Reg. No.										

Manipal Institute of Technology, Manipal

(A Constituent Institute of Manipal University)

FIFTH SEMESTER B.TECH (INSTRUMENTATION AND CONTROL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

SUBJECT: SYSTEM MODELING AND SIMULATION [ICE 319]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitably assumed.

1A. For the mechanical system shown in Fig. Q(1A), $x_1(t)$, $x_2(t)$ and $x_3(t)$ are the displacements and f(t) is the input force. Write the differential equation governing the system and obtain the state space model. Consider displacement $x_3(t)$ as the output. Write a MATLAB program to obtain the response of the system for an applied input of 1N. **5**

1B. An unoccupied passenger rail car of mass m = 43000 kg is attached to a electric locomotive using a spring of stiffness k = 20,000 N/m and a damper of constant b = 200 Ns/m, as shown in Fig. Q(1B). The locomotive moves at a constant acceleration of a = 0.9 m/s^2. Obtain the transfer function between the speed of the locomotive and speed of passenger car. **3**

1C. Consider the human transportation vehicle (HTV) depicted in Fig. Q(1C). The self-balancing HTV is actively controlled to allow safe and easy transportation of a single person. Using block diagram, describe a closed-loop feedback control system to assist the rider of the HTV in balancing and maneuvering the vehicle. A gyro sensor can be used to measure the angle from vertical. **2**

2A. Write the differential equations governing the mechanical system shown in Fig. Q(2A). Draw the force – voltage electrical analogous circuit and verify by writing mesh equations. Let x_1 and x_2 be the displacements of M_1 and M_2 respectively. **4**

2B. For the rotational system shown in Fig. Q(2B), (i) obtain the equivalent at the output after reflection of input torque (ii) obtain the equivalent at the input after the reflection of mechanical impedences. **3**

2C. Linearize the following equation for small excursions about $x = \frac{\pi}{4}$ **3**

$$\frac{d^2x}{dt^2} + 2\frac{dx}{dt} + \cos x = 0$$

3A. Consider the liquid level system shown in Fig. Q(3A). In the system, Q_1 and Q_2 are steady-state inflow rates H_1 and H_2 are steady-state heads. The quantities q_{i1}, q_{i2}, h_1, h_2, q_1, and q_o are considered small. Obtain a state-space representation for the system when h_1 and h_2 are the outputs and q_{i1} and q_{i2} are the inputs. **5**

3B. Consider a building that consists of two adjacent rooms, The resistance of the walls room 1 and ambient is R_{1a}, between room 2 and ambient is R_{2a} and between room 1 and room 2 is R_{12}. The capacitance of rooms 1 and 2 are C_1 and C_2, with temperatures θ_1 and θ_2, respectively. A heater in room 1 generates a heat q_{in}. The external temperature is θ_a and is assumed to be zero. Draw a thermal model of the system showing all relevant quantities and write the differential equation governing the system. **5**

4A. In the mechanical system shown in Fig. Q(4A), assume that the input and output are the displacements p and x respectively. The displacement x is measured from the equilibrium position. Suppose that p(t) = P sin wt. What is the output x(t) at steady state? Assume that the system remains linear throughout the operating period. **5**

4B. A rigid body is mounted on an isolator to reduce vibratory effects. Assume that the mass of the rigid body is 500kg, the damping coefficient of the isolator is very small ($\zeta = 0.01$), and the effective spring constant of the isolator is 12,500 N/m. Find the percentage of motion transmitted to the body if the frequency of the motion excitation of the base of the isolator is 20 rad/sec. **3**

4C. Define transmissibility for force excitation and motion excitation. **2**

5A. Briefly explain the body axis system and stability axis system of an aircraft. Derive the rotation matrix for transforming the earth axis system to body axis system. **5**

5B. Express all the forces (namely weight, aerodynamic and thrust forces) acting on an aircraft in body axis system. **3**

5C. What is an airfoil? Define angle of attack, chord line and camber line. **2**

6A. Magnetic levitation trains provide a high-speed, very low friction alternative to steel wheels on steel rails. The train floats on an air gap as shown in Fig. Q(6A). The levitation force F_L is controlled by the coil current *i* in the levitation coils and may be approximated by $F_L = k\,\frac{i^2}{z^2}$, where *z* is the air gap. This force is opposed by the downward force $F = mg$. Determine the linearized relationship between the air gap *z* and the controlling current near the equilibrium condition and obtain the transfer function Z(s)/ I(s) **6**

6B. For the system shown in Fig. Q(6B), the objective is to balance a rolling ball on a tilting beam. Will assume the motor input current *i* controls the torque with negligible friction. Assume the beam may be balanced near the horizontal ($\phi = 0$); therefore, we have a small deviation of ϕ. Find the transfer function *X(s)/I(s).* **4**

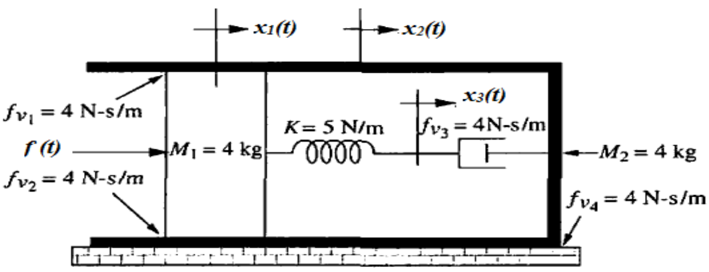

Fig. Q(1A)

