For a given fourth order system as follows:

1. The equation of motion will be in the form of:

$$\dddot{\theta}\dot{} + \ddot{\theta}\ddot{} \cos(\theta) + 4\ddot{\theta} + 5\dot{\theta} + 8\tan(\theta) = u(t) \tag{1}$$

2. Use the Taylor Series Expansion and linearize the equation around the equilibrium point of $\theta^*(0) = 0$. (10)

3. Use Laplace transform and derive the CLOSED LOOP transfer function of $\frac{\theta(s)}{U(s)}$. All initial conditions are zero. (10)

4. Use the Routh stability criteria and determine the internal stability of the system. Is the system stable or unstable? If it is unstable, **how many right hand poles it has**? As an engineer, what would be your solution?(15)

5. Now use the Final Value Theory $\left(e_{ss} = \lim_{s\to 0} \frac{sX(s)}{1+G(s)}\right)$ to calculate the steady state errors of Impulse, Step, Ramp, and Parabolic inputs. What is your solution to remove the steady state error if you have any? Just suggest that!(20)

6. Use Simulink, make an Unity Feedback Closed loop block diagram, then apply the inputs stated above including impulse, step, ramp, and parabolic, and plot the system responses for 10s. (40)

7. Show that, using Simulink, the ramp response is integration of the step and derivative of the parabolic responses!(5)