Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, DEC 2017

SUBJECT: AIRCRAFT DESIGN - I [AAE 3104]

REVISED CREDIT SYSTEM
(01/01/2018)

Time: 3 Hours MAX. MARKS: 50

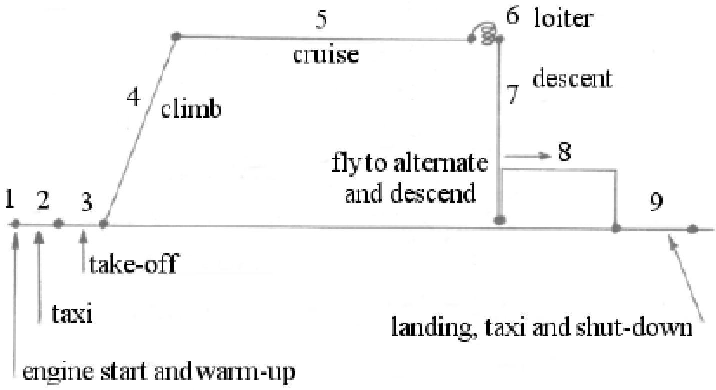
Instructions to Candidates:

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

1A. Name any five key design parameters that come out from initial sizing. **(02)**

1B. Which transportation model is firmly believed by the Airbus and Boeing as the future aviation transportation Model? Briefly explain **(03)**

1C. **Requirements:** Payload: 150 pax at 175 lb & 30 lb baggage each; Crew: 2 Pilots and 3 Cabin attendants at 175 lb each and 30 lb baggage each; Range: 9114173 ft, followed by 1 hour loiter, followed by 607612 ft flight to alternate and descent; Altitude: 35,000 feet for design range (rho =0.000735 slug/ft^3; speed of sound = 973 ft/s) ; Cruise speed: Mach number = 0.82 at 35,000 ft; Climb: direct climb to 35,000 ft at maximum W_{TO} is desired; Take-off and Landing: FAR 25 Field Length of 5,000 ft at an altitude of 5,000 ft and a 95° F day; Landing performance at $W_L = 0.85 * W_{TO}$; Powerplants: Two Turbofans; Assume ISA deg °C atmosphere; For an empty weight calculation: A = 1.02 and c = -0.06 (weight in lbs). **(05)**



Assumptions: Maximum Aerodynamic efficiency = 16; Specific Fuel Consumption (SFC) at cruise flight = 0.5 lb/hr/lb; Specific Fuel Consumption at loiter flight = 0.6 lb/hr/lb; Diversion: Cruise speed of 250 knots (FAR 25); L/D = 10 and Specific Fuel Consumption = 0.9 lb/hr/lb; Reserve Fuel Fraction = 10%.

Fuel Weight Fraction	W_1/W_0	W_2/W_1	W_3/W_2	W_4/W_3	W_7/W_6	W_9/W_8
Value	0.990	0.990	0.995	0.980	0.990	0.992

Compute the design gross weight of the medium range jet transport aircraft, empty weight and fuel weight for the given requirements.

2A. An aircraft has a maximum take-off mass of 100 tonnes and a thrust to weight ratio of 0.25. Calculate the take-off thrust of the aircraft (all engines together). **(02)**

2B. A propeller driven airplane must have a power off stall speed of no more than 50 knots at sea level $(\rho = 1.225\ \text{kg/m}^3)$ with full flaps down ($C_{L,max} = 2$ at landing). With flap up ($C_{L,max} = 1.6$) the stall speed is to be less than 60 knots. Note 1 knots = 0.5144444 m/s. In order to meet both requirements at take-off gross weight, what should be the highest value of wing loading (W/S)? **(03)**

2C. The master equation for constraint analysis of military aircraft is given as **(05)**

$$\frac{T}{W} = \frac{\beta}{\alpha}\left\{\frac{qS}{\beta W_{TO}}\left[K_1\left(\frac{n\beta W_{TO}}{qS}\right)^2 + K_2\left(\frac{n\beta W_{TO}}{qS}\right) + C_{D0} + \frac{R}{qS}\right] + \frac{1}{V}\frac{d}{dt}\left(h + \frac{V^2}{2g}\right)\right\}$$

Modify the master equation for the given below flight conditions.

