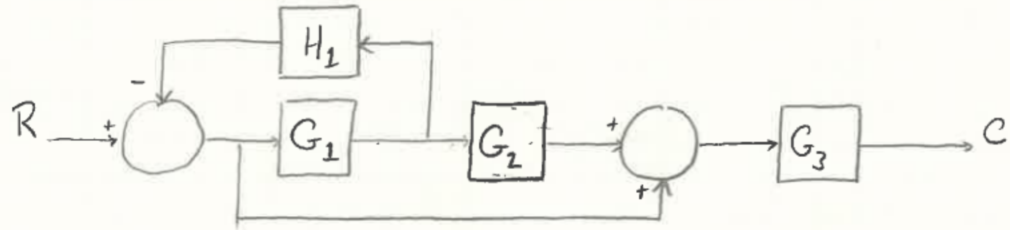
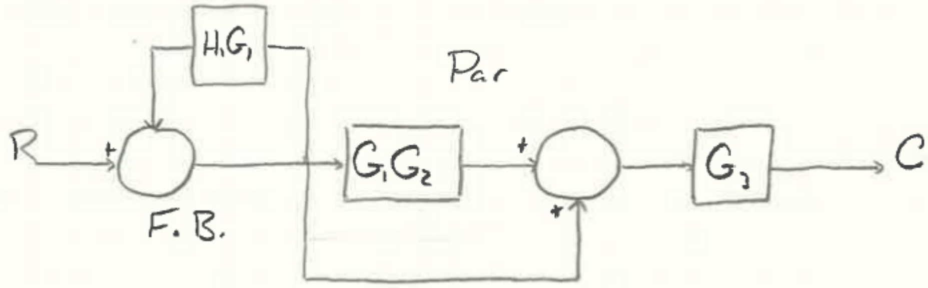
METTLER HW #9

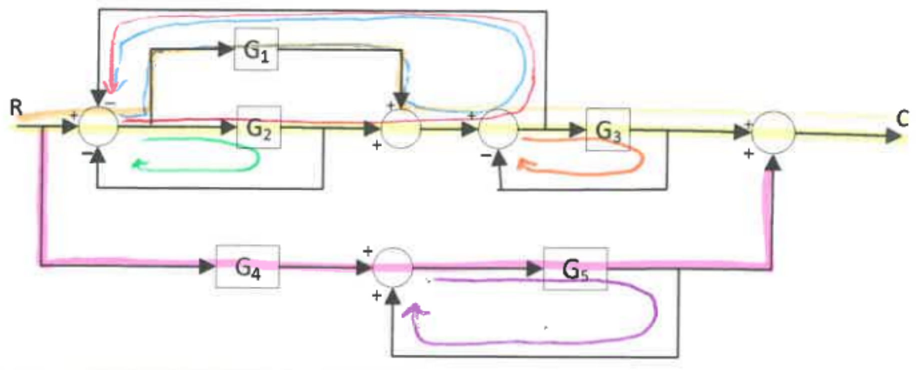


Move G_1 RIGHT



$$\frac{C}{R} = \frac{(G_1G_2+1)G_3}{1 + H_1G_1}$$

METTLER HW #7



1AAT	2AAT	3ATT	FORWARD
$L_1 = -G_2$	$L_1 L_4$	$L_1 L_4 L_5$	$F_1 = G_2 G_3$
$L_2 = -G_1$	$L_1 L_5$		$F_2 = G_1 G_3$
$L_3 = -G_2$	$L_2 L_5$		$F_3 = G_4 G_5$
$L_4 = -G_3$	$L_3 L_5$		
$L_5 = -G_5$	$L_4 L_5$		

$\Delta_1 = 1 - L_5$

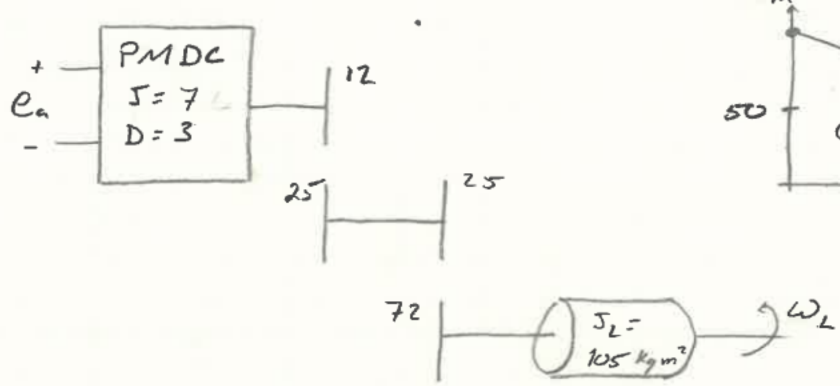
$\Delta_2 = 1 - L_5$

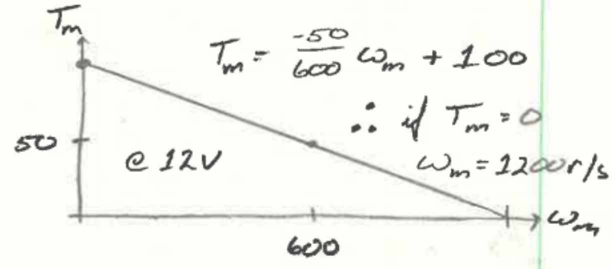
$\Delta_3 = 1 - (L_1 + L_2 + L_3 + L_4) + (L_1 L_4)$

