System Dynamics Homework 4

November 28, 2023

First Last

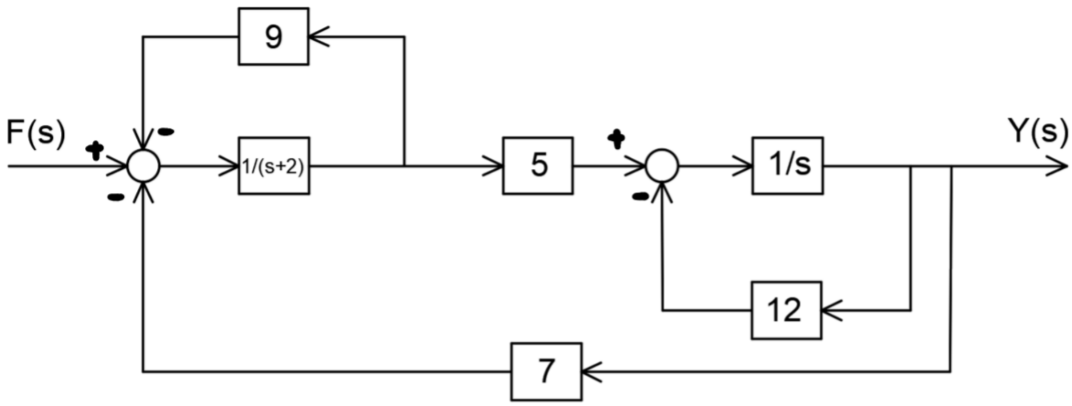
[1]:
```python
import sympy as sp
import control as ct
import matplotlib.pyplot as plt
import numpy as np
from scipy.integrate import odeint

# Use whichever pertains to your set-up
# plt.style.use('maroon_ipynb.mplstyle')
# plt.style.use('../maroon_ipynb.mplstyle')
```

Contents

1 Problem 1

1.1 Given



1.2 Find

Find the transfer function $\frac{Y(s)}{F(s)}$ for the block diagram.

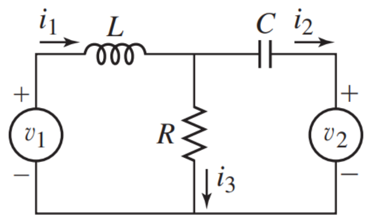
1.3 Solution

The solution can be determined using two different methods. The first is an algebraic solution where B is the expression after the first block seen above. The second can be determined using the feedback and series functions.

[ ]:

2 Problem 2

2.1 Given



$$L = 500\,mH,\ C = 100\,\mu F,\ R = 300\,\Omega$$

$$v_1 = 5e^{-t}\sin(6t)\,V,\ v_2 = 10\sin(t)\,V$$

All initial conditions are zero.

2.2 Find

a. The system of ODE's (should be two equations if using mesh currents).
b. Solve the system for i_1, i_2, and i_3 as seen the figure above. Use any method to find the result and plot up to 6 seconds.

2.3 Solution

2.3.1 Part A

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2.3.2 Part B

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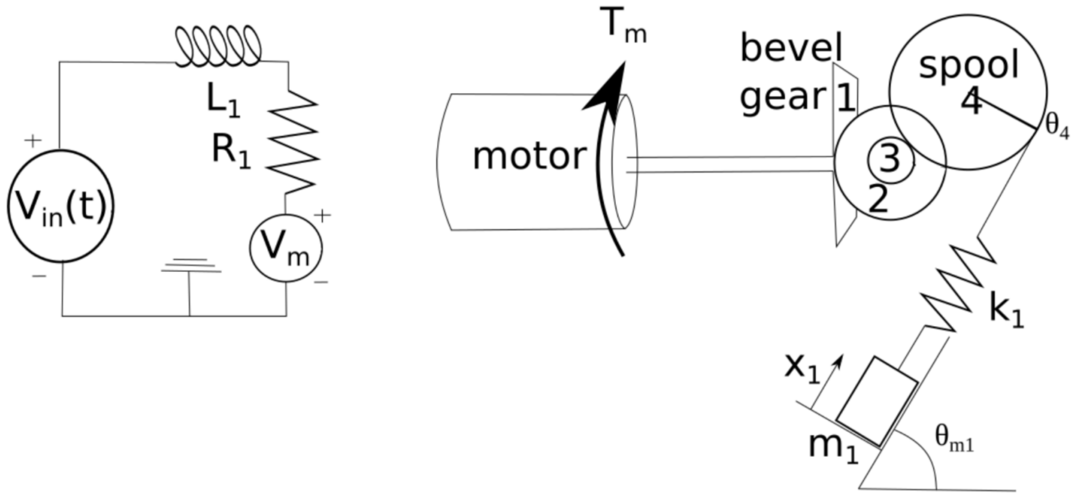
3 Problem 3

