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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL

A Constituent Institution of Manipal University

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: AIRCRAFT DESIGN [AAE 3104]

REVISED CREDIT SYSTEM
(05/12/2016)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A. What is the significance of Quality Function Deployment (QFD) in the aircraft design process? **(02)**

1B. Explain the different stages involved in the aircraft design process? How much percentage each stage contributes to the design process? **(03)**

1C. You are to design a conventional civil transport aircraft that can carry 700 passengers plus their luggage. The aircraft must be able to fly with a cruise speed of Mach 0.8, and have a range of 3.1168×10^7 ft (9500 km) followed by 1 hour loiter, followed by 250 nm flight to alternate and descent. At this point, you are only required to estimate the aircraft maximum take-off weight. You need to follow FAA regulations and standards. Assume that the aircraft equipped with two high bypass ratio turbofan engines with SFC as 0.45 lb/hr/lb (during cruise and loiter) and is cruising at 35,000 ft altitude (density = 7.3820×10^-4 slugs/ft^3; Temperature = 394.08° R; Pressure = 4.9934×10^2 lb/ft^2; speed of sound at this altitude is 937 ft/s). As defined in section 125.9 Definitions, flight crew members are assumed to have a weight of 200 lbs. Flight attendant's weight is designated in 119.3 and requires that 140 lbs be allocated for a flight attendant whose sex in unknown. To observe the reality and to be on the safe side, an average weight of each passenger is assumed to be 180 lb. On the other hand, 100 lbs of luggage is considered for each passenger. Fuel weight ratios for the segments of taxi, take-off, climb, descent, approach and landing are 0.98, 0.97, 0.99 and 0.997 respectively. Maximum aerodynamic efficiency is 17. Reserve fuel fraction = 10%. During diversion, the cruise speed of the aircraft is given as 250 knots, SFC as 0.9 lb/hr/lb and aerodynamic efficiency as 10. **(05)**

2A. List all requirements that should be known when the aircraft design of a passenger aircraft is started. **Hint: Requirements are from cruise performance and airport performance.** **(02)**

2B. Draw any possible matching chart (from aircraft preliminary sizing) with its five constraints. Highlight the area in the chart that yields feasible design. What are the two rules for finding an optimum design point? **(03)**

2C. A new business jet design concept has a clean subsonic drag polar of $C_D = 0.02 + 0.06\, C_L^2$, design point of thrust to weight ratio as 0.35 and wing loading as 65 lb/ft^2. Its design mission consists of take-off at sea level, acceleration during climb to M = 0.5, climb to h = 20,000 ft, cruise at 0.78 Mach for 2000 nm, then descent and landing with enough fuel to loiter at h = 10,000 ft for 20 min. The speed of sound and density at 20,000 ft are 1036.9 ft/s and 0.001267 slug/ft^3. Weight ratio during climb is given as 0.9953. **(05)**

The master equation for constraint analysis of military aircraft is given as

$$\frac{T}{W} = \frac{\beta}{\alpha}\left\{\frac{q}{\beta}\left[K_1\left(\frac{n\beta}{q}\right)^2\left(\frac{W_{TO}}{S}\right) + \frac{C_{D0}}{(W_{TO}/S)}\right] + \frac{1}{V}\frac{dh}{dt} + \frac{1}{g}\frac{dV}{dt}\right\}$$

Rearrange the master equation, Calculate the rate of climb and time to climb using the average value method.

$$\text{Time to climb using average value method}, t = \frac{(h_{final} - h_{initial})}{dh/dt}$$

3A. 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

3B. What are the two different approaches that used to calculate the drag of an aircraft at conceptual design phase? How these methods are different from each other? **(03)**

