Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

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A Constituent Institution of Manipal University

SECOND SEMESTER M.TECH. (AEROSPACE ENGINEERING)

END SEMESTER EXAMINATIONS, MAY/JUNE 2017

SUBJECT: FLIGHT MECHANICS [ICE 5202]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Derive the moment equations for aircraft motion in the body axis system. **5**

1B. Express all forces (namely weight, aerodynamic and thrust forces) acting on aircraft in its most convenient axis system. Consider the aircraft model **T-37** at the following Euler angles: **3**

$$\boldsymbol{\psi = 90\ deg}, \quad \boldsymbol{\theta = 10\ deg}, \quad \boldsymbol{\phi = 10\ deg}$$

Describe the aircraft attitude and transform the weight force through these angles to the body axis system. The gross weight is **6600 lbf .**

1C. Illustrate the axis transformation for a vector in the stability axis system into the body axis system. **2**

2A. Derive Breguet range equation. **A T-37** aircraft model at **20000 ft.** has a drag polar $\boldsymbol{C_D = 0.02 + 0.057C_L^2}$ and $\boldsymbol{S = 184\ ft^2}$. The aircraft has an initial weight of 6000 lb. and 500 lb. of usable fuel. If the TSFC at sea level is 0.9/h, determine the max range for the **T-37** at **20000 ft.** using constant altitude cruise and a cruise climb. **5**

2B. Find the expression for turn rate and turn radius in the pull-ups case for the aircraft level flight. An **F-22** is performing a **5-g** pull-up at **10000 ft**. and **500 kn**. true airspeed. What is the turn rate and turn radius? **3**

2C. Sketch a thrust required curve and a power required curve, and show where $\boldsymbol{\left(\frac{L}{D}\right)_{max}}$ occurs on each curve. **2**

3A. Using the average acceleration method, find the max power takeoff ground roll with no wind and a zero-runway slope for a 12000 lb. T-38 at sea level and 6000 ft. given the following conditions: **5**

$$\boldsymbol{S = 170\ ft^2}, \quad \boldsymbol{C_{L_{max}} = 0.88}, \quad \boldsymbol{\mu_r = 0.025}, \quad \boldsymbol{C_{D_0} = 0.02}, \quad \boldsymbol{K = 0.2},$$
$$\boldsymbol{\rho = 0.00238}, \ \boldsymbol{a_{SL} = 1116.4}, \ \boldsymbol{T_{avg} = 6000\ lb}.$$

3B. Derive the expression to estimate the landing ground roll during the period of wheel braking. **3**

3C. A **T-37** aircraft model has a drag polar $\boldsymbol{C_D = 0.02 + 0.057C_L^2}$. Find its max glide ratio and max glide range from **20000 ft.** to sea level. **2**

4A. Find the expression for aircraft aerodynamic center. Consider the aircraft model A-10 with the followings parameters: $\boldsymbol{S = 506\ ft^2}$, $\boldsymbol{S_h = 120\ ft^2}$, $\boldsymbol{\eta_h \approx 0.9}$, $\boldsymbol{AR = 6.54}$, $\boldsymbol{AR_h = 3}$, $\boldsymbol{\frac{d\epsilon}{d\alpha} \approx 0.1}$, $\boldsymbol{\bar{c} = 8.8\ ft}$, $\boldsymbol{x_{AC_h} = 26.25\ ft}$, $\boldsymbol{\bar{x}_{AC_{wf}} \approx 0.25}$, $\boldsymbol{C_{l_\alpha} =}$ **5**

$\mathbf{0.11}$, $\bar{x}_{cg} = \mathbf{0.5}$. Determine the static margin C_{m_α} and $C_{m_{C_l}}$. Is the aircraft statically stable in pitch?

4B. Determine the aileron and rudder deflections required for an **F-15** aircraft model to maintain a +1 degree wings level sideslip at **0.9** Mach and **20000** ft. Also determine the value of the side-force coefficient under these conditions. Applicable derivatives are as follow: $C_{y_0} = 0$, $C_{y_\beta} = -0.\frac{9056}{rad}$, $C_{y_{\delta_\alpha}} = -0.\frac{0047}{rad}$, $C_{y_{\delta_r}} = 0.1492/rad$, $C_{l_0} = 0$, $C_{l_\beta} = -0.0732/rad$, $C_{l_{\delta_\alpha}} = 0.0226/rad$, $C_{l_{\delta_r}} = 0.0029/rad$, $C_{n_0} = 0$, $C_{n_\beta} = 0.1638/rad$, $C_{n_{\delta_\alpha}} = 0.0026/rad$, $C_{n_{\delta_r}} = -0.0712/rad$. **3**

4C. What are the two requirements for the longitudinal static stability? **2**

5A. The transfer function for an aircraft model T-37 at 30000 ft. and 0.46 Mach is given by **5**

$$\frac{\alpha}{\delta_e} = -0.0924\frac{(s+336.1)(s^2+0.0105s+0.0097)}{(s^2+4.58s+21.6)(s^2+0.0098s+0.0087)}$$

Find the natural frequency, damping ratio, damped frequency and time constant for the short period and phugoid modes.

5B. Find the transfer function $\frac{\phi(s)}{\delta_a(s)}$ for the following simplified differential equation defining roll response of the aircraft. **3**

$$\ddot{\phi} + 0.704\,\dot{\phi} = 0.037\delta_a$$

Assume zero initial conditions. Also obtain time response $\phi(t)$.

5C. Write a note on short period mode and phugoid mode. **2**

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