Duke University

Edmund T. Pratt, Jr. School of Engineering

ECE 141 Spring 2008

Test I

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Name (please print)____

In keeping with the Community Standard, I have neither provided nor received any assistance on this test. I understand if it is later determined that I gave or received assistance, I will be brought before the Undergraduate Judicial Board and, if found responsible for academic dishonesty or academic contempt, fail the class. I also understand that I am not allowed to speak to anyone except the instructor about any aspect of this test until the instructor announces it is allowed. I understand if it is later determined that I did speak to another person about the test before the instructor said it was allowed, I will be brought before the Undergraduate Judicial Board and, if found responsible for academic dishonesty or academic contempt, fail the class.

Signature:____

Instructions for Written and Discussion Sections

For each of these problems, there will be some groundwork in using frequency models for translational, rotational, and electrical systems. Be sure to indicate which part of a problem you are answering and put your name on the paper. If you need extra pieces of paper, make sure that you only do work from one problem on a page - you will be turning in the four problems as individual entities, much like the homeworks. Make sure your name and NET ID appear on each page and that you staple the relevant pages together before turning them in. If parameter values are given without units, you may assume base SI units.

Instructions for Computer-Based Sections

All your files for this test will be placed in a directory on your OIT account. There are two scripts you will be running to set everything up. The first - `StartTest1` - will create a folder called `ECE141TEST1` in your account and then set the permissions such that I can look at the files. You *must* make sure all your scripts, worksheets, and graphs end up in this folder. The second - `EndTest1` - will send me a snapshot of the directory contents and lock the directory from further changes. After I receive the e-mail, I will copy the directory contents to another location and delete the originals. Be sure to use the stated names for files.

To run the `StartTest1` script, log into your UNIX account and type:

```
~mrg/public/ECE141S08/StartTest1
```

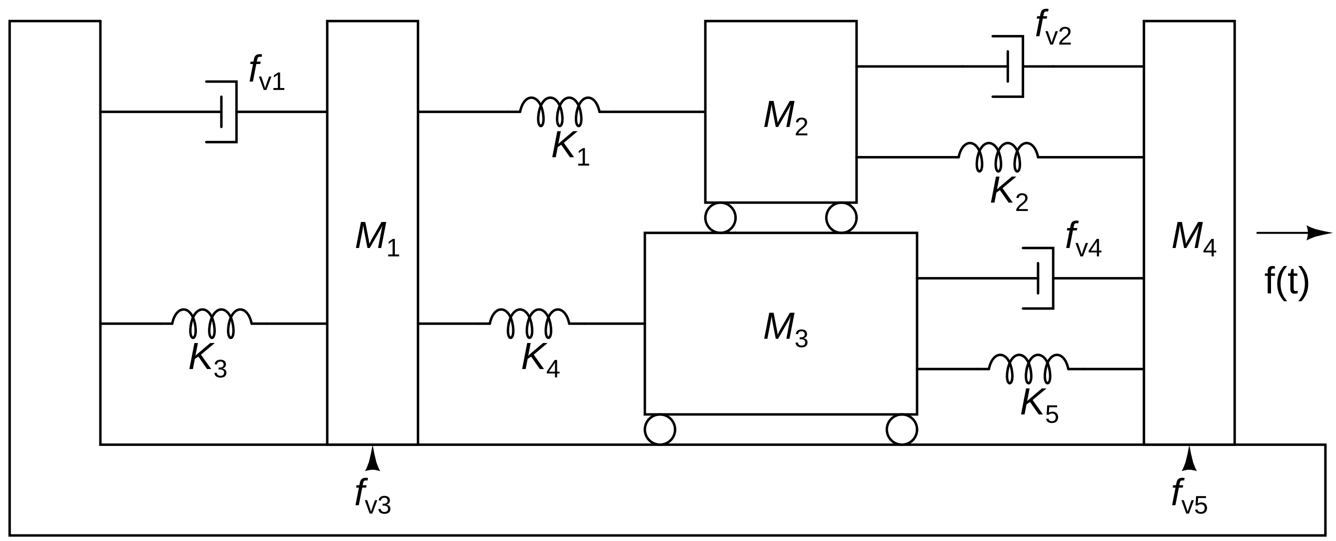
Similarly, when you are finished and ready to lock your directory, type:

```
~mrg/public/ECE141S08/EndTest1
```

Name (please print):
Community Standard (print ACPUB ID):

Problem I: [20 pts.] Translational Systems

For this problem, call your Maple script `Translation.mw`. Given the following translational system:



(a) Clearly set up a system of equations that could be used to solve for the Laplace transform of any of the positions of the masses as a function of the Laplace transform of the input force $\mathcal{L}\{f(t)\} = \mathcal{F}(s)$ and the symbolic representation of the physical parameters given. The position of mass $M_{\rm i}$ should be labeled $x_{\rm i}$.