(a) constant altitude/speed cruise
(b) constant speed climb
(c) constant altitude/speed turn
(d) constant acceleration
(e) ceiling

3A. Why do we need a higher maximum lift coefficient for the wing than for the whole aircraft? **(02)**

3B. List the sources of miscellaneous, leakage and protuberance drag of a transport aircraft. **(03)**

3C. The F-16 uses a NACA 64A-204 airfoil, which has its maximum thickness point of the airfoils, $\Lambda_{t,max} = 24\ \text{deg}$. The flapped area for the trailing edge flaps is approximately 13.94 sq.m. The flap hinge line sweep angle $\Lambda_{HL} = 10\ \text{deg}$. The span of the wing and horizontal tail are 9.144 m and 5.49 m respectively. The planform area of the wing and horizontal tail are 27.87 sq.m and 10.03 sq.m. The lift curve slope of the airfoil is 0.1 per degree. The area of the strakes is given as 1.86 sq.m. Distance from the quarter chord of the main wing's mean chord to the same point on horizontal tail (l_h) =4.48m; Height of center line of horizontal tail from wing = 0.3048 m. Maximum absolute angle of attack = 14 deg. Average chord of the wing = 3.048 m; wing taper ratio = 0.21. **(05)**

Calculate the maximum lift coefficient for take-off $\left(\Delta\alpha_{a_{2-D}} = 10^\circ\right)$

Empirical Relations:

$$e = \frac{2}{2 - AR + \sqrt{4 + AR^2\left(1 + \tan^2 \Lambda_{t.max}\right)}}$$

$$\frac{\partial \varepsilon}{\partial \alpha} = \frac{21^{\circ} C_{L_\alpha}}{AR^{0.725}}\left(\frac{c_{avg}}{l_h}\right)^{0.25}\left(\frac{10 - 3\lambda}{7}\right)\left(1 - \frac{z_h}{b}\right)$$

$$\Delta\alpha_a = \Delta\alpha_{a_{2-D}} \frac{S_f}{S} \cos \Lambda_{HL}$$

4A. There are several factors and design choices that directly influence the drag performance of an aircraft. Which of the following would help lowering drag? **(02)**

a. Lower the Oswald factor
b. Decrease the ratio of planform area/wetted area
c. Increase the cruise lift coefficient (without affecting the lifting surface area)
d. Lower the equivalent skin friction coefficient

4B. What are the two different approaches that used to calculate the drag of an aircraft at the conceptual design phase? How the methods are different from each other? **(03)**

4C. Consider a cargo aircraft with the following features: **(05)**

Mass = 3,80,000 kg; Wing area = 567 m^2; MAC = 9.3m; maximum thickness to chord ratio = 18%; minimum drag coefficient = 0.0052; chord-wise location of maximum thickness: for low speed airfoil = 0.3 and high speed airfoil = 0.5; Fuselage length = 27.66 m; Horizontal tail span = 10.97 m; Fin height = 6.15 m; Finess ratio of the fuselage = 7.42; Surface roughness of smooth paint = 0.0634 mm; Interference factor for wing, fuselage and conventional tail are 1.0, 1.0 and 1.05 respectively; Sweep of maximum thickness line = 20 deg.

The aircraft is flying at sea-level with a speed of 400 knot. Assume the aircraft zero-lift drag coefficient is 2.3 times the wing zero-lift drag coefficient, determine the aircraft profile drag coefficient using component build-up method.

Use the following empirical relations:

For Wing, HT and VT:

$$FF = \left[1 + \frac{0.6}{(x/c)_m}(t/c) + 100(t/c)^4\right]\left[1.34M^{0.18}(\cos\Lambda_m)^{0.28}\right]$$

For Fuselage:

$$FF = \left[1 + \frac{60}{f^3} + \frac{f}{400}\right]; \text{where } f = \frac{1}{\sqrt{(4/\pi)A_{max}}}$$

5A. The payload-range-diagram: Is it possible to go maximum range with maximum payload? Explain your answer **(02)**

5B. Draw a typical payload-range diagram for a transport aircraft and explain the significance of payload-range diagram in the conceptual design phase. **(08)**