Duke University
Edmund T. Pratt, Jr. School of Engineering

ECE 141 Spring 2009

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 with PuTTY and type:

```
~mrg/public/ECE141S09/StartTest1
```

Next, type `cd ~/ECE141TEST1`, use `pwd` to make sure you are in the right place, and start `xmaple`.

When you are finished with the test and ready to lock your directory, type:

```
~mrg/public/ECE141S09/EndTest1
```

Name (please print):
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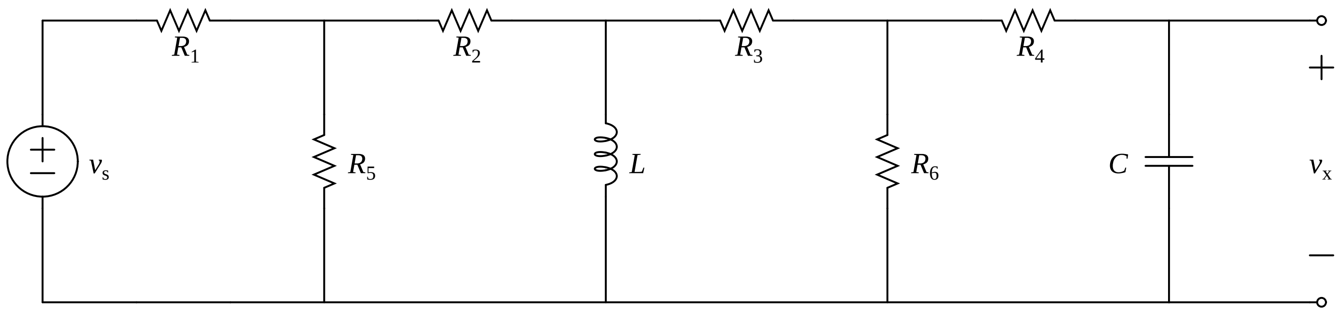
Problem I: [25 pts.] Electrical Systems

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



(a) Use the Mesh Current Method to clearly set up and solve a system of equations to find the Laplace transform of each of the mesh currents as functions of the Laplace transform of the input voltage $\mathcal{L}\{v_\text{s}(t)\} = \mathcal{V}_\text{S}(s)$ and the symbolic representation of the physical parameters given. Assign this solution set to a variable called `MySoln` and put a colon at the end of the line where you get the solutions... Because nobody wants to see that.

(b) Assuming that each of the parameters has a value of 1 unit (Ω, H, or F as appropriate), use Maple and the appropriate mesh current(s) solution(s) to determine the value of the transfer function $\mathcal{Y}(s) = \mathcal{V}_\text{x}(s)/\mathcal{V}_\text{s}(s)$. Be sure to `simplify` your answer and present it as a ratio of polynomials.

(c) Again using the numerical values and assuming the capacitor is initially uncharged and the inductor has no current through it at time 0, use Maple to find $v_\text{x}(t)$ for $t >= 0$ if $v_\text{s}(t) = \left(e^{-t} - e^{-2t}\right)\, u(t)$. Be sure to `simplify` your answer.

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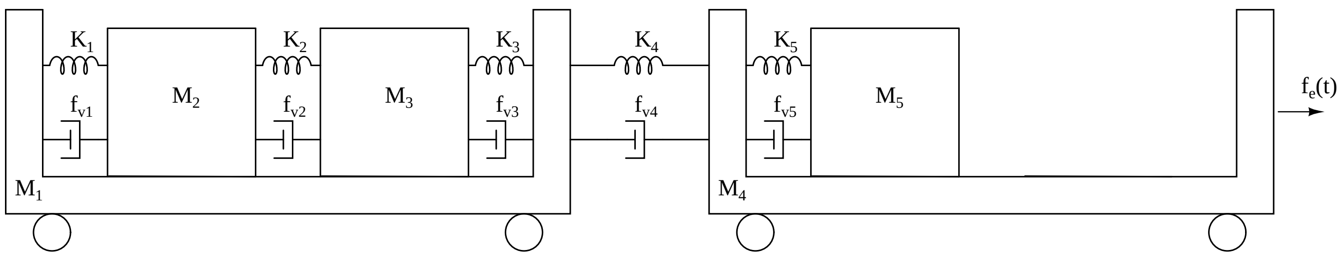
Problem II: [25 pts.] Translational Systems

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



Assume the contact between the boxes and the train cars is frictionless.