(b) Using Maple, generate a worksheet that solves for the Laplace transforms of each of the four positions as functions of the Laplace transform of the input force $\mathcal{L}\{f(t)\} = \mathcal{F}(s)$ and the numerical values of the physical parameters, given below:

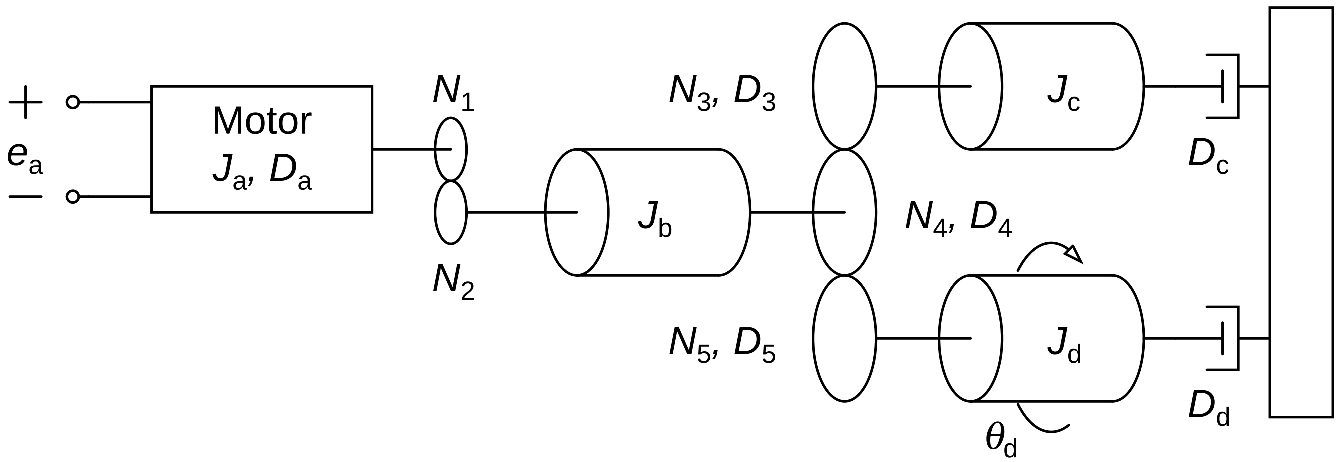
$M_1 = 1$	$M_2 = 1$	$M_3 = 1$	$M_4 = 1$	
$f_{v1} = 1$	$f_{v2} = 1$	$f_{v3} = 1$	$f_{v4} = 1$	$f_{v5} = 1$
$K_1 = 1$	$K_2 = 1$	$K_3 = 1$	$K_4 = 1$	$K_5 = 1$

Do not present the solutions until after you have `subs`tituted in the numerical values, but be sure to `simplify` your answer.

Name (please print):
Community Standard (print ACPUB ID):

Problem II: [30 pts.] Rotational Systems

For this problem, call your Maple script `Motor.mw`. Given the following rotational system:



(a) Draw the equivalent system, in frequency space, as seen by the motor. You may assume that a positive voltage $e_a(t)$ causes gear 1 to rotate such that the top comes towards you - i.e. it will spin in the same direction as $\theta_d(t)$.

(b) Assuming K_t, K_b, and R_a are known, determine an expression for the transfer function, $\mathcal{G}(s) = \Theta_d(s)/\mathcal{E}_a(s)$, using the physical parameters of the system and the motor characteristics.

(c) Determine the impulse response of the system, $g(t) = \mathcal{L}^{-1}\{\mathcal{G}(s)\}$, using the transfer function calculated above and the parameters:

$J_a = 1$	$J_b = 200$	$J_c = 10000$	$J_d = 10000$		
$D_a = 1$	$D_c = 4000$	$D_d = 9000$	$D_3 = 1000$	$D_4 = 100$	$D_5 = 1000$
$N_1 = 2$	$N_2 = 20$	$N_3 = 50$	$N_4 = 10$	$N_5 = 100$	

Assume a torque equation of:

$$T_m = -6\,\omega_m + 400$$

was measured when $e_a = 40$ V. Do not present the solution until after you have `subs`tituted in the numerical values, but be sure to `simplify` your answer.