$\Delta = 1 - (L_1 + L_2 + L_3 + L_4 + L_5) + (L_1 L_4 + L_1 L_5 + L_2 L_5 + L_3 L_5 + L_4 L_5) - L_1 L_4 L_5$

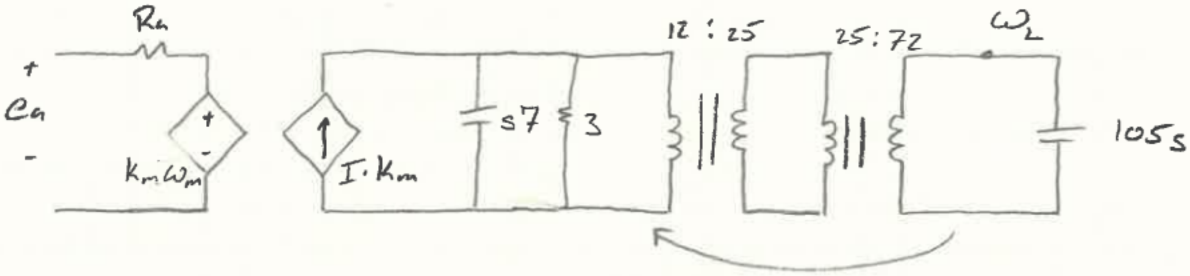
$$T(s) = \frac{F_1 \Delta_1 + F_2 \Delta_2 + F_3 \Delta_3}{\Delta}$$

METTLER HW #4





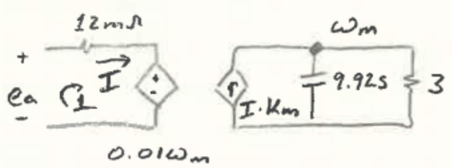
CONVERT



$$\left(\frac{25}{72}\right)^2\left(\frac{12}{25}\right)^2 105s$$
$$= 2.92s$$

$K_m = 12/1200 = 0.01$

$R_a = 12/[100/0.01] = 12\,m\Omega$



KCL @ m

$0.01\,I = \omega_m(9.92s + 3)$

KVL @ 1

$e_a = I \cdot 12m\Omega + 0.01\omega_m$

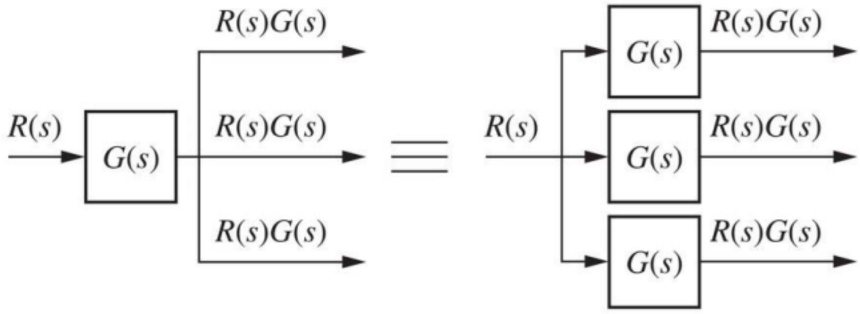
$\frac{e_a - 0.01\omega_m}{12\,m\Omega} = I$

