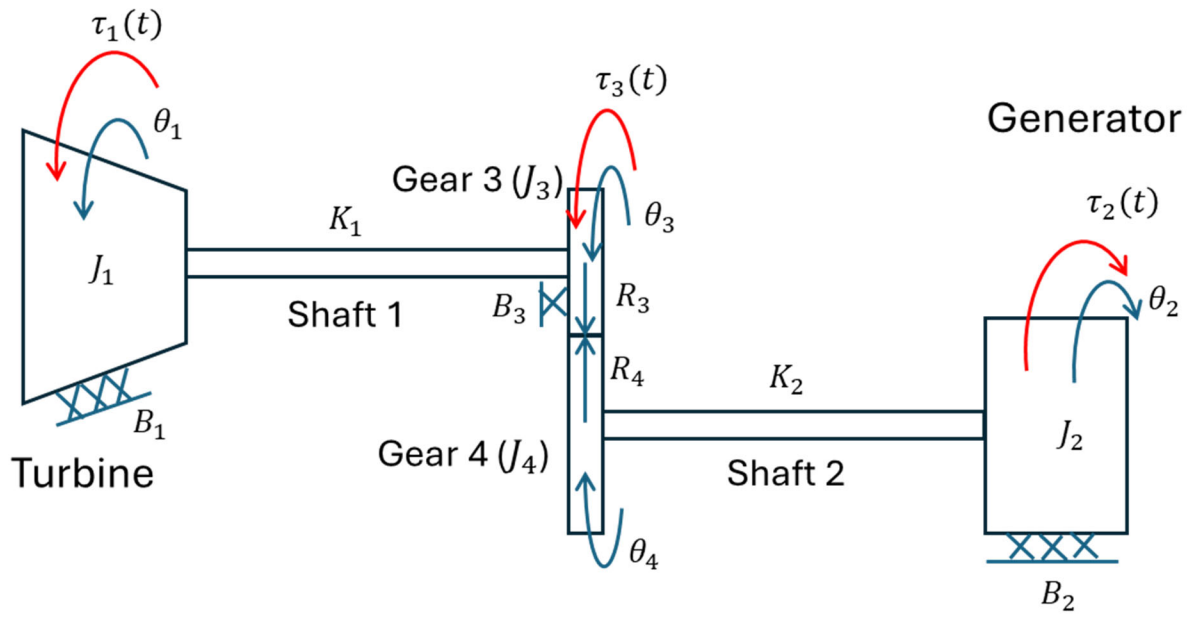
**ME-340 Project**

**Spring 2025**

A turbine drives an electrical generator through a gear pair. The radius ratio of the gears is $\frac{R_4}{R_3} = 1.5$. The mass moment of inertia of gear 3 is $J_3 = 100$ kg-m$^2$ and of gear 4 is $J_4 = 200$ kg-m$^2$. The mass moment of inertia of the turbine is $J_1 = 2000$ kg-m$^2$ and for the generator is $J_2 = 1000$ kg-m$^2$. The torsional stiffness of shaft 1 is $3 \times 10^5$ N-m/rad and of shaft 2 is $8 \times 10^4$ N-m/rad. Assume that dampers are applied to the turbine ($B_1 = 300$ N-m/rad/s), the generator ($B_2 = 8 \times 10^2$ N-m/rad/s), and Gear 3 ($B_3 = 100$ N-m/rad/s).




a. Write the equations of motion for the system shown. Equations should be expressed in terms of angular displacements $\theta_1, \theta_2, \theta_3$. (40 points).
b. Develop the state-space model for the system. Assume the outputs are the <u>angular velocities</u> of the turbine, generator, and Gear 3 (30 points).
c. Develop the Simulink model for the system (30 points).
d. Determine the angular velocity of the turbine and generator using the state-space and Simulink models to a unit step input applied to the turbine $\tau_1(t) = U(t)$. (10 points).
e. Determine the angular velocity of the turbine and generator using the state-space and Simulink models to a unit step input applied to the generator $\tau_2(t) = U(t)$. (10 points).
f. Determine the angular velocity response of the generator using the state-space model to a unit impulse applied to the gear $\tau_3(t) = \delta(t)$ (10 points).
g. Find the frequency response (i.e., Bode plots) between the angular velocity of the generator for a sinusoidal input at Gear 3 using the state-space model. Check your answer

by finding the steady state response for a sinusoidal input at the first mode using Simulink (10 points).

h. Reduce the damping constants by a factor of 10. Find the frequency response (i.e., Bode plots) between the angular velocity of the generator and an input at Gear 3 using the state-space model. Determine the steady state response for an input of $\tau_3(t) = \sin(30t)$ (10 points)
i. Increase the damping constants by a factor of 10. Find the frequency response (i.e., Bode plots) between the angular velocity of the generator and an input at Gear 3 using the state-space model. Determine the steady state response for an input of $\tau_3(t) = \sin(30t)$ (10 points)
j. Sketch (by hand using PowerPoint) the first two vibratory modes of the system (10 points).
k. Redesign the system to increase both the first and second resonant frequencies by over 20% (20 points).