(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 $\mathcal{L}\{f_{\rm e}(t)\} = \mathcal{F}_{\rm e}(s)$ 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 five positions as functions of the Laplace transform of the input force $\mathcal{L}\{f_{\rm e}(t)\} = \mathcal{F}_{\rm e}(s)$ and the symbolic parameter values. Assign this solution set to a variable called `MySoln` and put a colon at the end of the line where you get the solutions... Because, again, nobody wants to see that.

(c) Using Maple, substitute the following numerical values for the physical parameters into your solutions above and present the simplified results.

$M_1 = 1000$	$M_2 = 10$	$M_3 = 10$	$M_4 = 1000$	$M_5 = 10$
$f_{\rm v1} = 10$	$f_{\rm v2} = 10$	$f_{\rm v3} = 10$	$f_{\rm v4} = 10$	$f_{\rm v5} = 10$
$K_1 = 20$	$K_2 = 20$	$K_3 = 20$	$K_4 = 20$	$K_5 = 20$

There should be five simplified numerical expressions for the Laplace transforms of each of the five positions, and each should be a function of $\mathcal{F}_{\rm e}(s)$ alone.

(d) Re-write the numerical expression for the transfer function of $\mathcal{X}_5(s)$ with respect to $\mathcal{F}_{\rm e}(s)$ as a differential equation relating $x_5(t)$ to $f_{\rm e}(t)$.

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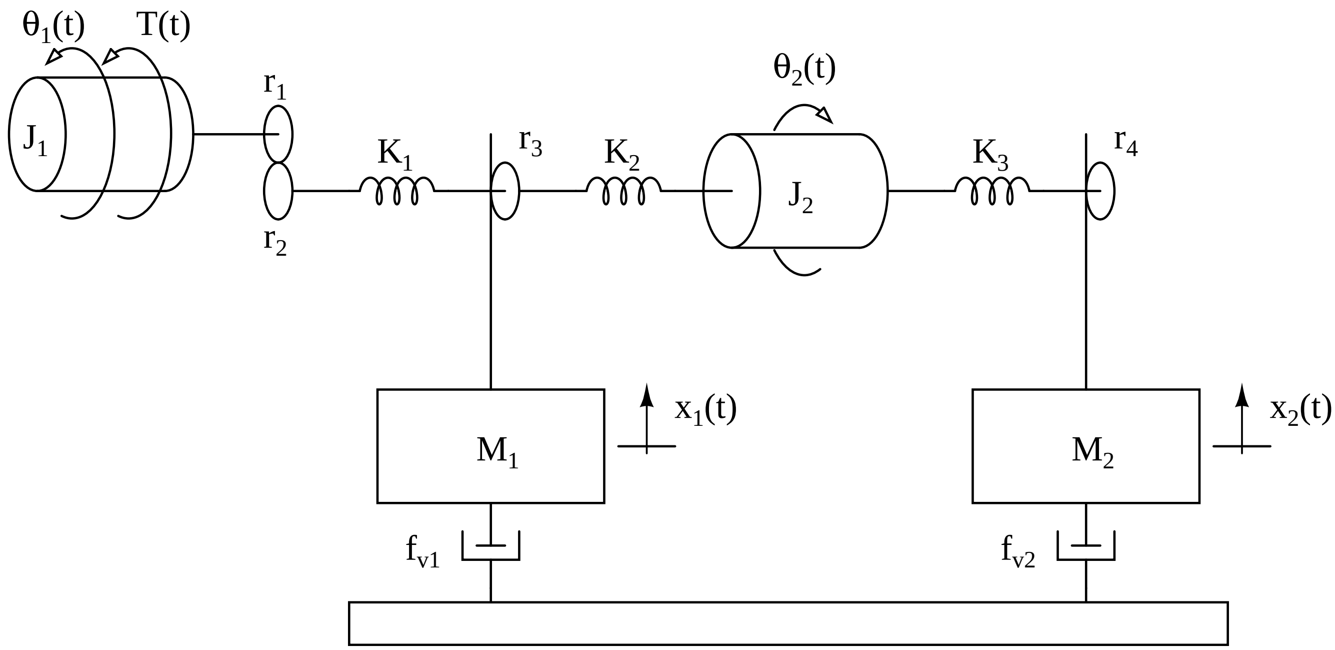
Problem III: [25 pts.] Translational and Rotational Systems

For this problem, call your Maple script `Dumbwaiter.mw`. A crank-driven lift is in place to raise and lower two dumbwaiters simultaneously. The system can be modeled as:



(a) Clearly draw the system from the perspective of the crank shaft J_1, using symbols.