$8.33\left[e_a - 0.01\omega_m\right] = \omega_m(9.92s + 3)$

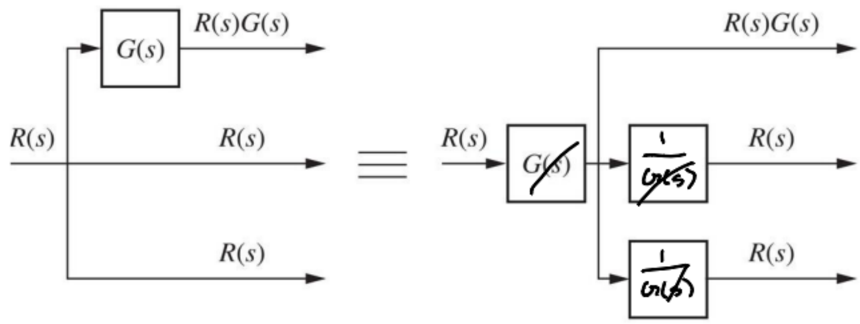
$8.33\,e_a = \omega_m(9.92s + 3.1)$

$\frac{\omega_m}{e_a} = \frac{8.33}{(9.92s + 3.1)} = \frac{0.84}{s + 0.3}$

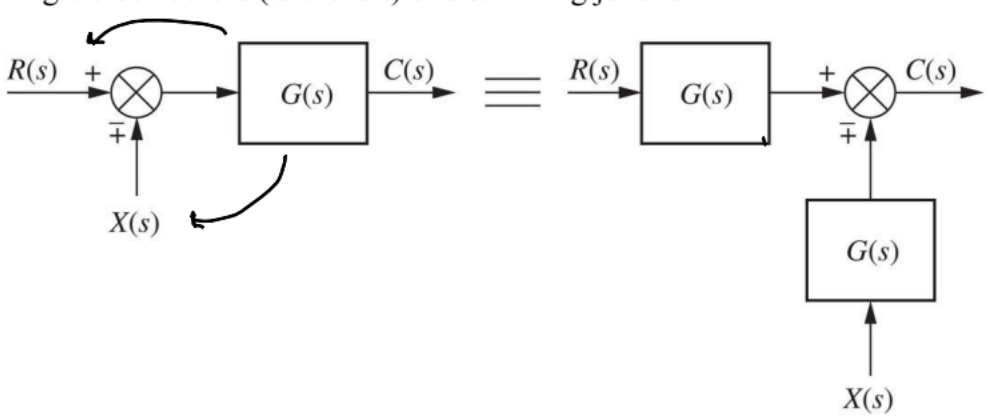
B. Moving a block across (to the right) of a "pick off point" (new term for a node)



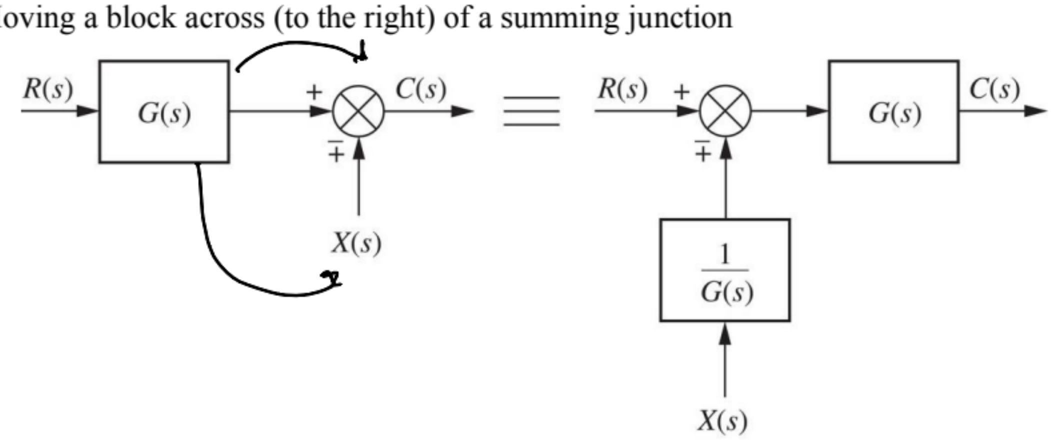
C. Moving a block before (to the left) of a pick off point



D. Moving a block before (to the left) of a summing junction



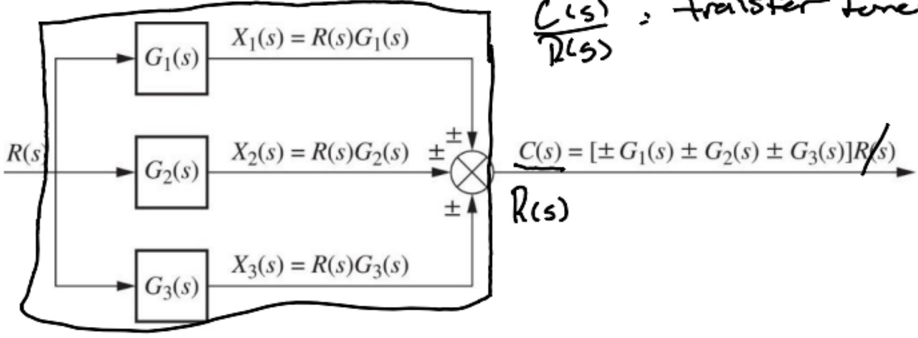
E. Moving a block across (to the right) of a summing junction



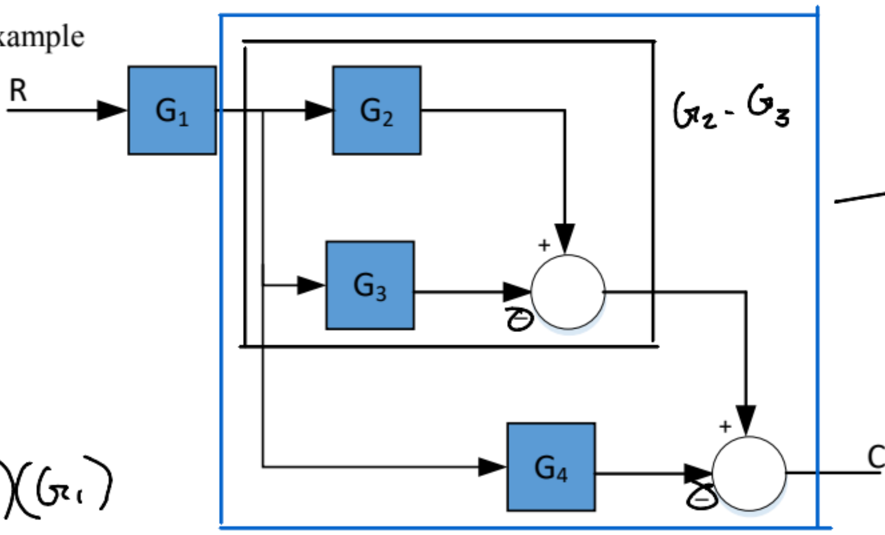
2. More advanced reduction techniques
Remember, we want the output to remain the same for all I/O regardless of movement

