Reg. No.										

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

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2019

SUBJECT: AIRCRAFT DESIGN I [AAE 3104]

REVISED CREDIT SYSTEM
(14/11/2015)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Draw suitable sketches to support your answers and plot your results using graph

1A. Calculate parasite drag area ($C_F S_{Wet}$) and C_{D0} for a swept back wing of sweep 25 deg., gross wing area (S_W) 128 m^2, Aspect ratio 10.3 and mean aerodynamic chord of 4.3 m at flight RNo of 2.929 x 10^7 (based on MAC). It is given that 21 m^2 of gross wing area is inside the fuselage and the wetted area of the wing ($S_{Wet\ W}$) is 2.08 times exposed wing area. Assume Form Factor (K_{Wing}) = 1.04 and Flow Interference Factor Q_{Wing} = 1.02 for the wing. Average Turbulent Skin Friction coefficient $C_F = 0.455/\{\log_{10}RNo\}^{2.58}$ **(03)**

1B. Calculate parasite drag area and C_{D0} of a fuselage 44.5 m long and 4.15 in diameter at flight RNo of 3.031 x 10^8 (based on length). The fuselage wetted area is given to be 94% of its cylindrical surface area. The reduction in wetted area is to account for near frustum of cone geometry of cockpit and afterbody with a flare. Assume a Form Factor (K_{Fus}) of 1.075 for the fuselage and Flow Interference Factor Q_{Fus} = 1.025. Use wing area S_W given in Q1A above as reference area and the same dependency of turbulent skin friction C_F on R.No as in Q1A. **(03)**

1C. Using following additional information, obtain C_{D0} of the whole aircraft (Wing of Q1A + Fuselage of Q1B + Empennage + Nacelle) **(04)**

i) Parasite drag area of empennage of above aircraft is 18% of corresponding wing value calculated in Q1A above. However, the Form Factor $K_{Emp} = K_{Wing}$ and the Flow Interference Factor Q_{Emp} = 1.05

ii) Parasite drag area of Engine Nacelles is 10% of fuselage value calculated in Q1B above. However, the Form Factor $K_{Nac} = K_{Fus}$ and the Flow Interference Factor Q_{Emp} = 1.05

iii) Excrescence drag is 1% of sum of C_{D0} of all the 4 aircraft components (Wing, Fuselage, Empennage and Nacelle) estimated above.,

iv) Tabulate C_{D0} contributions of the 4 major components to 5 decimal accuracy also as percentage of total aircraft C_{D0} and comment on component wise contributions.

2A. The following relationships between wing loading (W_{TO}/S) and thrust to weight ratio (T_{SSL}/W_{TO}), were obtained for a twin engine aircraft using design requirements of take-off distance ($\leq$ 1800 m) at chosen altitude h, climb to 11 km, cruise (0.85 M at 11 km), landing distance ($\leq$ 1800 m) at chosen altitude h, supplemented by preliminary design inputs and FAR requirements on climb gradient (3% for OEI case): **(04)**

Take Off: $(T_{SSL}/W_{TO}) = (7.045 \times 10^{-5}/\sigma^2)(W_{TO}/S) + (0.02/\sigma)$ (σ is density ratio)

Cruise: $(T_{SSL}/W_{TO}) = 770.6 /(W_{TO}/S) + 1.0317 \times 10^{-5} (W_{TO}/S)$

Landing: $(W_{TO}/S) = 7840\sigma$ N/m^2

Climb: $(T_{SSL}/W_{TO}) = 0.2452$.

If the twin engine aircraft configuration is now altered to 4 engine configuration, how does its climb performance requirements (T_{SSL}/W_{TO}) change in meeting the same climb gradient requirements (CGR) of 3% specified by FAR for one engine inoperative case (OEI). Does (T_{SSL}/W_{TO}) increase or reduce for the 4 engine configuration? Assume that remaining 3 performance relationships do not change. Draw constraint diagram at SL for the 4 engine aircraft and obtain optimum (W_{TO}/S) and (T_{SL}/W_{TO}).