3C. The F-16 uses a NACA 64A-204 airfoil, which has its maximum thickness at 50% chord. The lift curve slope for an airfoil is 0.1/deg. The sweep angle of the line connecting the maximum thickness points of the airfoils, Λ_{max} = 24 deg. The flapped area for the trailing edge flaps is approximately 150 ft^2. The flap hinge line sweep angle Λ_{HL} = 10 deg. Distance from the quarter chord of the main wing's mean chord to the same point on horizontal tail(l_h) is 14.7 ft. Increment in absolute angle of attack for airfoil during take-off and landing are 10° and 15° respectively. Mean Aerodynamic chord =10 ft; Wing taper ratio = 0.21; Height of center line of horizontal tail from wing (z_h) = 1 ft; Maximum Absolute angle = 14 degree; Wing area = 300 ft^2; Tail area = 108 ft^2; Area of the strake = 20 ft^2; wing span = 30 ft; tail span = 18 ft. Using the fact that the F-16's landing gear limit its maximum angle of attack for take-off and landing to 14 degree. Estimate the lift curve slope for the airfoil, lift curve slope with strake, lift curve slope of a whole aircraft and maximum lift coefficient during take-off and landing for a given aircraft. **(05)**

Use the following equations,

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

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

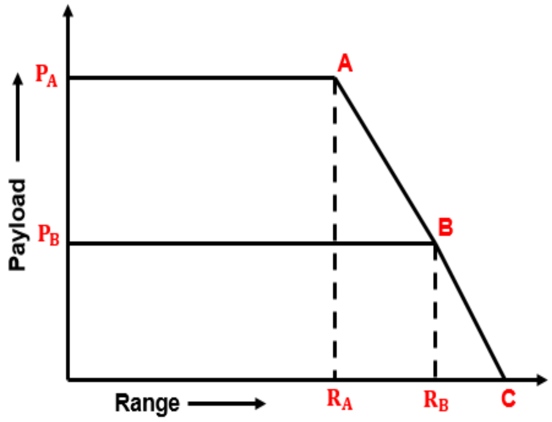
4A. The Payload-Range diagram: Is it possible to go maximum range with maximum payload? Explain your answer **(02)**

4B. Explain briefly the following terms: **(03)**

a. Harmonic range
b. Ferry range
c. Gross Still Air Range (GSAR)

4C. Maximum Take-off Weight (MTOW) = 44226 kg; Maximum Landing Weight (MLW) = 40143 kg; Maximum Zero Fuel Weight (MZFW) = 37422 kg; Operating Empty Weight (OEW) = 25600 kg; Maximum Fuel Capacity = 11728 liters; Maximum number of passengers = 112 (weight of passenger = 95 kg each); Weight of the cargo = 1182 kg; Density of the fuel = 0.788 kg/litre^3; Maneuver allowances (Warm-up + Taxi + Take-off) = 300 kg. The reserve fuel weight for the given aircraft is assumed to be 15% of maximum fuel weight. Specific range is given as 0.19 nm/kg. **(05)**

Calculate Payload weight, Take-off Weight, Fuel Weight and Range at points $\mathbf{P_A}$, A, B and C from the given typical payload-range diagram for a civil transport aircraft.



5A. Direct Operating Costs (DOC) are calculated from a maximum of 7 cost elements. Name at least four of them. **(02)**

5B. When the pilot pushes the throttle all the way forward, an excess power is generated in the amount $P_S = 91$ m/s. Calculate the maximum unaccelerated rate of climb and rate of change of velocity of the aircraft during level flight. **(03)**

5C. Consider an aircraft with the following features: **(05)**

Mass of the aircraft = 2300 kg; Wing area = 19.33 m^2; Maximum lift coefficient = 2; Negative maximum lift coefficient = -1.2; Aspect ratio = 7; lift curve slope = 6.3/rad;

Cruise velocity of an aircraft = 310 KEAS (at 10000 ft); Positive load factor = 6. Determine the coordinate points of the Velocity-load factor diagram and the maximum load factor for a given aircraft.

Use the following equations:

The variation of load factor as a function of airspeed:

$$n = 1 + \frac{k_g V_{gE} V_E a \rho S}{2W}$$

where

$$k_g = \frac{0.88\mu_g}{5.3 + \mu_g}$$