A. Summing parallel branches

$\frac{C(s)}{R(s)}$: transfer function



Example



$G_2 - G_3$

$\longrightarrow G_5$

$C = (R)(G_5)(G_1)$

$(G_2 - G_3) - G_4 = G_5$

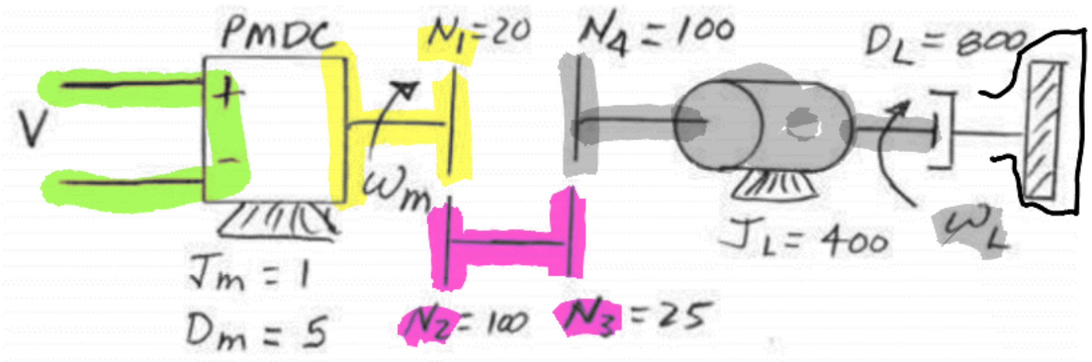
Series

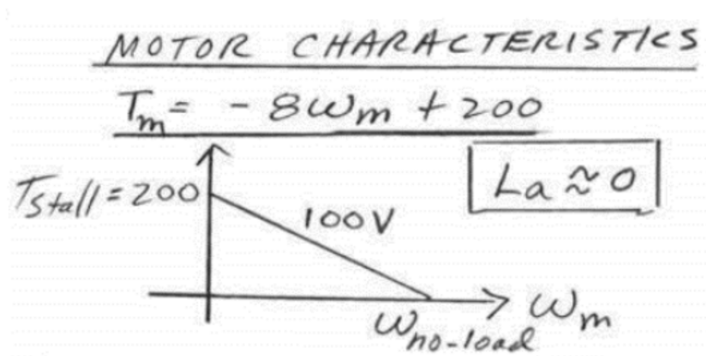
$R \rightarrow \boxed{G_1} \rightarrow \boxed{G_5 = G_2 - G_3 - G_4} \rightarrow C = (G_5)(G_1)(R)$

$T(s) = \frac{C}{R} = G_1 G_5$

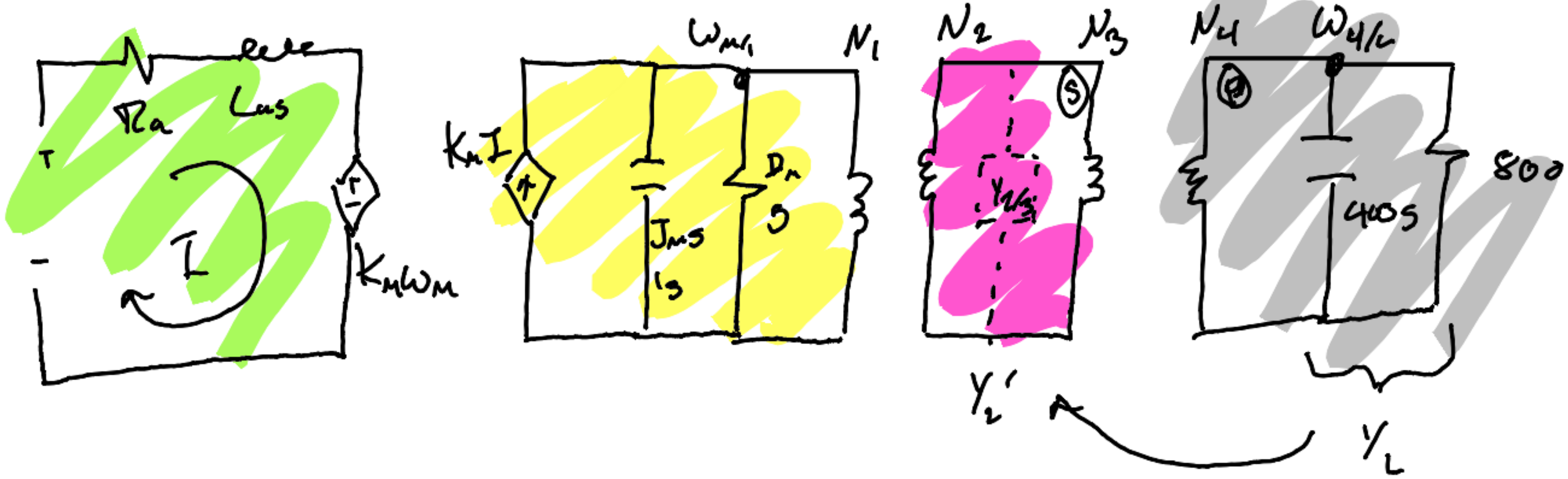
4. Example: TAPPS
(Sometimes when I do TAPPS, I intentionally include commonly made mistakes or leave blanks. Your job is to walk through the exercise carefully enough to identify mistakes and complete the solution. This time I will help you get started)

Given this electromechanical system, determine the transfer function $\frac{\omega_L}{V}$ if the PMDC has the provided motor characteristics.





