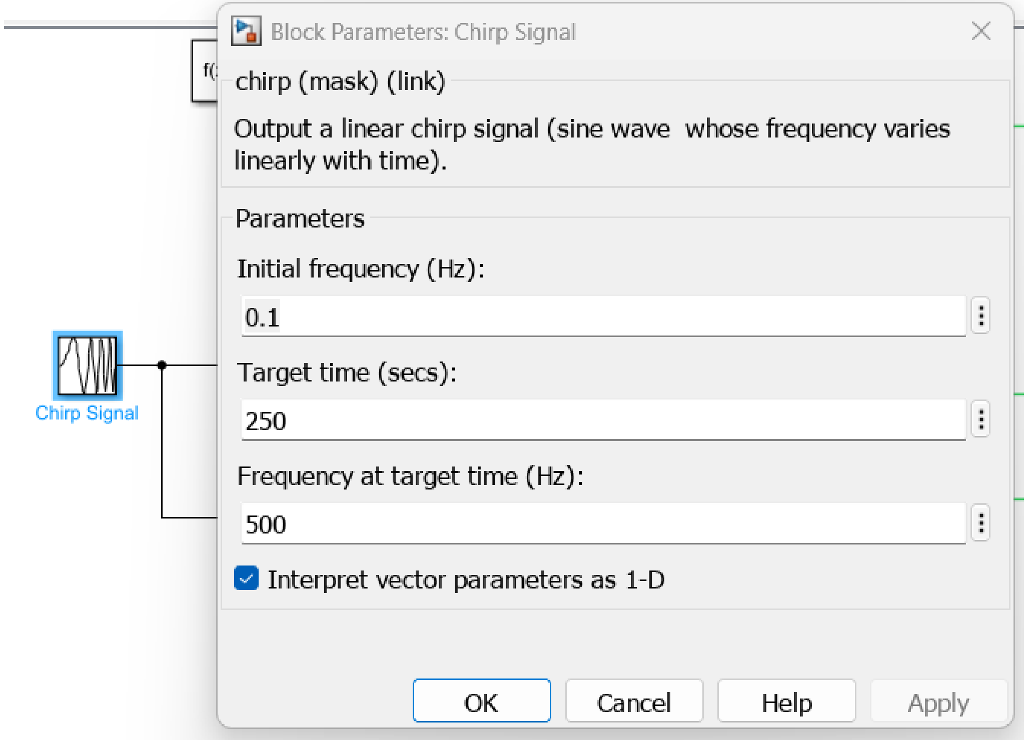


f(x) = 0
out.INPUT
To Workspace
Block Parameters: To Workspace
To Workspace
Write input to specified timeseries, array, or structure in a workspace. For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.
To log a bus signal, use "Timeseries" save format.
Parameters
Variable name:
INPUT
Limit data points to last:
inf
Decimation:
1
Save format: Array
Save 2-D signals as: 3-D array (concatenate along third dimension)
Log fixed-point data as a fi object
Sample time (-1 for inherited):
.001
0.001
OK
Cancel
Help
Apply



Block Parameters: To Workspace1
To Workspace
Write input to specified timeseries, array, or structure in a workspace. For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.
To log a bus signal, use "Timeseries" save format.
Parameters
Variable name:
OUTPUT
Limit data points to last:
inf
Decimation:
1
Save format: Array
Save 2-D signals as: 3-D array (concatenate along third dimension)
Log fixed-point data as a fi object
Sample time (-1 for inherited):
.001
0.001
OK
Cancel
Help
Apply
out.OUTPUT
To Workspace1
12:19 AM: Simu

