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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

V SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, DEC 2016

SUBJECT: AIRCRAFT DESIGN [AAE 3104]

REVISED CREDIT SYSTEM
(07/01/2017)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A. Name 5 key design parameters that come out from initial sizing. **(02)**

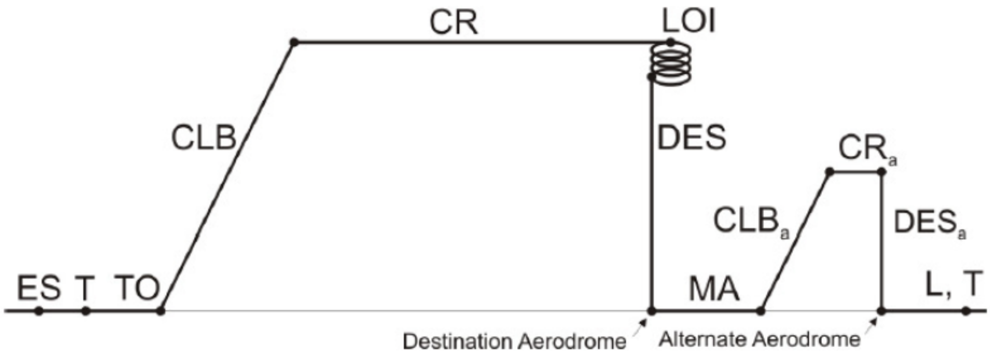
1B. An aircraft carries 10 tonnes of payload. Its relative fuel mass is 0.4 and its relative operating empty mass is 0.5. Calculate the maximum take-off mass. **(03)**

1C. A Jet transport aircraft has the following mission specification: **(05)**

Payload: 150 passengers at 80 kg each and 25 kg of baggage each, **Crew:** Two pilots and 3 cabin attendants at 75 kg each and 15 kg of baggage each. **Range:** 4000 km. Reserve for flight to an alternate airport at 250 km. **Cruise Altitude:** 11,200 m (speed of sound = 295 m/s). Flight to alternate airport is at an altitude of 5,500m, **Cruise speed:** M = 0.87, **Climb:** Climb to cruise altitude in 20 min, Maximum aerodynamic efficiency = 16, Power-plant: 2 Turbofans, SFC at cruise condition = 0.5 lb/hr/lb; SFC at loiter = 0.55 lb/hr/lb, **Diversion:** cruise speed = 250 knots; aerodynamic efficiency = 10; SFC = 0.9 lb/hr/lb

Flight Phase	Fuel Weight Fraction
Engine warm-up, Taxi and Takeoff	0.98
Climb	0.97
Approach and Landing	0.997

Calculate Take-off weight, Empty weight and Fuel weight for this aircraft with following mission profile.



2A. Which two of the following statements are true: **(02)**

a) Missed approach gradient and climb gradient puts an upper limit on T/W
b) Stall velocity and Landing distance puts a lower limit on wing loading (W/S)
c) Cruise and Loiter puts lower limit on T/W and wing loading (W/S)
d) d. Ceiling puts a lower limit on wing loading (W/S)

2B. The master equation for constraint analysis of military aircraft is given as **(03)**