First, build an electrical model,



$$Y_s = Y_p\left[\frac{N_s}{N_p}\right]^2$$

Now, let's reflect the load toward the source in one step

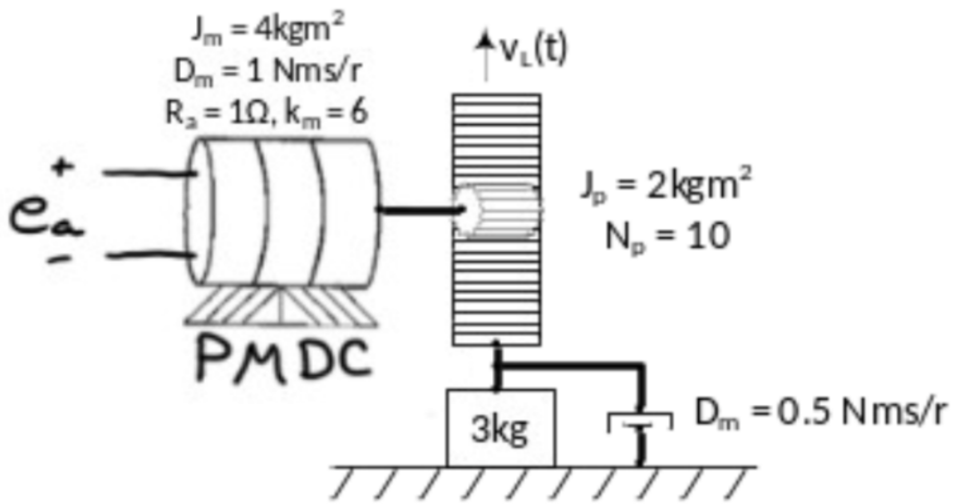
3. Electrical-Mechanical Conversions [30pt]

Learning Objectives:

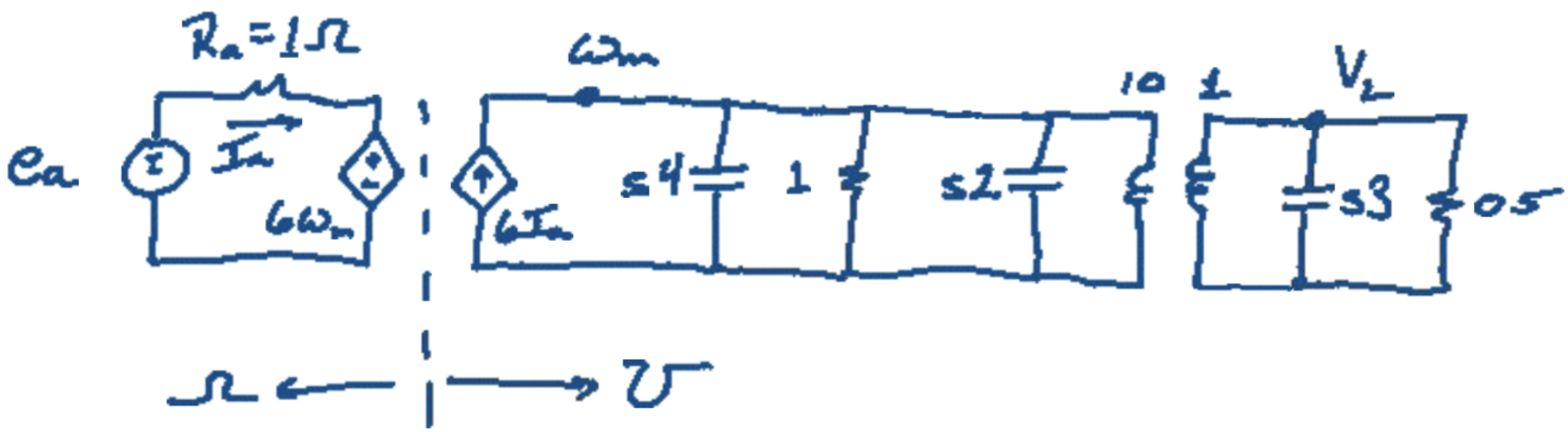
6. *Develop transfer functions*
7. *Identify a system's signals and characteristic equation*
8. *Convert between translational and electrical systems*
9. *Convert between rotational and electrical systems*
10. *Apply analogies for mechanical gears*
11. *Build electrical models and block diagram of electromechanical systems.*

Problem Statement:

Given this system driven by a PMDC, draw the Torque/Force – Velocity equivalent circuit in the Laplace domain, in units of mhos, without any simplification/reduction. Assume the PMDC is supplied an external voltage e_a and v_L is the speed of the load.