2B. Take off and landing requirements are often revised to a higher altitude of 4000 ft (1219 m with density ratio σ = 0.8897). Redraw the constraint diagram using above performance equations from Q2(A) duly modified for the case of the 4 engine configuration with revised take off distance ($\leq$ 1800 m) and landing distance ($\leq$ 1800 m) requirements at 4000 ft altitude. Assume changes in climb is limited to increase in number of engines. Obtain optimum (W_{TO}/S) and (T_{SL}/W_{TO}) for this case. **(06)**

3A. Using climb performance data given in Fig. 1, obtain best flight speed for efficient climb segment for the aircraft. Given the lift off speed $V_{Lift\ Off}$ at the end of ground run, as also the take off speed V_2 (= $V_{LiftOff}$) in climb segment clearing h =10.6 m obstacle and thereafter up to a height of 400 ft (122 m), to be 65 m/s and aircraft cruise speed to be 259.6 m/s at an altitude of 11 km, identify level acceleration segments at i) an altitude of 122 m (400 ft) and ii) cruise altitude. Draw these realistic mission segments from take off to cruise altitude in (h vs V) domain. **(04)**

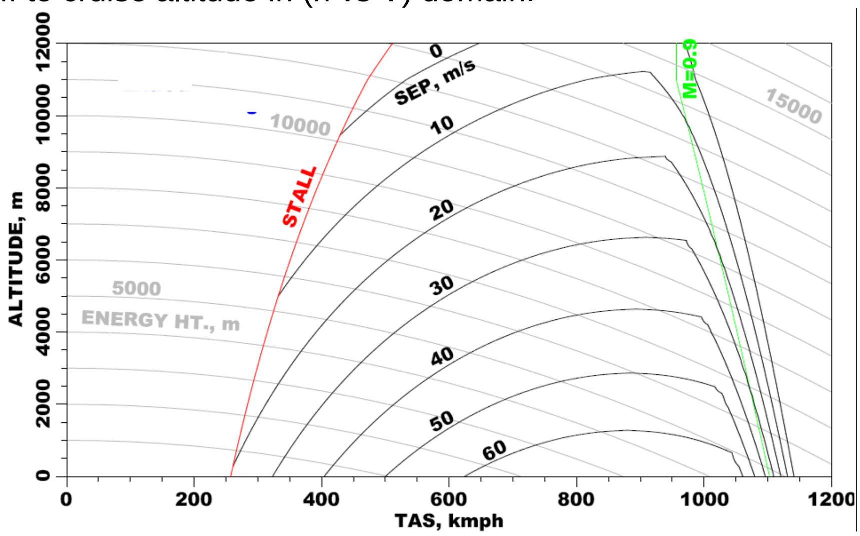

Fig. 1 Climb Performance (Flight Envelope for Constant SEP)

3B. Using SEP data at 500 m altitude in Fig. 1, estimate acceleration time and distance covered in a level acceleration from 300 km/h (83.3 m/s) to 400 km/h (111.1 m/s) at that altitude. You may use **a** = (g x SEP)/V, the relationship between SEP and level **(06)**

acceleration **a**, and follow suitable tabular column approach (at speed interval of 50 km/h or 13.9 m/s) to estimate incremental time and distance in the successive speed intervals and get the cumulative time and distance for going from 300 to 400 km/h. Given $(L/D)_{Climb}$ = 17, initial aircraft mass = 16 T and TSFC = 65 kg/kN/hr at 500 m altitude, calculate fuel burnt in the short level acceleration segment (300 to 400 km/h).

4A. Figure 2 below shows Aircraft Weight and CG characteristics for a range of pay load (PL) (10 to 100%) and fuel onboard (10 to 100%), obtained using mass and CG data for empty aircraft, partial to full PL and partial to full fuel onboard. Using data at four corner points in the carpet plots - (10% PL, 100% Fuel), (100% PL, 100% Fuel), (100% PL, 10% Fuel) and (10% PL, 10% Fuel), obtain maximum Takeoff Weight, Empty Weight, maximum (**100**%) PL and maximum (**100**%) Fuel. Show these 4 points on relevant curves in a schematic plot identifying coordinates Mass and CG distance (Note: 1. The vertical line represents 75% Fuel line along which the PL varies. 2. The 10% and 50% Fuel lines are seen partially overlapping) **(04)**

