Notes:

1. **DO NOT OPEN THIS EXAM UNTIL YOU ARE NOTIFIED.**

2. Permitted resources: 1.5 pages single sided notes, calculator, pencil, and eraser. This is a closed book exam.

3. Approximately 120 minutes will be provided to take this exam.

4. **DO NOT USE ADVANCED CAPABILITIES ON YOUR CALCULATOR SUCH AS PLOTTING, ROOT FINDING, OR ALGEBRAIC EQUATION SOLVING.** SHOW YOUR WORK FOR FULL CREDIT

Name: ________________________________

Student Number: ______________________

#1. ______
#2. ______
#3. ______
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#5. ______
#6. ______

TOT: ______
1) Consider the following diagram of a water transfer system. In this system the distance between the tanks is significant and a pump driven by a DC motor is used to assist the transfer. Construct a linear graph of the system that includes the fluid system, pump, and DC motor. The motor model should include the armature resistance, $R_a$ and back-EMF. Inductance can be neglected. Clearly indicate all velocities, pressures, and voltages on both the linear graph and system diagram. (25 points)
2) A linear graph and diagram for a tachometer are shown below. Determine the transfer function $\frac{T_{bl}(s)}{\Omega_s(s)}$, which is representative of the torque disturbance created by the tachometer. (25 points)
3) Determine the transfer function \( \frac{Y(s)}{R(s)} \) of the following block diagram: (25 points)
4) Consider the following closed loop transfer function. Determine if the system is stable, marginally stable, or unstable. Show your work for credit. (25 points)

\[
\frac{C(s)}{R(s)} = \frac{6(s + 3)}{s^4 + 4s^3 + 4s^2 + 4s + 3}
\]
5) Consider the following unity feedback system where

\[ G_C(s) = K(s + 3) \quad \text{and} \quad G_P(s) = \frac{5}{(s+1)(s+2)} = \frac{5}{s^2 + 3s + 2} \]

Sketch the root locus of the closed loop system for \( 0 \leq K \leq \infty \). Indicate details about asymptotes, breakaway points, and imaginary axis crossings on the root locus. Also indicate values of K at key locations (start, finish, imaginary axis crossing, breakaway/in points). Show your work for full credit. (25 points)
6) Consider the following root locus of a unity feedback system \( G(s) \) shown below. Estimate the range of gain \( K \) that will result in \( OS \leq 16.2\% \) and indicate this region on all branches of the root locus. (25 points)

\[
G(s) = \frac{s + 4}{(s + 1)(s + 3)(s + 6)}
\]