1 mistake: -3
2 mistakes -9
3 or more mistakes: -30



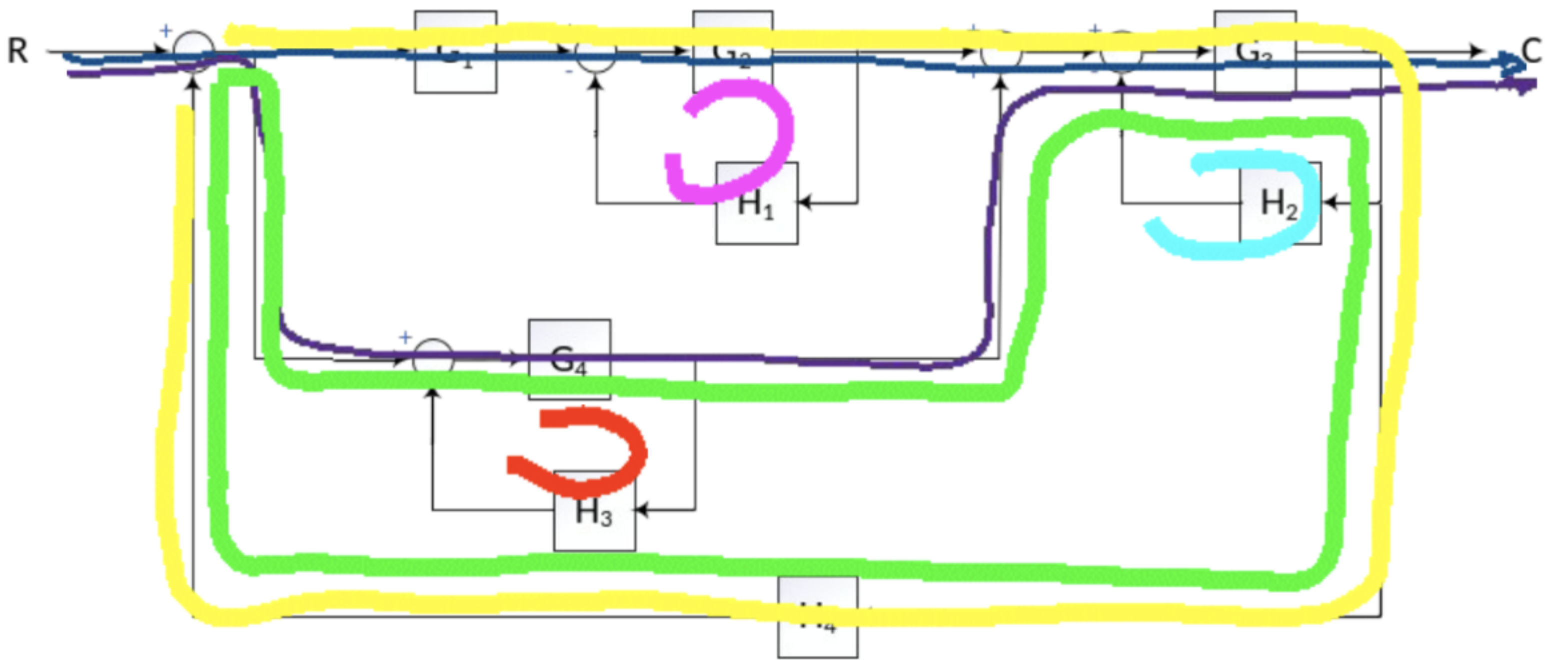
2. Mason's Gain Rule **[30pts]**

Learning Objectives:

22. Apply Mason's Gain Rule to directly determine closed loop transfer functions

Problem Statement:

Use MGR to find the following:



<u>Two 1 AAT Loops</u>

$L_1 = -G_1G_2G_3H_4$

$L_2 = -G_3G_4H_4$

$L_3 = -G_2H_1$

$L_4 = -G_3H_2$

$L_5 = -G_4H_3$

+5each

<u>One Forward Path</u>

$F_1 = G_1G_2G_3$

$F_2 = G_3G_4$

+5 for one

<u>Two 2 AAT Loops</u>

L_1L_5

L_2L_3

L_3L_4

L_3L_5

L_4L_5

+5 for one

<u>The Δ specific to the forward path you listed</u>

$\Delta_1 = 1 - L_5$

$\Delta_2 = 1 - L_3$

+5 for one

<u>One 3 AAT Loop</u>

$L_3L_4L_5$

+5 for one

1. **General Control System Terminology** **[10pts]**
   What are the two primary control system configurations?

