Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

I SEMESTER M.TECH. (AVIONICS)

END SEMESTER EXAMINATIONS, NOV/DEC 2019

SUBJECT: MECHANICS OF FLIGHT [AAE 5154]

REVISED CREDIT SYSTEM
(15 /11/2019)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- (Kindly specify any chart, tables and any other information permitted to use. Else delete the current line)

1A. The following data is given for a non - afterburning fighter aircraft at sea level, static, standard day condition: **(04)**

$n_{max} = 7.33$ $T/W = 0.40$ $W/S = 2875\ N/m^2$
$k = 0.12$ $C_{Do} = 0.015$ $C_{Lmax} = 1.12$

Calculate the corner velocity and the corresponding (L/D) at this velocity.

1B. Find the maximum instantaneous turn rate and corresponding turn radius. **(03)**

1C. Does the aircraft have sufficient thrust to sustain this turn at corner velocity? What is the T/W ratio required to sustain this turn? **(03)**

2A. For up and away flight longitudinal trim characteristics in linear range of operation is given by $\delta_e = \delta_{e0} + (d\delta_e/dC_L)C_L$ where δ_{e0} may be assumed to remain constant with aircraft CG and $(d\delta_e/dC_L)$ is known to depend on CG. For a given aircraft $\delta_{e0} = +3.5^o$ and for the forward most CG of 35% of MAC (from the leading edge of MAC), the aircraft uses maximum available up elevator $\delta_e = -20^o$ for trimming C_{Lmax} of 1.8. Draw δ_e Vs C_L plot for above CG location (35%). Given elevator control power $C_{m\delta e} = -0.00825$/deg, obtain static margin (SM) of the aircraft and location of its neutral point NP on MAC. **(04)**

2B. A transport aircraft has 4 engines symmetrically mounted on its wings of 65 m span and area of 525 m^2. Inboard and outboard engines are located respectively at 11.7 m and 21.7 m from aircraft plane of symmetry. The SL maximum thrust (T_{SL}) per engine is 282 kN. The engine thrust T at any altitude is related to density ratio σ by $T = T_{SL}\sigma$. The aircraft encounters port side outboard engine failure at V = 160 m/s at h = 2000 m (σ = 0.8216). The **(06)**

engines were set at 75% throttle for trimmed level flight prior to engine failure. Following engine failure, Pilot manages to maintain level flight by setting remaining 3 working engines at 100% throttle. i) Calculate yawing moment (kNm) due to engine failure and resulting imbalance in C_N, yawing moment coefficient due to asymmetric thrust. Given rudder control power $C_{N\delta r}$ = -0.0014/deg obtain rudder deflection required to trim asymmetric yawing moment to maintain zero side slip angle. Show in aircraft plan view asymmetric thrust, resulting yawing moment and rudder deflection required to trim the yawing moment. ii) If $C_{Y\delta r}$ = 0.004536/deg, what is the net side force (in kN) generated for above flight condition with yawing moment trimmed by rudder. Given aircraft weight is 4360 kN, obtain the magnitude and nature bank angle required to trim the side force.

3A. Following standard notations 6 force and moment equations governing aircraft motion are given below: **(04)**

$$
\begin{aligned}
X - mg\sin\theta &= m(\dot{u} + qw - rv)\\
Y + mg\cos\theta\sin\phi &= m(\dot{v} + ru - pw)\\
Z + mg\cos\theta\cos\phi &= m(\dot{w} + pv - qu)\\
L &= I_{xx}\dot{p} - I_{xz}\dot{r} + (I_{zz} - I_{yy})qr - I_{xz}pq\\
M &= I_{yy}\dot{q} + (I_{xx} - I_{zz})pr + I_{xz}(p^2 - r^2)\\
N &= -I_{xz}\dot{p} + I_{zz}\dot{r} + (I_{yy} - I_{xx})pq + I_{xz}qr
\end{aligned}
$$

Starting from the above set of equations, obtain 2 decoupled set of equations for Longitudinal motion and Lateral – Directional motion of aircraft. State your assumptions made in obtaining decoupled equations.