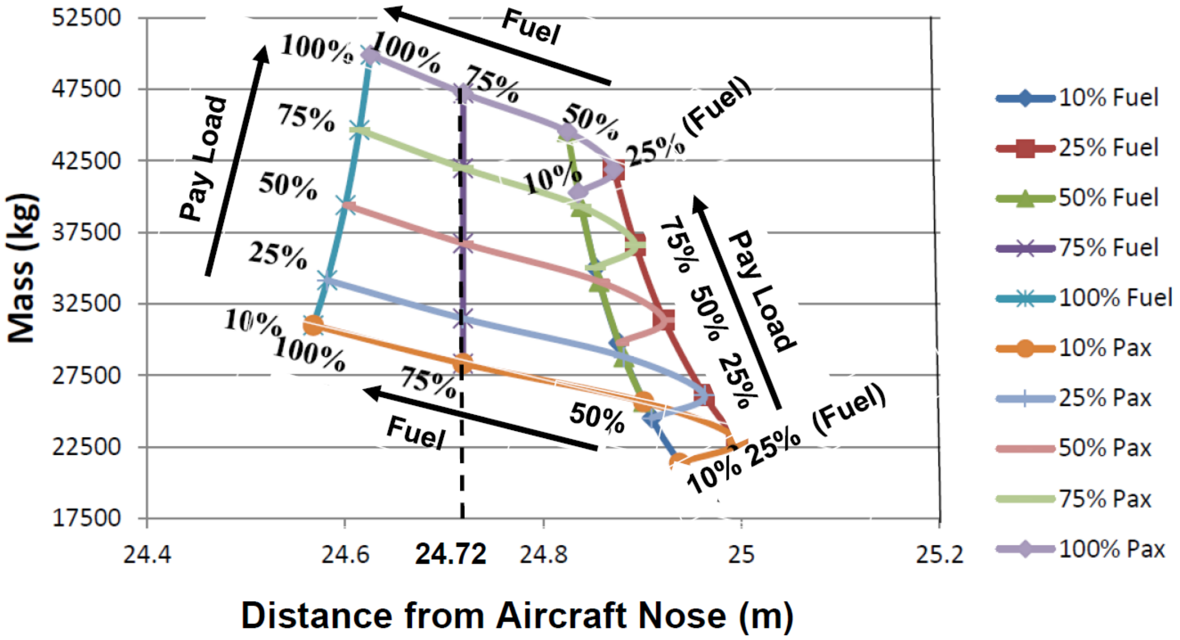

Fig. 2 Aircraft Weight and CG Characteristics

4B. Using mass and CG data Q4(A) from constant 75% fuel line and 10% Pay Load line, obtain
CG location for partial Pay Load and partial Fuel (10%, 25%, 50%, 75% and 100%).
Plot CG variation for partial Pay Load and Fuel with mass. Comment on the nature of Pay Load and Fuel CG characteristics. **(06)**

5A. Figures 3 and 4 below (see next page) show variation of ground speed with acceleration distance and acceleration time with ground speed respectively, for a multi-engine aircraft in take-off run for all engine operative (AEO) and one engine inoperative (OEI) cases, as in input data for estimating Decision Speed (V_D) and Balanced Field Length (BFL). Assuming rotation time of 3 s, climb angle γ for AEO and OEI cases to be respectively 12 deg and 8 deg, calculate normal take off distance s_{TO} for AEO case. Also calculate take off distnace required (TODR) for OEI case for three engine failure speeds (V_F) of $0.55V_R$,, $0.7V_R$,and $0.85V_R$,, where V_R = 91 m/s (see Figs. 3 and 4) is rotation speed in take off grund run. **(04)**

5B. Assuming pilot response time of 3s for cutting off the working engine/s and average ground deceleration of 0.25g for stopping distance from braking speed V_B, calculate **(03)**

accelerate stop distance (ASDR) for above three engine failure speeds in Q5A.

5C. Plot TODR and ASDR calculated at 3 engine failure speeds Vs V_F and obtain Decision Speed V_D and BFL. What is the take off distance of above aircraft as per FAR? **(03)**