3.1 Given

The system shown below is designed to lift the mass with a stiff chain.



$$K_T = 0.01\,\frac{Nm}{A},\ R_1 = 0.5\,\Omega,\ L_1 = 0.002\,H$$
$$I_1 = 9\cdot 10^{-5}\,kg\,m^2,\ I_2 = 4\cdot 10^{-5}\,kg\,m^2,\ I_3 = 1\cdot 10^{-5}\,kg\,m^2,\ I_4 = 25\cdot 10^{-5}\,kg\,m^2$$
$$r_1 = 7.62\,cm,\ r_2 = 60.96\,cm,\ r_3 = 2.2\,cm,\ r_4 = 13\,cm$$
$$k_1 = 500\,N/m,\ m_1 = 220\,kg,\ \theta_{m1} = 70^{\circ}$$
$$V_{in} = 285\,V$$

[8]:
```
# Constants
KT, R1, L1, = sp.symbols('K_T R1 L1')
I1, I2, I3, I4 = sp.symbols('I1 I2 I3 I4')  # sympy automatically makes the␣
↪numbers a subscript
r1, r2, r3, r4 = sp.symbols('r1 r2 r3 r4')
k1, m1, thm1 = sp.symbols(r'k1 m1 \theta_{m1}')

# Other items you should consider using
t = sp.Symbol('t')
th1, th2, th3, th4 = sp.Function(r'\theta_1')(t), sp.Function(r'\theta_2')(t),␣
↪sp.Function(r'\theta_3')(t), sp.Function(r'\theta_4')(t),
i = sp.Function('i')(t)
x1 = sp.Function('x_1')(t)
Vin = sp.Function('V_{in}')(t)  # Input function
```

```python
# The sp.S() function ensures that there is no floating point error
sub_values = [
    (KT, sp.S('0.01')),
    (R1, sp.S('0.5')),
    (L1, sp.S('0.002')),
    (I1, sp.S('9e-5')),
    (I2, sp.S('4e-5')),
    (I3, sp.S('1e-5')),
    (I4, sp.S('25e-5')),
    (r1, sp.S('0.0762')),
    (r2, sp.S('0.0762')*8),
    (r3, sp.S('0.022')),
    (r4, sp.S('0.13')),
    (k1, 500),
    (m1, 220),
    (thm1, sp.rad(70))
]


Vin_lamb = lambda t_: 285
```

3.2 Find

Create a model to determine if the motor is strong enough by finding the following:

a. Determine the equivalent inertia (I_{eq}) of the gear train involving I_1, I_2, I_3, and I_4 as seen by the output shaft 1 of the motor.
b. Find the governing ODE's of the system.
c. Solve for and plot $x_1(t)$, $\theta_1(t)$, $\omega_1(t)$, and $i(t)$ up to 20 seconds.
d. Comment on the results. Is the motor able to raise the mass?

3.3 Solution

3.3.1 Part A

Use the concept of velocity ratios to relate everything back to ω_1.

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3.3.2 Part B

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3.3.3 Part C

The best way to solve this is to put it in the state variable form.

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3.3.4 Part D

type answer here