Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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I SEMESTER M.TECH. (AVIONICS)

END SEMESTER EXAMINATIONS, FEB 2021

SUBJECT: MECHANICS OF FLIGHT [AAE 5154]

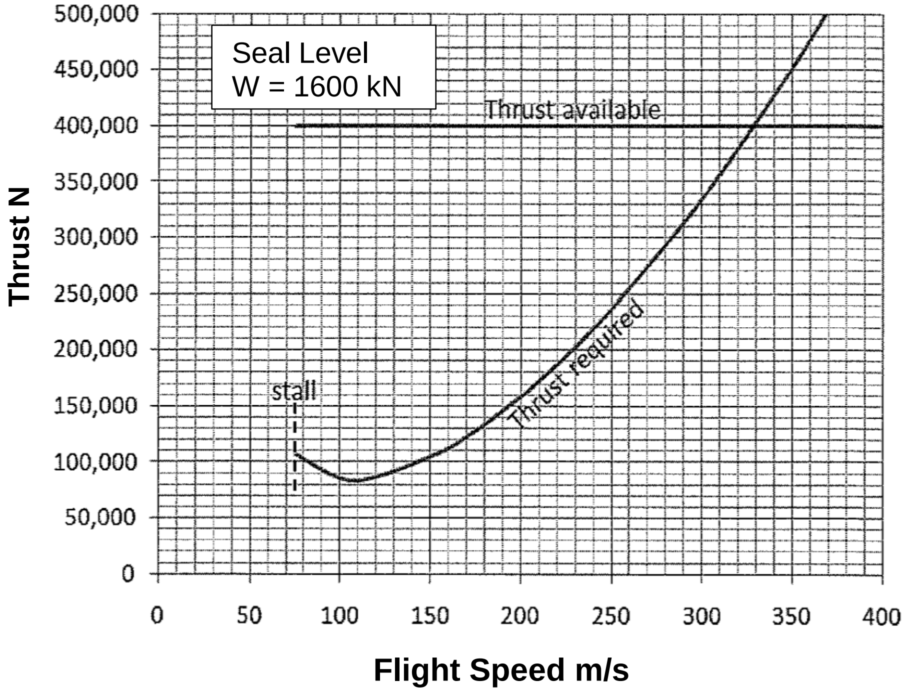
REVISED CREDIT SYSTEM
(22/02/2021)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Make suitable assumptions wherever necessary and state them clearly.
- Draw suitable figures wherever applicable to illustrate your final result/s

1A. A large jet transport aircraft with gross weight 1600 kN has a wing planform area of 260 m^2.The drag characteristics of the aircraft $C_D = C_{D0} + kC_L^2$ remains the same throughout the fight. The thrust required (drag polar) and maximum thrust available (100% throttle) curves for this aircraft at sea level and for W = 1600 kN are shown in the below. The engine thrust at any flight altitude may be assumed to be proportional to density ratio ratio σ. **[05]**



Using the above data calculate C_{Lmax}, $(L/D)_{max}$, C_{D0} and k for the aircraft.

1B Obtain the percentage throttle setting required for a steady level flight at sea level flight at M = 0.8. (at sea level a = 340.29 m/s). **[02]**

1C. Calculate the maximum climb angle possible and the corresponding flight speed at sea level for 100% throttle setting. **[03]**

2A. The following aircraft data is given for estimation of turn performance of a jet trainer **[04]**

Aircraft Weight and Wing Area: W = 149600 N and S= 55 m^2
Engine thrust (100% throttle) at any altitude: T = 89.76 σ kN
Flight altitude 2250 m with density ratio σ = 0.8
Maximum lift coefficient and Load Factor: C_{Lmax} = 1.2 and n = 8
Aircraft drag characteristics: $C_D = 0.025 + 0.07C_L^2$
Air density at sea level = 1.225 kg/m^3

Calculate corner speed of the aircraft at above altitude and also the corresponding turn radius and turn rate (degrees/s).