Fig. Q(1C)

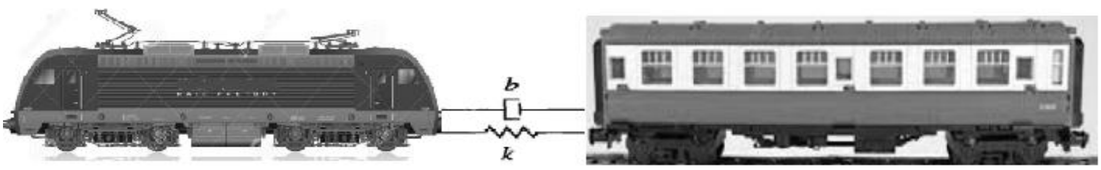

Fig. Q(1B)

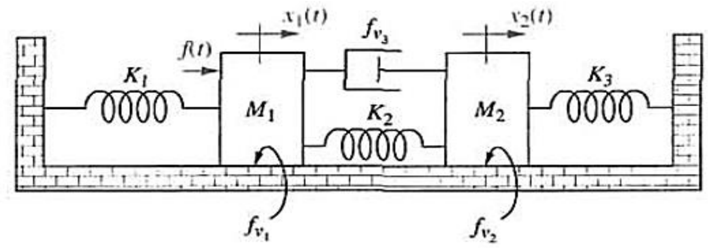

Fig. Q(2A)

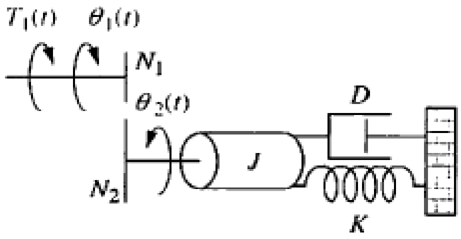

Fig. Q(2B)

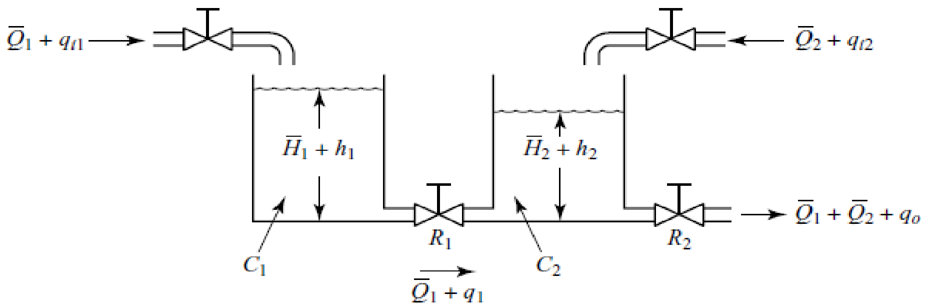

Fig. Q(3A)

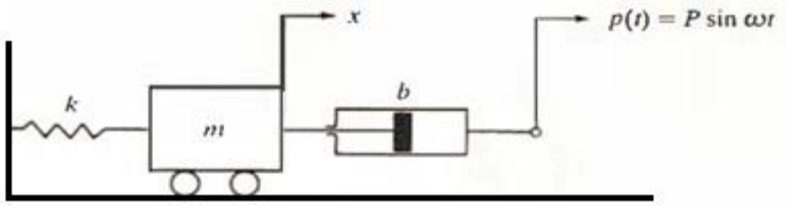

Fig. Q(4A)

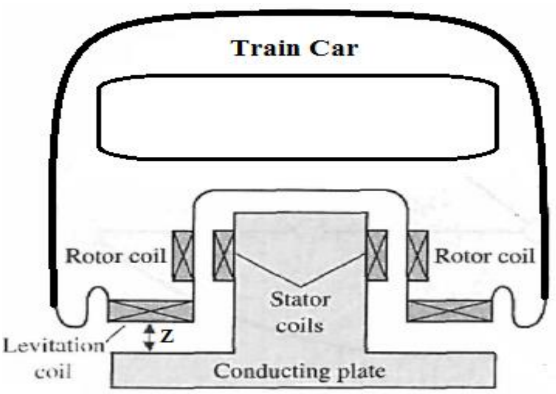

Fig. Q(6A)

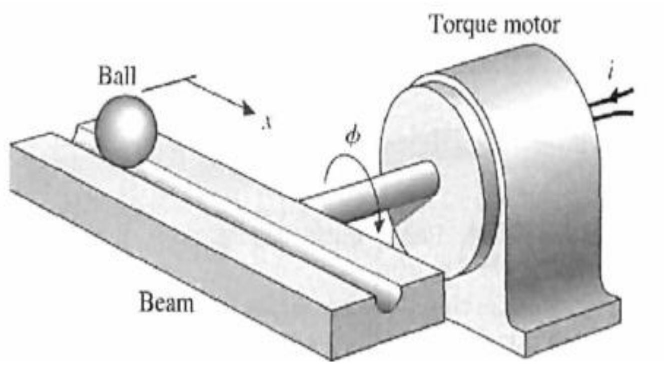

Fig. Q(6B)