Name (please print):
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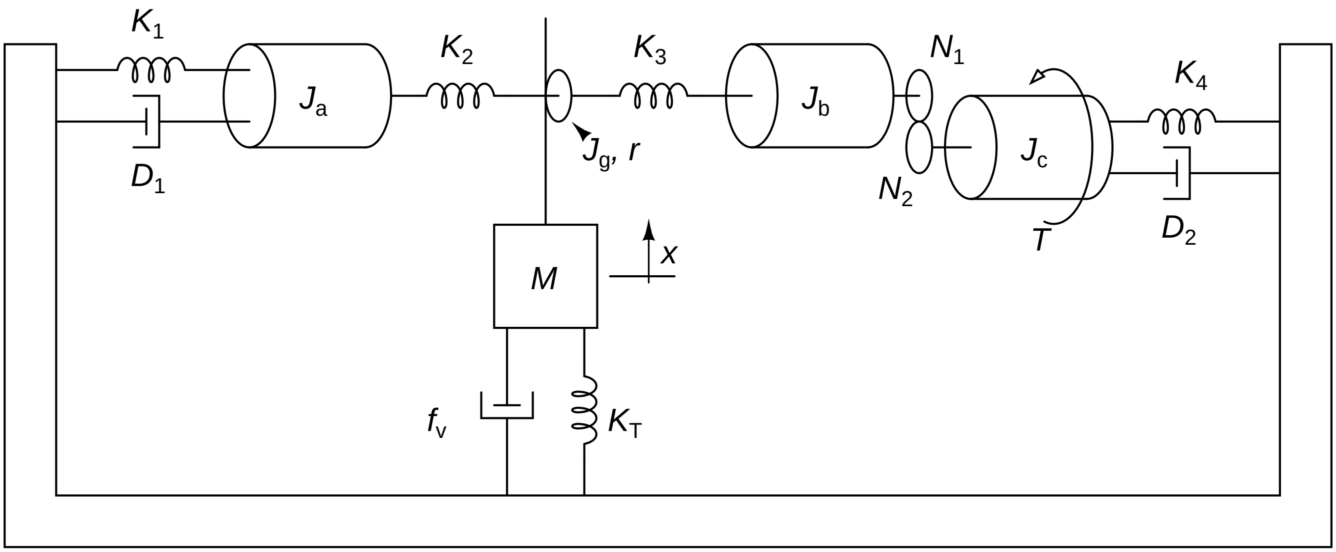
Problem III: [20 pts.] Translational and Rotational Systems

Given the following mechanical system:



(a) Clearly draw the system from the perspective of the pinion gear J_g, using symbols.

(b) Clearly set up a system of equations that could be used to solve for the Laplace transform of any of the angular positions of the shafts or of the position of the translational masses as a function of the Laplace transform of the input torque $\mathcal{L}\{T(t)\} = \mathcal{T}(s)$ and the symbolic representation of the physical parameters given. Be sure to clearly define any unknowns you introduce to the problem.

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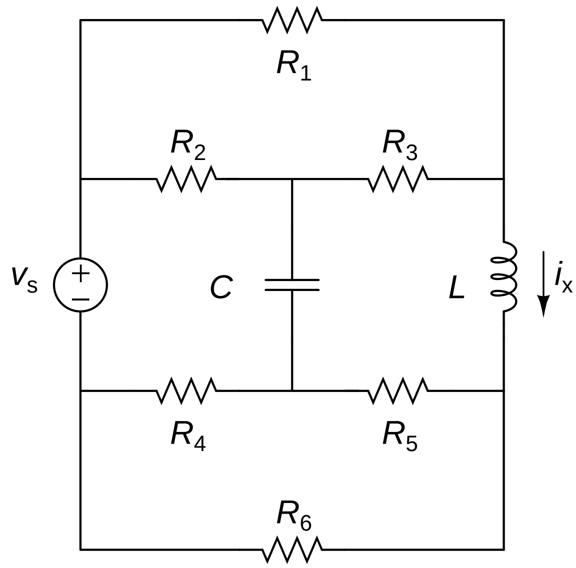
Problem IV: [30 pts.] Electrical Systems

For this problem, call your Maple script `Circuit.mw`. Given the following electrical system:



(a) Use the Mesh Current Method in the frequency domain to set up a system of equations that could be used to solve for the Laplace transform of any of the mesh currents as a function of the Laplace transform of the input source voltage $\mathcal{L}\{v_s(t)\} = \mathcal{V}_S(s)$ and the symbolic representation of the physical parameters given. Be sure to clearly define any unknowns you introduce to the problem.

(b) Assuming that each of the parameters has a value of 1 unit (Ω, H, or F as appropriate), determine the value of the transfer function $\mathcal{Y}(s) = \mathcal{I}_x(s)/\mathcal{V}_s(s)$. Do not present the solution until after you have `subs`tituted in the numerical values, but be sure to `simplify` your answer.

(c) Write the differential equation of $i_x(t)$ as a function of $v_s(t)$ that this represents.

(d) Again assuming unit values for all the physical parameters, and further assuming that it has been determined at time 0 that $i_x(0^+) = 1$ A and $\left.\frac{di_x}{dt}\right|_{0^+} = 2$ A/s, determine an analytical expression for $i_x(t)$ for $t > 0$ if $v_s(t) = \sin(t)\ u(t)$.