   Open & Closed loop

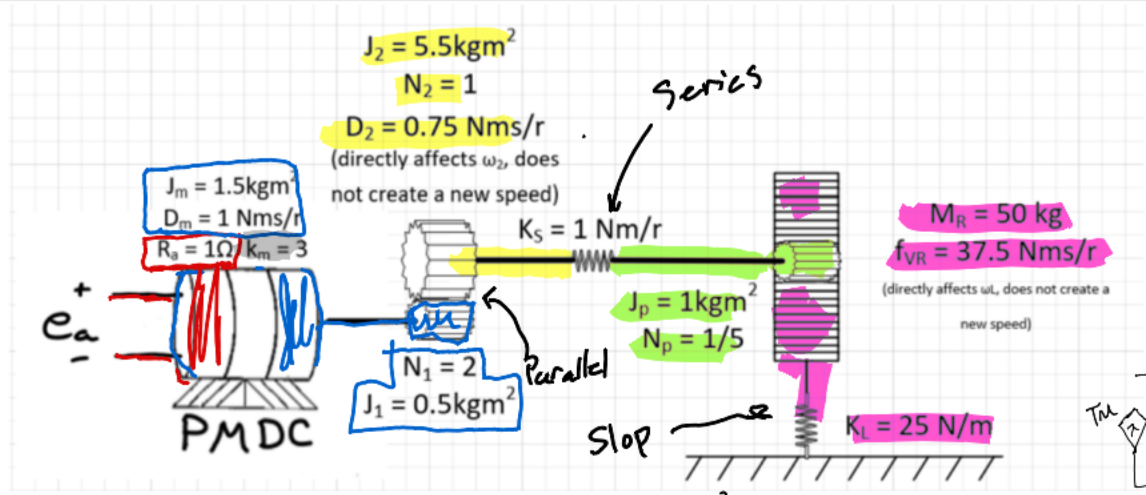
2. **Block Diagram Reduction**
   Moving a transfer function block before (left) of a summing junction requires at least:

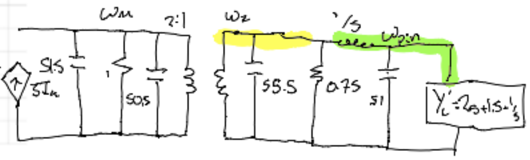
   1. The inclusion of an additional block of the inverse of the transfer function
   2. The inclusion of an additional block of the same transfer function
   3. That closed loop feedback is present
   4. That closed loop feedback is NOT present
   5. The summing junction is only part of a forward path (ie: only positive summations)
   6. The summing junction is part of the feedback loop (ie: there is at least 1 subtraction)

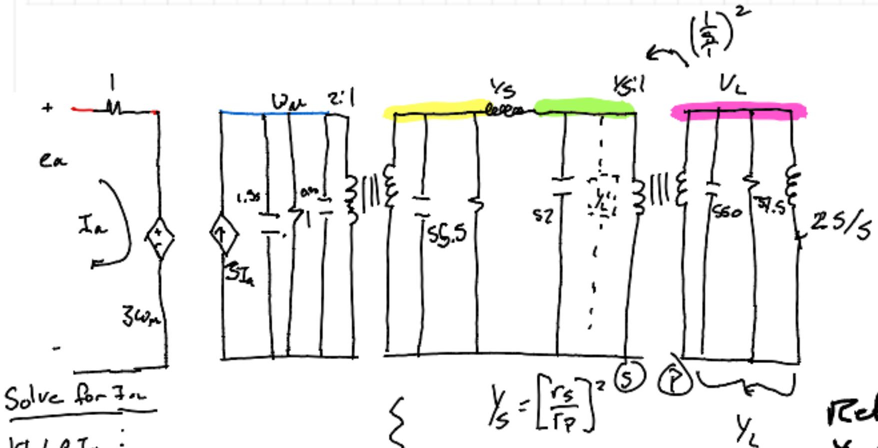
Project Prep #1 -

Thursday, September 7, 2023 2:44 PM

Create a model of this mechanical system







① Solve for I_a

KVL @ I_a:

$-e_a + I_a + 3\omega_m = 0$

$I_a = \left(\frac{e_a - 3\omega_m}{1}\right)$

$Y_S = \left[\frac{r_S}{r_P}\right]^2$

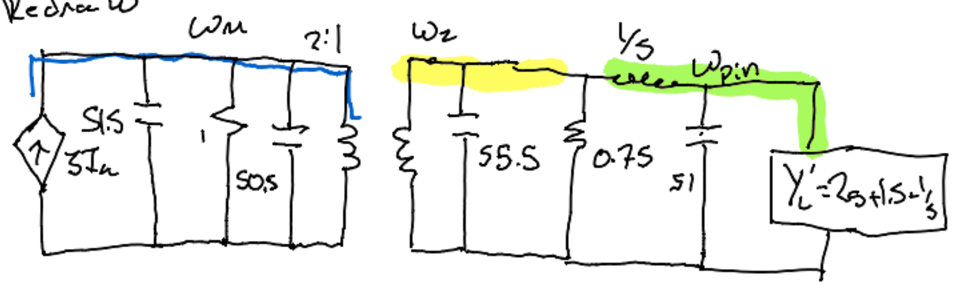
$Y_L = (50s + 37.5 + \frac{25}{s})$

$Y_L' = \left(\frac{1}{.5}\right)^2 (50s + 37.5 + \frac{25}{s})$

$Y_L' = 2s + 1.5 + 1/s$

Reflect Y_L to Y_L'

