ME Mechanical 1st Year 2nd Semester Examination, 2025

Subject: Dynamic Modeling for Mechatronic System

Time: Three hours **Full Marks: 100**

Answer any **FOUR** *questions.*

1. Draw a block diagram of a closed-loop control system. What are the advantages of a mechatronic system over mechanical systems with add-on features? What are the different modules of a real-time controller and what are the roles of these modules? Name the sensors for measuring temperature, pressure, linear and angular displacements. **7+8+8+2**

2. A solenoid-operated spring-loaded poppet valve controls air admission to an engine cylinder. The poppet is in the shape of a truncated cone and it gets un-seated, when a voltage excitation to the solenoid coil overcomes the maximum static friction. Construct
   a) a schematic diagram of the system
   b) an expression for the electromagnetic force produced by the solenoid
   c) a model of the poppet dynamics in terms of its displacement against the input voltage
   d) the error dynamics equation with respect to a displacement demand track. **7+6+6+6**

3. Consider an electric heater of 1600Ω resistance used in a furnace to heat a batch of 500kg steel of specific heat of 510J/(kg-K) at a rate $\dot{T}_{hd}$ equal to 1^0C/s from ambient temperature of 25^0C to 750^0C that is maintained subsequently for soaking the load for an hour followed by cooling at a rate $\dot{T}_{cd}$ equal to -1^0C/s to the ambient temperature. During the entire heat treatment phase, a flow at a rate of $0.012m^3/s$ of an inert gas of density $1.7kg/m^3$ and specific heat of 520J/(kg-K) at constant pressure is maintained for keeping the furnace purged.
   (a) Draw a simple sketch of the system.
   (b) Find the expected duration of the heat treatment process.
   (c) Estimate the feedforward voltage that would hold the constant soaking temperature.
   (d) Find the steady state error during the soaking phase under 1V/K P gain in a feedforward-P controller. **6+4+10+5**

4. Obtain a feedforward-PI controller design for an electrohydraulic motion-control system comprised of a vertical-axis double-acting single-rod cylinder, a zero-lap proportional valve, a fixed-displacement pump, a relief valve and other accessories. The piston should raise a heavy weight at constant speed. With respect the weight, the friction between the cylinder and piston and the weight of the piston are negligible. What are the roles of the feedforward, P and I controllers? **19+6**

5. Sketch an electrohydraulic control system in terms of standard symbols with a dual-tandem hydraulic cylinder with one end capped used for motion control through its piston rod. What is meant by individual metering? **25**

6. Write brief notes on
   (a) amplifier in a mechatronic system,
   (b) stability of a dynamic system,
   (c) state-space and input-output models,
   (d) control-system nonlinearities,
   (e) proportional and servo valves. **5×5**