(b) Clearly set up and solve a system of equations to find the Laplace transform of each of the angular positions of the shafts and of the positions of the translational masses as functions of the Laplace transform of the input torque $\mathcal{L}\{T(t)\} = \mathcal{T}(s)$ and the symbolic representation of the physical parameters given. Assign this solution set to a variable called `MySoln` and put a colon at the end of the line where you get the solutions... Because... you know...

(c) Using Maple, substitute unity (1) in for all physical parameters (masses, inertias, damping, spring constant, and radii) and present the simplified numerical results. At the end of your worksheet, you should have clear expressions for $\Theta_1(s)$, $\Theta_2(s)$, $\mathcal{X}_1(s)$, and $\mathcal{X}_2(s)$ in terms of the input torque.

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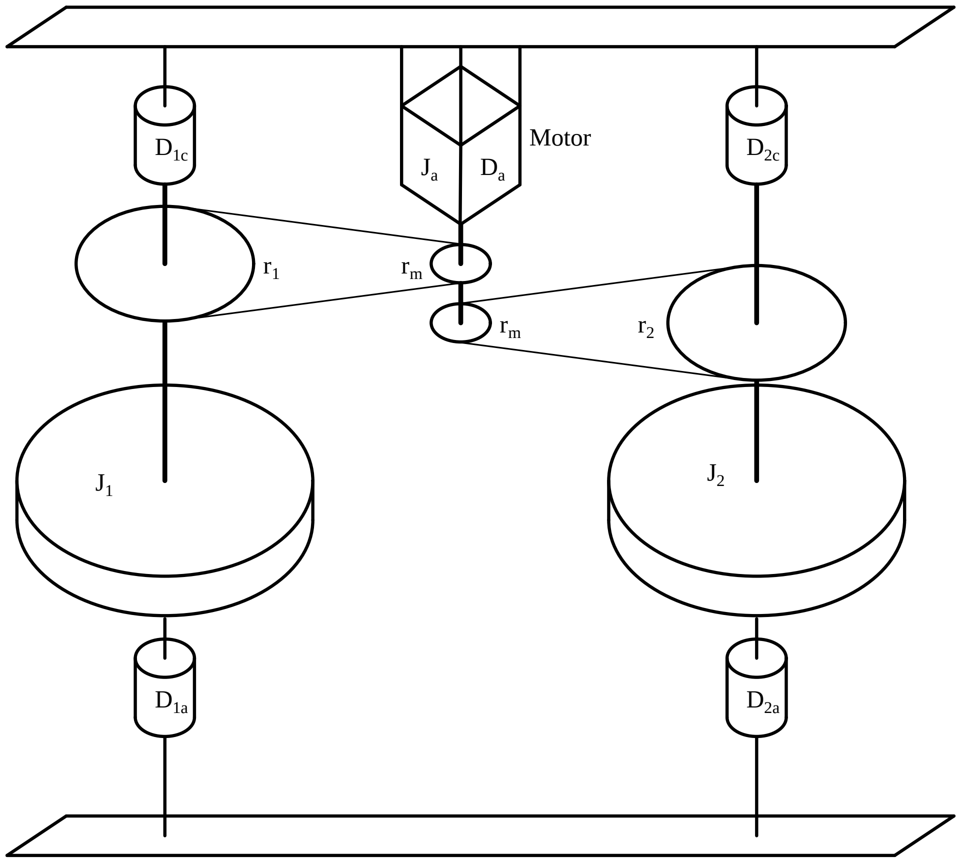
Problem IV: [25 pts.] Driven Rotational Systems

For this problem, call your Maple script `CeilingFan.mw`. A ceiling fan system with a single central motor and two satellite fans mounted some distance away and driven by belts can be modeled as:



where the dampers D_{1c} and D_{2c} represent the viscous damping between the unmoving ceiling and the rotating fan shafts, dampers D_{1a} and D_{2a} represent the viscous damping resulting from air flow, and the inertias J_1 and J_2 represent the rotational inertias of both the fan shafts and the fan blades.

(a) Draw the equivalent system, in frequency space, as seen by the motor. You may assume that a positive voltage $e_a(t)$ causes the motor shaft to rotate such that the motor shaft and the fans spin in the "positive z" direction. Also, the bands between the gears do not slip.

(b) Assuming K_t, K_b, and R_a are known, determine an expression for the transfer function between the angle of fan 1 and the voltage applied to the motor, $\mathcal{G}(s) = \Theta_1(s)/\mathcal{E}_a(s)$, using the physical parameters of the system and the motor characteristics. Using Maple, present a (simplified) symbolic representation of the transfer function as a ratio of polynomials. Because *everybody* wants to see *that*!