2B. Estimate thrust required for the level turn manoeuvre at the corner speed. Is the thrust available adequate for sustaining level turn at the corner speed at an altitude of h = 2250 m? **[03]**

2C. Variation of maximum rate of climb R/C or dh/dt (in m/s) with altitude h (in m) for a transport aircraft is given as h = -633.2(R/C) + 14500. Show on the linear plot of R/C Vs h, the absolute ceiling and R/C at the sea level. Estimate the time to climb from sea level to 11000 m altitude. **[03]**

3A. From the pitching moment data (C_M Vs α) tabulated below for zero elevator deflection (δ_e = 0) at three aircraft CG locations (20%, 25% and 30% of MAC behind the leading edge of the mean aerodynamic chord), plot the slope ($dC_M/d\alpha$) Vs CG locations. Using this plot identify the neutral point. Show on MAC the three CG positions and NP, and the static margin for aft most CG case. **[03]**

	C_M		
α (deg)	For CG position at 20% MAC	For CG position at 25% MAC	For CG position at 30% MAC
4	+0.018	+0.038	+0.058
8	−0.054	−0.014	+0.026
12	−0.126	−0.066	−0.006

3B. Given pitch control power $C_{M\delta e}$ = -0.00792/deg and maximum available elevator available is ±25 deg, calculate the maximum trimmable angle of attack α for the forward most CG (at 20% MAC). **[02]**

3C. The following directional derivatives are given for studying cross wind landing $C_{N\beta}$ = 0.127 /deg and $C_{N\delta r}$ = -0.0747 /deg. **[05]**
For aircraft approach speed of 55 m/s at sea level, what is the cross wind allowable for the landing with fuselage aligned with the runway? Show in a planform figure of an aircraft, cross wind from starboard side and the rudder control required for trimming the yawing moment.

4A. One degree of freedom equation for pitching motion may be written down as given below: **[03]**

$$\frac{d^2(\Delta\alpha)}{dt^2} - \left(M_{\dot{\alpha}} + M_q\right)\frac{d(\Delta\alpha)}{dt} - M_\alpha \Delta\alpha = M_{\delta_e}\Delta\delta_e$$

Suggest a suitable feedback control system for improving its frequency and damping characteristics in a schematic block diagram. Identify the motion sensors required onboard the aircraft for this feedback and the role of the individual sensors in stabilising the aircraft and improving the damping.

4B. Using the closed loop frequency ω and damping parameter ζ, formulate the equations for feedback gains for reducing the frequency by 25% and increasing damping factor by 15%. Bring out the nature of the stability derivatives (M_α+M_q), M_α, and $M_{\delta e}$ **[02]**

4C An aircraft flying at 11 km altitude at 270 m/s has the following lateral-directional characteristics equation: **[05]**

$$(s^2 + 0.28237s + 5.6567)\ (s^2 + 1.35211s + 0.01755) = 0$$

i) Obtain the roll mode constant.

ii) Determine Dutch Roll $T_{½}$ or T_2 as applicable

iii) Compute Spiral mode $T_{½}$ or T_2 as applicable

Draw typical aircraft motion trajectories bringing out variation of lateral-directional motion parameters

5A. Radar measurements can determine the components of a satellite velocity: **[04]**

v_r (the radial component along the radius vector) and

v_θ (the transverse component perpendicular to the radius vector).

If a satellite is observed at time t_0 with v_r = -3.475 km/s and a transverse component v_θ = 5.940 km/s, at a radial distance of r = 12595.9 km, then calculate

a) Flight-path angle

b) orbital period

c) eccentricity (magnitude only)

d) true anomaly

5B. A satellite is in a circular, 350 km orbit (i.e., it is 350 km above the earth's surface). Calculate (a) the speed in km/s (b) the period of motion. **[04]**

5C. Write the vis-viva (living force) relation. What does it mean? **[02]**