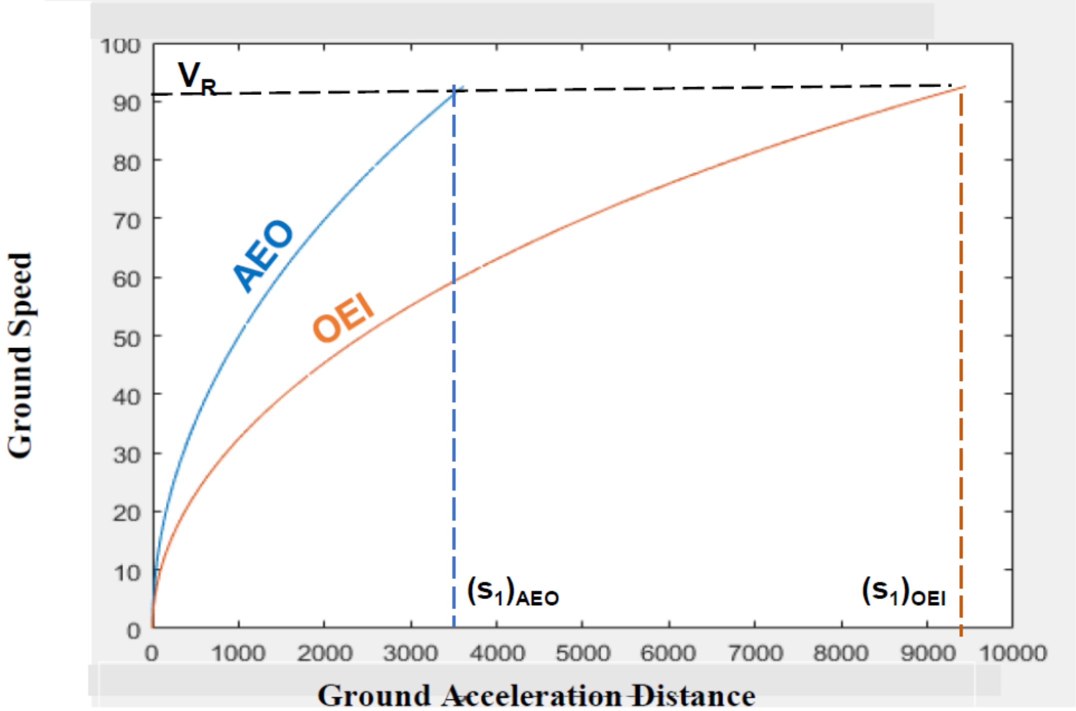

Fig. 3 Ground Speed Vs Acceleration Distance

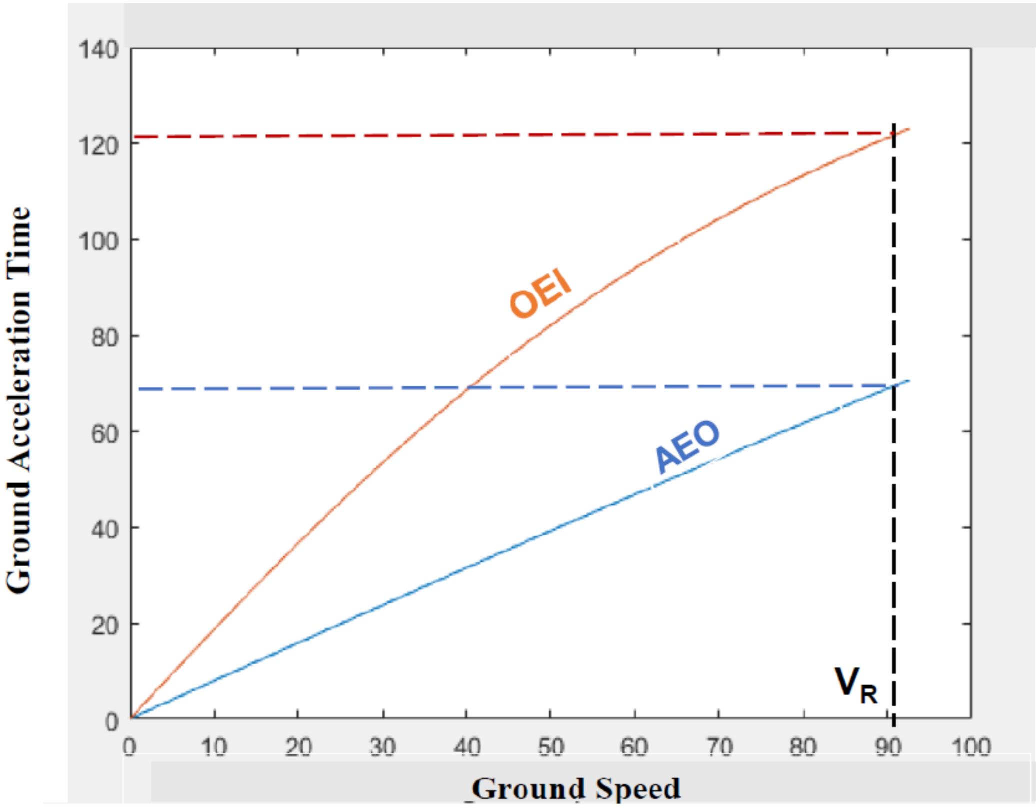

Fig. 4 Ground Acceleration Time Vs Speed