3B. Using qualitative description for three of the attributes in flight - Pilot Load (acceptable/moderately high/excessively high), Mission Effectiveness (good/satisfactory/unsatisfactory) and Flight Safety (safe/unsafe) classify Aircraft Handling Quality into Levels 1, 2 and 3. Give examples of dynamic characteristics of the aircraft on which these handling quality levels are known to be dependent on. **(03)**

3C. A military aircraft has the following longitudinal dynamics characteristics: **(03)**

Natural frequency: 0.0635 rad/sec
Damping ratio: 0.0867

Following a pulse elevator input, calculate time to half ($T_{½}$) or time to double (T_2) for the aircraft response as the case may be. State whether this ($T_{½}$ or T_2) is for transient or for forced response?

4A. Pilot of the military aircraft in Q3C applies a step elevator input to increase initial trim α of 5º to a final value 9º to decrease the flight speed. How long does it take for the aircraft with above characteristics to reach its first overshoot (peak time) and what is the percentage of the overshoot compared to nondimensional steady state response of unity? And what is the absolute value of maximum α attained at the first overshoot? **(05)**

How long does it take for the aircraft α to remain within ±2 % of its incremental steady state response from5º to 9º? What are the lower and upper values of actual α falling within this band of 2%?
Present your results in a typical second order system response for a step input showing elevator control input and corresponding aircraft α response clearly indicating the α values - initial α, steady state or final α, the first overshoot of α, final α band of 2% of incremental response (on y axis) and the corresponding time (on x axis) for the present case.

4B. The fourth order characteristic equation of the longitudinal dynamic transfer function of T-37 aircraft is given below: **(03)**

$$S^4 + 0.811\, s^3 + 1.32\, s^2 + 0.0102\, s + 0.00695 = 0$$

Identify the modes, find the natural frequencies and damping ratios and comment on dynamic stability of aircraft.

4C. Find the state space representation of the transfer function of a system given below: **(02)**

$$\frac{y(s)}{u(s)} = \frac{K}{S^4 + 4S^3 + 6S^2 + 3S + 2}$$

5A. A spacecraft is in a 480 km by 800 km earth orbit (orbit 1 in Figure 1). Find (a) the ΔV required at perigee *A* to place the spacecraft in a 480 km by 16 000 km transfer orbit (orbit 2); and (b) the ΔV (apogee kick) required at *B* of the transfer orbit to establish a circular orbit of 16 000 km altitude (orbit 3). **(06)**

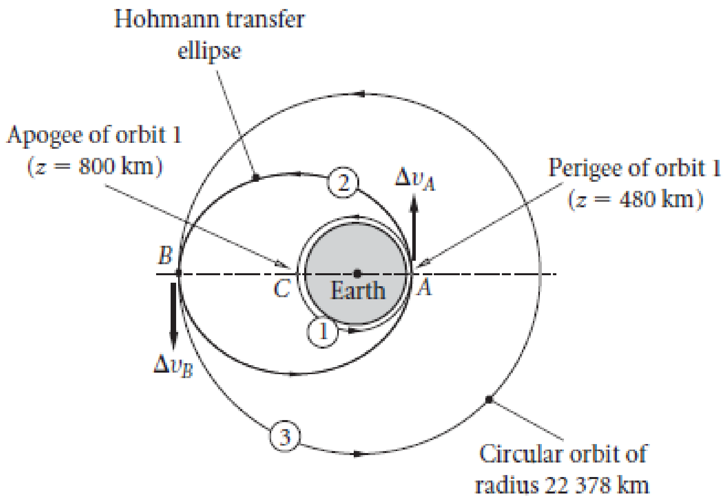

Figure 1

5B. With suitable diagrammatical explanation, explain the six classical orbital elements. **(04)**

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