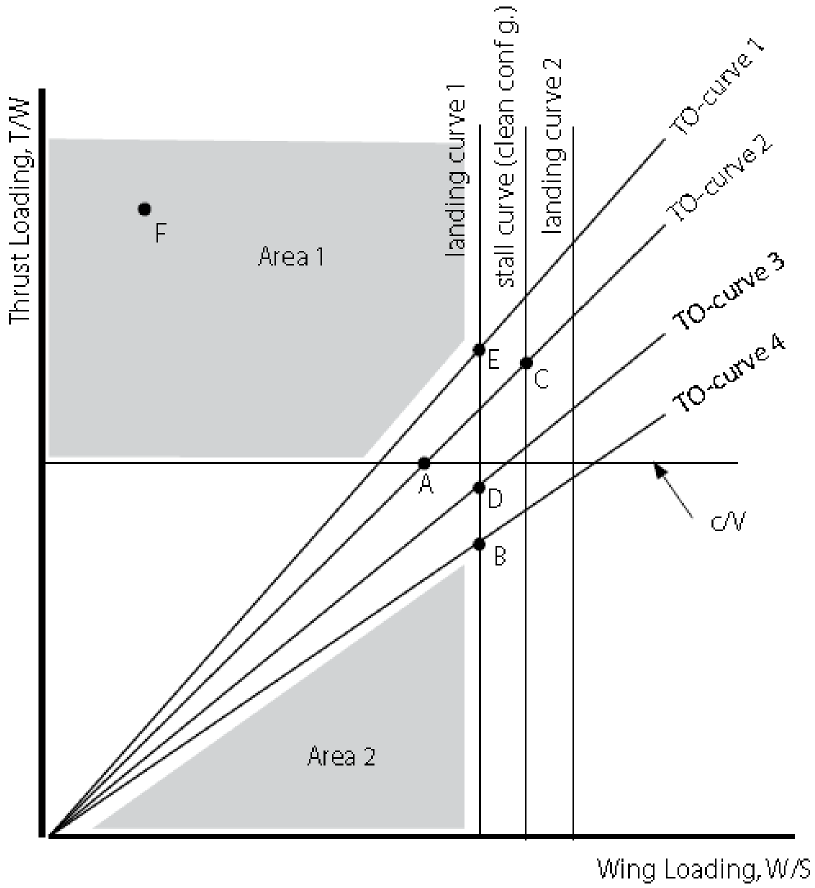
$$\frac{T}{W} = \frac{\beta}{\alpha}\left\{\frac{qS}{\beta W_{TO}}\left[K_1\left(\frac{n\beta W_{TO}}{qS}\right)^2 + K_2\left(\frac{n\beta W_{TO}}{qS}\right) + C_{D0} + \frac{R}{qS}\right] + \frac{1}{V}\frac{d}{dt}\left(h + \frac{V^2}{2g}\right)\right\}$$

Modify the master equation for each given flight condition. **Equation for each flight condition carries one mark.**

(a) constant altitude/speed cruise
(b) constant speed climb
(c) constant altitude/speed turn

2C. Looking at the W/S-T/W plot below, indicate which of the following statements are correct (more correct statements possible) **(05)**

a) A design point could be picked both in *Area 1* and *Area 2*, but design points in *Area 1* would demand a too high thrust loading
b) A design point could be picked only in *Area 2*, elsewhere the take-off constraint would be violated
c) A design point could only be picked in *Area 1* in order to comply with the takeoff, landing and wing loading requirements
d) In point D the climb gradient requirement is violated
e) In point E, the take-off constraint is satisfied for a lower CLmax value than Point A



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

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

3C. 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 equations:

For Wing, HT and VT:

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

For Fuselage:

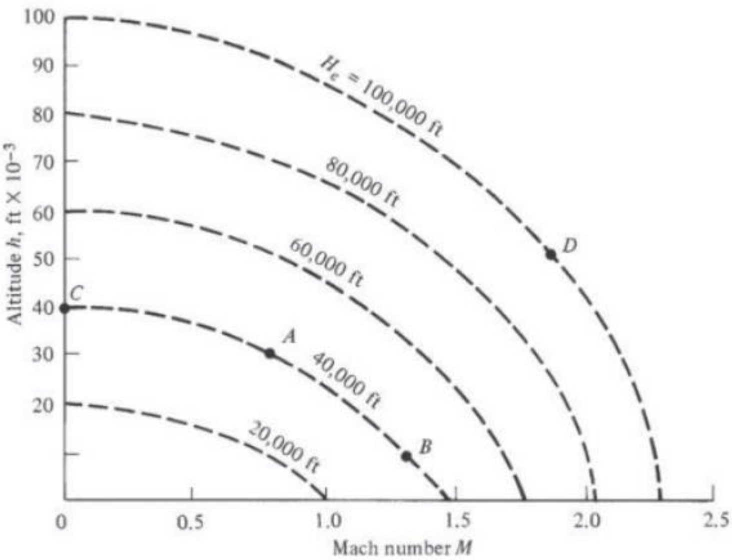
$$FF = \left[1 + \frac{60}{f^3} + \frac{f}{400}\right];\text{ where } f = \frac{1}{\sqrt{(4/\pi)A_{max}}}$$

4A. The payload-range-diagram: Why is the maximum payload limited by Maximum Zero Fuel Weight (MZFW)? **(02)**

4B. Enumerate the typical aircraft weight buildup of a transport aircraft with neat diagram. **(03)**

4C. Draw a typical payload-range diagram for a transport aircraft and write down the significance of payload-range diagram in the conceptual design phase. **(05)**

5A. How does an airplane change its energy height? How could airplanes A and B increase their energy heights to equal that of D? **(02)**



5B. Write a note on aerodynamic considerations of fuselage design. **(03)**

5C. Explain briefly the significance of Velocity-load factor diagram in the aircraft design process. **(05)**