② Redraw



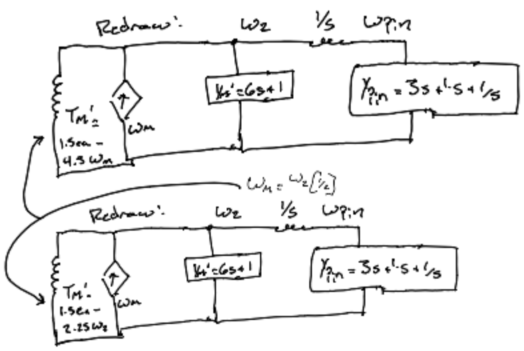
③ Reflect Input

Recall: $T_S = T_P\left[r_S/r_P\right] \rightarrow T_M' = (3e_a - 9\omega_m)\left[\frac{1}{2}\right]$

$Y_S = Y_P\left[r_S/r_P\right]^2 \rightarrow Y_M' = (2s+1)\left[\frac{1}{2}\right]^2$
$= 6s + 1$

④ Simplify right-side: $Y_{Pin} = S1 + Y_L'$

⑤ Simplify left-side: $Y_2 = (S1.5s + S0.5s) + Y_m'$

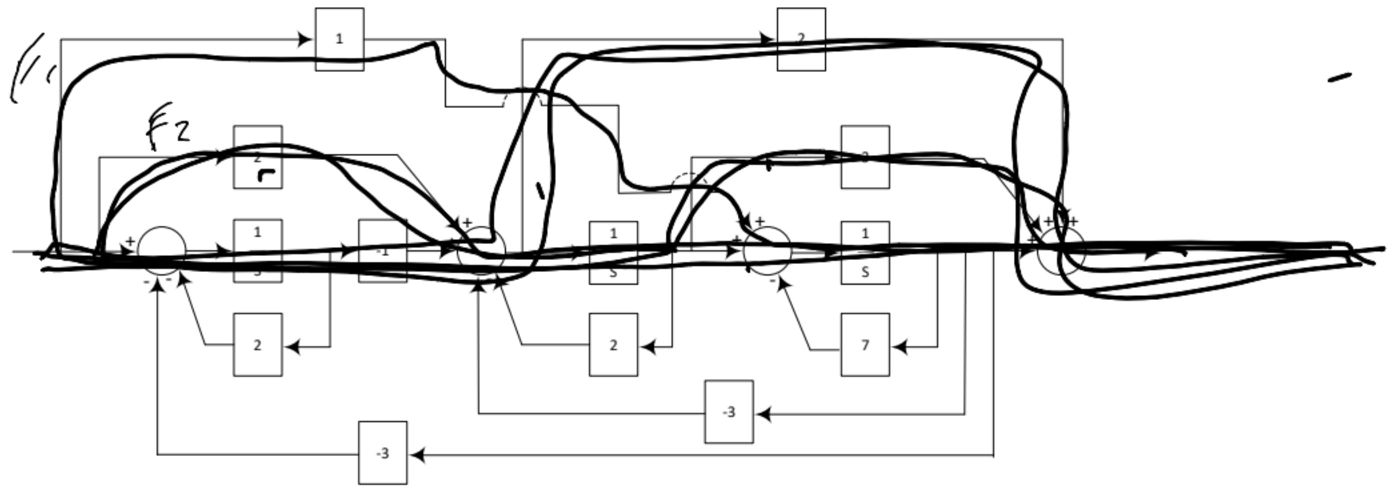


$$\frac{\omega_{Pin}}{e_a} = \frac{1.5s}{18s^4 + 18.75s^3 + 19.875s^2 + 8s + 1} = \frac{1.5s}{\Delta}$$

$\Delta/_{18}$

$$\frac{V_L}{e_a} = \frac{\omega_{Pin}}{e_a}\left[\frac{1}{5}\right] = \frac{0.3s}{\Delta}$$

$$\frac{P_L}{e_a} = \frac{0.3}{\Delta}$$



Step 4: Identify all the forward paths, labeled Forward

<u>Forward</u>

$k = 7$

$F_1 = \frac{1}{s}(-1)(\frac{1}{s})(\frac{1}{s}) = \frac{1}{s^3}$ $\qquad$ $F_5 = \frac{1}{s}(1)\,2$

$F_2 = 2(\frac{1}{s})(\frac{1}{s}) = 2/s^2$

Step 5: Determine the Deltas

$\Delta_1 = 1 –$ (sum of all 1att not touching F_1) + (sum of all 2att not touching F_1)….

$\Delta_1 = 1 - 0$ $\qquad$ $\Delta_5 = 1 - (L_3 + L_4 + L_5) + (L_3 L_5)$

$\Delta_2 = 1 - L_1$

$\Delta_3 =$

1AAT $\qquad$ 2AAT $\qquad$ 3AAT

$\Delta = 1 - (L_1 + \dots L_5) + (L_1L_3 + L_1L_4 + L_1 + L_5 + L_3L_5) - L_1L_3L_5$

Step 6: Solve

$$T = \frac{C}{R} = \frac{F_1\Delta_1 + F_2\Delta_2 + \dots F_7\Delta_7}{\Delta}$$

$1s^x + ?\,s^{x-1} \dots$