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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

FIRST SEMESTER M.TECH. (AEROSPACE ENGINEERING)

END SEMESTER EXAMINATIONS, NOV - 2017

SUBJECT: AEROSPACE SYSYEMS MODELLING [ICE 5101]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Notations are standard and provide specific meaning for aerospace system.

1A. Define transfer function and state whether transfer function modelling technique applies to the non-linear system. Obtain transfer function matrix model of the system defined by **5**

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix} = \begin{bmatrix}\mathbf{0} & \mathbf{1} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{1}\\ \mathbf{-2} & \mathbf{-4} & \mathbf{-6}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}\mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{1}\\ \mathbf{1} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\boldsymbol{u_1}\\ \boldsymbol{u_2}\end{bmatrix}$$

$$\begin{bmatrix}y_1\\ y_2\end{bmatrix} = \begin{bmatrix}\mathbf{1} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{1} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\boldsymbol{x_1}\\ \boldsymbol{x_2}\\ \boldsymbol{x_3}\end{bmatrix}$$

1B. Write the differential equations governing the mechanical system as shown in Fig. **Q1B** and determine the transfer function model **3**

1C. What do you mean by state and state variable? Draw the block diagram representation of state space model. **2**

2A. Derive Euler's and Bernoulli's equation. **5**

2B. Illustrate continuity equation. Consider a convergent duct with an inlet area $\boldsymbol{A_1 = 0.08\, m^2}$ and an exit area $\boldsymbol{A_2 = 0.771\, m^2}$. Air enters this duct with velocity $\boldsymbol{V_1 = 210 m/s}$ and a density $\boldsymbol{\rho_1 = 1.23\, kg/m^3}$ and air leaves with an exit velocity $\boldsymbol{V_2 = 321 m/s}$. Calculate the density of the air $\boldsymbol{\rho_2}$ at the exit. **3**

2C. Derive hydrostatic equation with neat diagram **2**

3A. Find gravitational force components in the small perturbation equations of aircraft motion. **5**

3B. Derive direction cosine matrix for axis transformation using linear quantitates transformation **3**

3C. Using direction cosine matrix, calculate height perturbation regarding aircraft motion referred to earth. **2**

4A. Obtain the thrust response transfer functions $\left(\frac{u(s)}{\tau(s)}, \frac{w(s)}{\tau(s)} \text{ and } \frac{\theta(s)}{\tau(s)}\right)$ from the following equations of longitudinal symmetric motion for aircraft system **5**

$$\boldsymbol{m\dot{u} - F^{\circ}{}_{x_u} u - F^{\circ}{}_{x_{\dot{w}}} \dot{w} - F^{\circ}{}_{x_w} w - \left(F^{\circ}{}_{x_q} - mW_e\right) q + mg\theta \cos\theta_e}$$
$$\boldsymbol{= F^{\circ}{}_{x_\eta} \eta + F^{\circ}{}_{x_\tau} \tau}$$

$$-F^{\circ}{}_{z_u}\,u + \left(m - F^{\circ}{}_{z_{\dot{w}}}\right)\dot{w} - F^{\circ}{}_{z_w}\,w - \left(F^{\circ}{}_{z_q} + mU_e\right)q + mg\theta \sin\theta_e$$
$$= F^{\circ}{}_{z_\eta}\,\eta + F^{\circ}{}_{z_\tau}\tau$$
$$-M^{\circ}_{u}u - M^{\circ}_{\dot{w}}\dot{w} - M^{\circ}_{w}w + I_y\dot{q} - M^{\circ}_{q}q = M^{\circ}_{\eta}\eta + M^{\circ}_{\tau}\tau$$
$$\dot{\theta} = q$$

4B. Illustrate angular relationship in symmetric flight. **3**

4C. Write the equations for disturbing forces and moments of the aircraft system. **2**

5A. Write linear differential equations governing the twin rotor MIMO system and obtain transfer function models using Cramer's rule. **5**

5B. Establish state space model from Euler's equation of the missile systems **3**

5C. Write servo dynamics equations for the aileron, elevator and rudder of missile system using standard second order lag. **2**

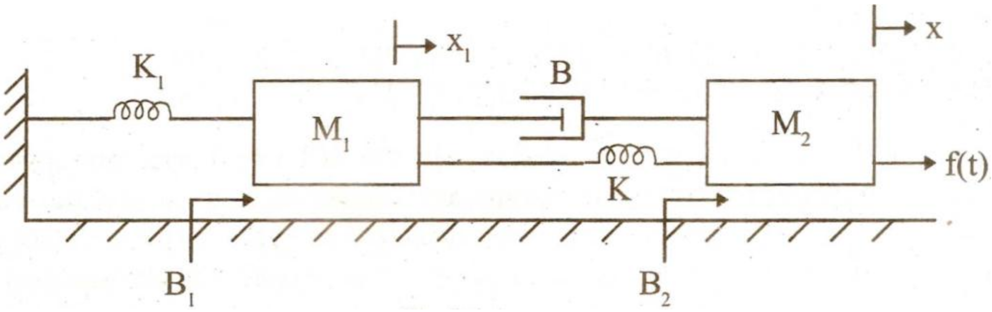

Fig. Q1B

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