ELEC 341 – Graded Assignments

Assignment A3
Mechanical Circuits

100 Marks

Required Files

Available on Canvas

- **e341-a3.pdf** *Assignment description (this document)*
- **a3Submit.p** *Grading script (**LATEST** version)*
- **e341-APE.pdf** *Instructions for submitting graded work (for reference)*

Topics

Electro-Mechanical Equivalents
- mechanical circuit analysis

Motor Model
- mixed mode systems

Power & Energy
- conservation of energy

Figure 1

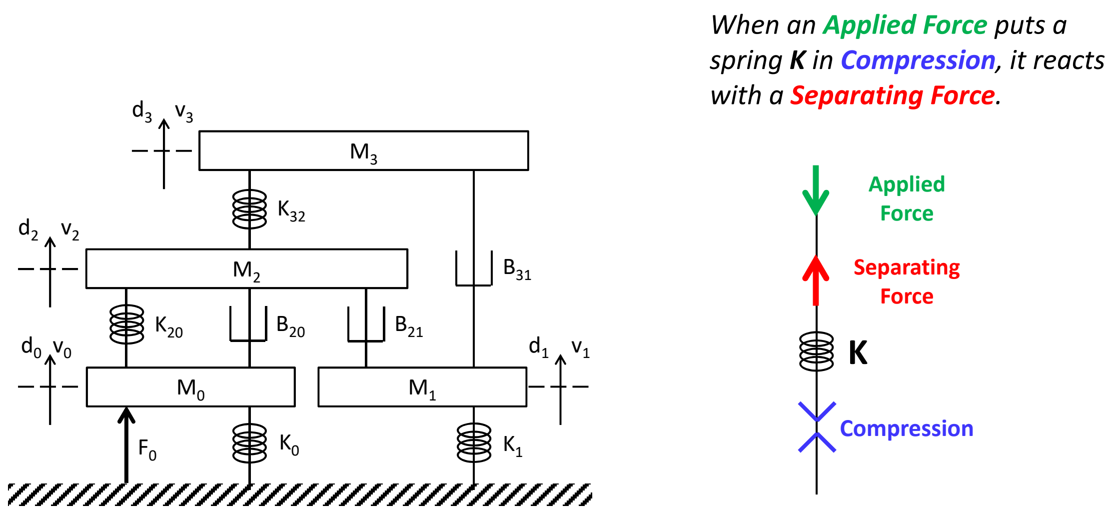

Figure 2

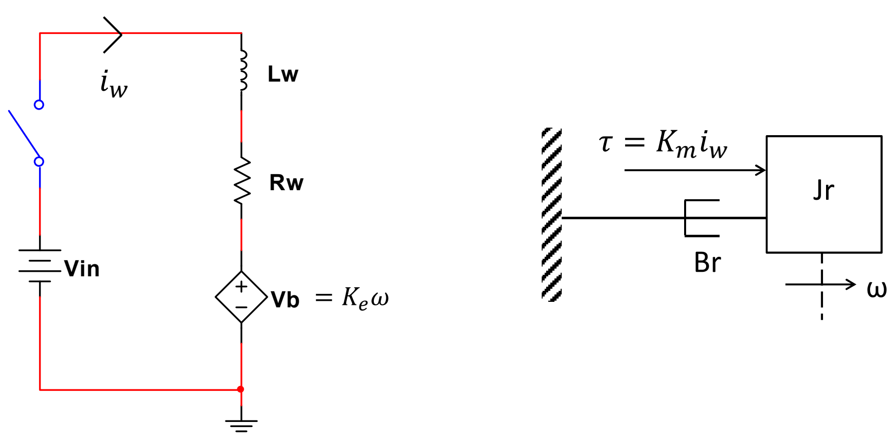

Figure 1 Parameters				Figure 2 Parameters		
Parameter	Value	Physical Units		Parameter	Value	Physical Units
M_0	#A / 5	Kg		R_W	#A / 3	Ω
M_1	#B / 10	Kg		L_W	#B	mH
M_2	#C / 10	Kg				
M_3	#D / 5	Kg		J_r	#C / 10	m-Nms^2
				B_r	#D + #E	m-Nms
B_{20}	#E / 2	Ns/m				
B_{21}	#F / 3	Ns/m		K_e	#G x 50	m-Vs
B_{31}	#G / 4	Ns/m		K_m	#G x 50	m-Nm/A
K_0	#A	N/m				
K_1	#B	N/m				
K_{20}	#C	N/m				
K_{32}	#D / 3	N/m				

Transform the mechanical circuit in **Figure 1** into its electrical equivalent.
Use nodal analysis to solve the circuit.
Find the transfer function: $\mathbf{G_{d1} = d_1/F_0}$
Find the transfer function: $\mathbf{G_{d3} = d_3/F_0}$

1. **20 mark(s) Distance Gains**
   - Q1.Gd1 (m/N) LTI
   - Q1.Gd3 (m/N) LTI

Find the transfer function: $\mathbf{G_{f1} = f_{k1}/F_0}$ $\mathbf{f_{k1}}$ is **separating** force in spring $\mathbf{K_1}$
Find the transfer function: $\mathbf{G_{f32} = f_{k32}/ F_0}$ $\mathbf{f_{k32}}$ is **separating** force in spring $\mathbf{K_{32}}$

2. **20 mark(s) Force Gains**
   - Q2.Gf1 (N/N) LTI
   - Q2.Gf32 (N/N) LTI

COW: *Plot the Step Response of each transfer function.*
When the step is first applied, does the mass move in the right direction ???
After a long time, does the FV make sense ???
Do not confuse Distance with Velocity.

A model of an electric motor is shown in **Figure 2**.

The motor model integrates electrical and mechanical systems with dependent sources.

Rotor torque τ depends on winding current $\mathbf{i_w}$, and winding back-EMF (voltage) $\mathbf{v_b}$ depends on rotor speed $\boldsymbol{\omega}$.

Convert the mechanical system into its electrical equivalent, and combine the two systems.

Use nodal analysis to solve the circuit.

Find the transfer function: $\mathbf{G_i = i_w/V_{in}}$

3. 20 mark(s) Current Gain

- Q3.Gi (A/V) LTI

Find the transfer function: $\mathbf{G_w = \omega/V_{in}}$

4. 20 mark(s) Speed Gain

- Q4.Gw (rad/Vs) LTI

COW: *Plot a 1V Step Response.*
Do the Peak & Final values seem reasonable ???
Are they the same ??? Should they be ???

Use $\mathbf{G_i}$ and $\mathbf{G_w}$ to find current and speed for a **1V** unit step input.

Find the power dissipated by the resistor $\mathbf{R_w}$ and the bearings (damper $\mathbf{B_r}$).

Use the electrical analogy to determine mechanical power dissipation.

Estimate the total **energy** dissipated after **50 ms**. Use **1 ms** time increments.

The area under a curve can be approximated by summing the parts (as shown).

Find the total energy dissipated $\mathbf{E_d}$ after **50 ms**.

Find the energy stored in the inductor $\mathbf{L_w}$ and inertia $\mathbf{J_r}$ after **50 ms**.

Find the total energy stored $\mathbf{E_s}$ after **50 ms**.

Find the total energy provided $\mathbf{E_p}$ by the source $\mathbf{V_{in}}$ after **50 ms**.

5. 20 mark(s) Energy

- Q5.Ed (J) Scalar
- Q5.Es (J) Scalar
- Q5.Ep (J) Scalar

COW: *Does* $\mathbf{E_p = E_d + E_s}$ *???*
"Conservation of Energy" must always hold.