Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech(ME)/SEM-1/ME-102/2009-10

2009

MECHATRONICS SYSTEMS DYNAMICS

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer any *five* question at least two from **Group A.**

GROUP – A

1. a) Determine the transfer function $V_o(s)$ to $V_i(s)$ for the network shown below : 7

Fig. 1

b) Obtain the transfer function of the mechanical system shown below between x_1 and f (Fig. 2). 7

Fig. 2

2. a) Obtain the transfer function of field controlled DC motor between applied field voltage and angular displacement. 7

b) Obtain the unit step response of the following system :

$$\frac{C(S)}{R(S)} = \frac{10}{S^2 + 2S + 10} \cdot$$ 7

3. a) The open loop transfer function of a system with unity feedback gain is given by

$$G(S) = \frac{20}{S^2 + 5S + 6} .$$

Determine the damping ratio, maximum overshoot, rise time and peak time. 7

b) The moment of inertia J_m and the co-efficient of viscous friction f_m for a field controlled *dc* servomotor are $5 \infty 10^{-4}$ kg-m^2 and $12{\cdot}5 \infty 10^{-4}$ Nm / (rad/s). Take motor torque constant k_f being 2·5 Nm / A. Determine the transfer function relating angular speed of the shaft and field current. Draw the block diagram. 7

GROUP – B

4. a) Define rigid body. 2

b) A mechanical system consisting of spring, mass and damper is shown in Fig. 3. The system is initially at rest and the displacement x is measured from the equilibrium position. Assume that mass m = 1 kg, damping co-efficient $b = N - s/m$ and spring constant k = 100 N / m. Obtain the response of the system when 10 N of force (a step input) is applied to the mass m. 12

Fig. 3

5. a) Define ideal damper. 3

b) An optical scanner used reading bar codes is shown in Fig. 4. As the mirror rotates, a friction force is developed

which is proportional to its angular speed. The friction constant b is equal to 0·04 *N.S.*/rad and the moment of inertia J is equal to 0·1 kg m^2 . The output variable is the velocity $\omega(t)$.

i) Obtain the differential equation of motion of the motor. 3

ii) Find the response $\omega(t)$ of the system when the input torque $T(t)$ is an unit step function and the initial velocity at $t = 0$ is equal to 0·5 rad/s. The unit step function is defined as 8

$$u_s(t) = 0 \text{ for } t \leq 0$$

$$= 1 \text{ for } t > 0$$

Fig. 4

6. a) Derive an expression showing that the capacitance of a tank containing liquid is related with area of cross-section of the tank and liquid mass density. 4

b) A two capacity liquid flow system (Fig. 5) has time constants ($R_1 C_1$ and $R_2 C_2$) of 600 and 1800 seconds respectively. The liquid is water and $R_2 = 3{\cdot}2 \times 10^6$ N-S / m^5. Find the transfer function relating 'h_2' and inflow rate 'm'. 10

Fig. 5

7. a) How do a simple pressure relief and compound relief value differ in operation ? 3

b) Explain the role of an unloading valve in a hydraulic circuit with two pumps (one a high pressure low flow pump and the other a low pressure high flow one). 6

c) A double acting cylinder is hooked up in a regenerative circuit. The relief value setting is 105 bars. The piston area is 130 cm^2 and the rod area is 65 cm^2. If the pump flow is 0·0016 m^3 /s, find the cylinder speed for the (i) extending stroke (ii) retracting stroke. 5

8. a) Discuss the working principle of a torque motor and how it controls the flow through the servo value ? 4

b) Discuss the principle of operation of a lubricator in a pneumatic system. 4

c) Two pneumatic cylinders are to be sequentially operated. Draw the pneumatic circuit and explain its working principle. 6