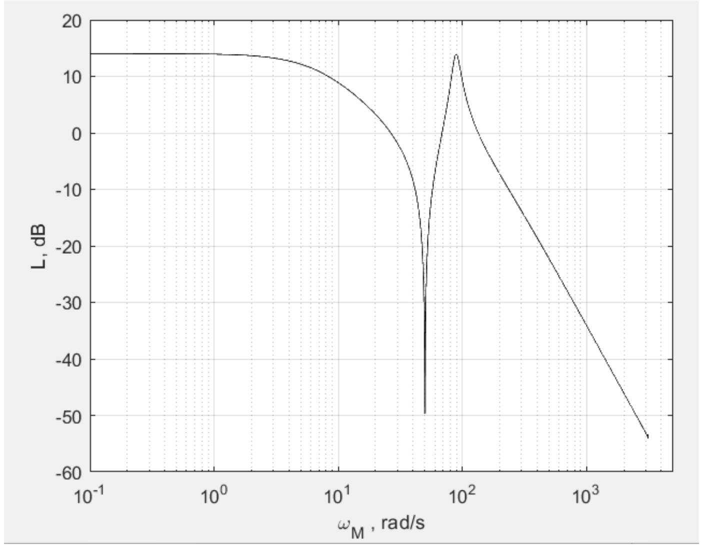
Task 3


Block Parameters: Chirp Signal
chirp (mask) (link)
Output a linear chirp signal (sine wave whose frequency varies linearly with time).
Parameters
Initial frequency (Hz):
0.1
Target time (secs):
250
Frequency at target time (Hz):
500
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply
Chirp Signal

Task 3

b) Find the frequency response function of the system from simulation data:

```
%%
u = out.INPUT(:, 1);
y = out.OUTPUT(:, 1);
Ts = 1e-3;
[txy, f] = tfestimate(u,y,[],[],[],(1 / Ts));
om = 2 * pi * f;
L = 20 * log10(abs(txy));
figure();
plot(om, L, '-k');
xlim([0.1, 5000]);
xlabel('\omega_M , rad/s')
ylabel('L, dB')
ax = gca;
set(ax,'XScale','log')
grid on
hold all
```



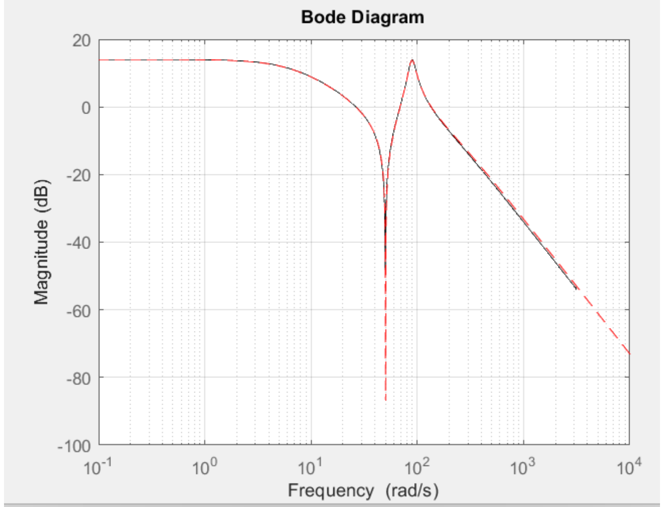
Task 3

c) Identify the transfer function from FRF:

```
% Define number of poles and number of zeros
pole_num = 4;
zero_num = 2;

sys_fr = idfrd(txy,om,Ts);
id_freq_tf = tfest(sys_fr, pole_num, zero_num);
W_ident_1 = tf(id_freq_tf.num, id_freq_tf.den);

bodemag(W_ident_1, '--r');
grid on
```



d) Compare the identified transfer function with the original one $W_1(s) = \dfrac{\omega_M(s)}{U(s)}$

Report content

1. Your name and HDU ID
2. Your variant and initial data
3. Simscape model of DC-motor with two-mass load
4. Block diagram model of DC-motor with two-mass load
5. Transfer functions of DC-motor with two-mass load
6. State space model of DC-motor with two-mass load
7. Simulation results
8. Bode plots of transfer functions
9. Value of resonant frequency
10. Experimentally estimated frequency response function
11. Experimentally estimated transfer function
12. Comparison of estimated transfer function with original one

Deadlines and penalties

ITMO

7 points - max

Deadline 1: 2025/03/25 – missing the deadline gives you 1-point penalty

Deadline 2: 2025/04/08 – missing the deadline gives you 2-point penalty

Missing the Task 2 gives you 1-point penalty

Missing the Task 3 gives you 1-point penalty

The link for uploading your report:

https://forms.yandex.ru/u/67cdcfcfd04688925ba8360e/

THANK YOU
FOR YOUR TIME!

ITsMOre than a UNIVERSITY