Introduction to Aircraft Design
July-2023

Assignment 5

Q 1	Read the following statements and choose the correct option: I. Mission Profile of an airliner is generally specified by DGCA in India. II. Initial Sizing results in estimation of only the Empty weight of an aircraft. III. Most of the procedures in Initial Sizing are Empirical or Semi Empirical.	
MCQ (1 mark)	(A)	All the statements are correct.
	(B)	Only I is correct.
	(C)	Only II is correct.
	(D)	Only III is correct.
	(E)	Both I and II are correct.
	(F)	Both I and III are correct.
	(G)	Both II and III are correct.
	(H)	All the statements are incorrect.
Solution: (D)		

Q 2	Which of the following statement(s) is/are TRUE about Empty Weight of an aircraft?	
MSQ (1 mark)	(A)	An aircraft with variable sweep wing has lower empty weight.
	(B)	For a given aircraft type, heavier aircraft have a lower empty weight fraction.
	(C)	Military cargo aircraft have the lowest empty weight fraction.
	(D)	Flying boats have the highest empty weight fraction.
Solution: (B), (C), (D)		

Q 3	Which of the following statement(s) is/are TRUE about the estimation of fuel weight of an aircraft?	
MSQ (1 mark)	(A)	Mission fuel fraction is independent of Aircraft L/D ratio.
	(B)	Reserve fuel fraction is decided by the aircraft manufacturer.
	(C)	Fuel weight fraction is independent of aircraft gross weight.
	(D)	Mission fuel depends on the engine characteristics.
Solution: (C), (D)		

Q 4	Which of the following mission segment weight fraction(s) is/are estimated by historical trends, or is/are neglected?	
MSQ (1 mark)	(A)	Warm-up and Taxi-out
	(B)	Take-Off
	(C)	Climb
	(D)	Cruise
	(E)	Descent
	(F)	Loiter
	(G)	Approach and Landing
Solution: (A), (B), (C), (E), (G)		

Q 5	Which of the following statement(s) is/are TRUE about the Cruise Range of an aircraft as per Breguet Range Equation?	
MSQ (1 mark)	(A)	It is independent of L/D, TSFC and Aircraft weight fraction before Cruise.
	(B)	It is independent of L/D and TSFC, but depends on Aircraft weight fraction before Cruise.
	(C)	It is independent of L/D and Aircraft weight fraction before Cruise, but depends on TSFC .
	(D)	It is independent of TSFC and Aircraft weight fraction before Cruise, but depends on L/D.

	(E)	It is adversely affected by the increasing TSFC and decreasing L/D.
	(F)	It is dependent on L/D, TSFC and Aircraft weight fraction before Cruise.
	(G)	It is adversely affected by decreasing TSFC and increasing L/D.
Solution: (E), (F)		

Q 6-15	A passenger jet transport aircraft is designed to perform a simple mission consisting of Warm-up, Taxi-out, Take-off, Climb, Cruise, Loiter, Descend, Approach, Land, and Taxi-in segments. It has to cover a total Range of 3000 nm and Loiter for half an hour before Landing. It has a seating capacity of 250 passengers. It has four cockpit crew and eight cabin crew, and requires operating items weighing 500 kg. It is designed to cruise at Mach Number of 0.8 at an altitude of 11 km AMSL under ISA conditions. Assume: Mass of each passenger and crew members alongwith their baggage is 95 kg. Maximum value of L/D = 16. Specific Fuel consumption in Cruise = 16 mg/Ns. Specific Fuel consumption in Loiter = 12 mg/Ns. Reserve Fuel Fraction = 5%. Fuel weight fractions during: Warm-up, Taxi-out, Take-off = 0.97 Climb = 0.985 Approach, Land, and Taxi-in = 0.995 Neglect the fuel consumed in the Descent phase.

Q 6	Estimate the Crew weight including Operating items (in kg).
NAT (1 mark)	Answer : 1620 - 1660

Solution:

$Number\ of\ crew\ members\ =\ Cockpit\ crew\ +\ cabin\ crew$

$Number\ of\ crew\ members\ =\ 4\ +\ 8\ =\ 12$

$Weight\ of\ Crew\ members\ alongwith\ their\ baggage\ =\ 12\ *\ 95\ =\ 1140\ kg$

$Crew\ Weight\ =\ Crew\ Members\ Weight\ +\ Operating\ Weight$

$Crew\ Weight\ =\ 1140\ +\ 500\ =\ 1640\ kg$

Q 7	Estimate the Payload weight (in kg).
NAT (1 mark)	Answer : 23740- 23760

Solution:

$Number\ of\ Passengers\ =\ 250$

$Payload\ Weight\ =\ Number\ of\ pax\ *\ 95\ =\ 250\ *\ 95\ =\ 23750\ kg$

Q 8	Estimate the Cruise Velocity (in m/s).
NAT (1 mark)	Answer : 230 - 240

Solution:

$Cruise\ Mach\ Number\ is\ 0.8$

$Temperature\ at\ 11\ km\ =\ 216.66\ K$

$V_{Cr} = M_{Cr}\sqrt{\gamma RT} = 0.8\sqrt{1.4\ *\ 287\ *\ 216.66} = 236\ m/s$

Q 9	Estimate the fuel weight fraction during cruise.
NAT (1 mark)	Answer : 0.73 - 0.79
Solution: $V_{Cr} = 236\ m/s$ $L/D_{Cr} = 0.866 * 16 = 13.856$ $SFC_{Cr} = 16 * 9.81 * 10^{-6} = 1.56 * 10^{-4}\ per\ second$ $R_{Cr} = 3000 * 1.852 = 1852\ km$ $\frac{W_{i+1}}{W_i} = e^{\frac{-R_{Cr} * SFC_{Cr}}{V_{Cr} * (L/D_{Cr})}} = e^{\frac{-5556000 * 1.56 * 10^{-4}}{236 * 13.856}} = e^{\frac{-866.736}{3270.016}} = 0.76$	
Q 10	Estimate the value of L/D during Loiter.
NAT (1 mark)	Answer : 16
Solution: L/D during Loiter will be L/D max.	
Q 11	Estimate the fuel weight fraction during Loiter.
NAT (1 mark)	Answer : 0.95- 0.99
Solution: $E_{loiter} = 0.5\ hrs = 1800\ s$ $L/D_{loiter} = 16$ $SFC_{loiter} = 12 * 9.81 * 10^{-6} = 1.1772 * 10^{-4}\ per\ second$ $\frac{W_{i+1}}{W_i} = e^{\frac{-E_{loiter} * SFC_{loiter}}{(L/D_{loiter})}} = e^{\frac{-1800 * 1.1772 * 10^{-4}}{16}} = 0.98$	

Q 12	Estimate the Total Fuel Weight fraction.
NAT (1 mark)	Answer : 0.27 - 0.33

Solution:

$0-1: Take\ off,\ 1-2:\ Climb,\ 2-3:\ Cruise$

$3-\ 4:\ Loiter, 4-\ 5: Descend,\ 5-6:\ Approach\ and\ Land$

$\frac{W_1}{W_0} = 0.97,\ \frac{W_2}{W_1} = 0.985,\ \frac{W_3}{W_2} = 0.76,\ \frac{W_4}{W_3} = 0.98,\ \frac{W_5}{W_4} = 1,\ \frac{W_6}{W_5} = 0.995$

$\frac{W_6}{W_0} = \frac{W_6}{W_5} * \frac{W_5}{W_4} * \frac{W_4}{W_3} * \frac{W_3}{W_2} * \frac{W_2}{W_1} * \frac{W_1}{W_0}$

$\frac{W_6}{W_0} = 0.995 * 1 * 0.98 * 0.76 * 0.985 * 0.97 = 0.7080$

$\frac{W_f}{W_0} = (1 + RFF)(1 - \frac{W_6}{W_0}) = (1 + 0.05)(1 - 0.7080) = 0.30$

Q 13	Estimate the Total Design Gross Weight (in kg).
NAT (1 mark)	Answer : 110000 - 120000

Solution:

$W_0 = \frac{W_{crew} + W_{pay}}{1 - \widehat{W_e} - \widehat{W_f}} = \frac{1640 + 23750}{1 - 0.97 W_0^{-0.06} - 0.3}$

Upon iterations, $W_0 = 116338.4\ kg$

Q 14	Estimate the Empty Weight the aircraft (in kg).
NAT (1 mark)	Answer : 55000 - 60000
Solution: $\widehat{W_e} = \frac{W_e}{W_0}$ $W_e = \widehat{W_e} * W_0 = 0.48 * 116338.4 = 55842.43\ kg$	
Q 15	Estimate the mission fuel weight (in kg).
NAT (1 mark)	Answer : 33000 - 36000
Solution: $W_f = \left(1 - \frac{W_6}{W_0}\right) * W_0 = (1 - 0.7) * 116338.4 = 34901.52\ kg$	