

Introduction to Aircraft Design

July-2023

Assignment 8

Q 1	An aircraft is cruising at a speed of 900 kmph at an altitude of 11 km AMSL. Estimate its Energy Height (in km). (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 13.50- 14.50

Solution:

Cruising speed = 900 kmph = 250 m/s

Energy Height is calculated as:

$$H_e = h + \frac{V^2}{2g} = 11000 + \frac{250^2}{2 * 9.807} = 11000 + 3186.49 = 14186.49 \text{ m}$$
$$H_e = 14.19 \text{ km}$$

Q 2	Which of the following equation can be used to determine the constraint on Climb Rate?	
MCQ (1 mark)	(A) $\frac{T}{W} + \frac{D}{W} = \frac{I}{V} \frac{dh}{dt} + \frac{I}{g} \frac{dV}{dt}$	
	(B) $\frac{T}{W} - \frac{L}{W} = \frac{I}{V} \frac{dh}{dt} + \frac{I}{g} \frac{dV}{dt}$	
	(C) $\frac{T}{W} - \frac{D}{W} = \frac{I}{g} \frac{dh}{dt} + \frac{I}{V} \frac{dV}{dt}$	
	(D) $\frac{T}{W} - \frac{D}{W} = \frac{I}{V} \frac{dh}{dt} + \frac{I}{g} \frac{dV}{dt}$	
Solution: (D)		

Q 3	An aircraft, equipped with low-bypass ratio turbofan engine without afterburner, generates a maximum Thrust of 10 kN at Sea level. What will be the maximum Thrust generated by the same engine at an altitude of 10 km AMSL under standard ISA conditions? (Write your answer correct upto the nearest integer)
NAT (1 mark)	Answer : 3400
Solution: Air density at 10 km = 0.4135 kg/m^3 $\frac{T}{T_{SL}} = \alpha = \frac{\rho}{\rho_{SL}} = \frac{0.4135}{1.2256} = 0.34$ $T = \alpha T_{SL} = 0.34 * 10000 = 3400$	

Q 4	<p>An aircraft is operating at ISA Sea Level conditions. It has stalling speed of 180 kmph with a maximum lift coefficient of 1.0 in clean condition. What will be the permissible value of Wing Loading (in kg/m^2) due to Stalling Speed constraint?</p>	
MCQ (1 mark)	(A)	≤ 1532
	(B)	≤ 156.2
	(C)	≥ 1532
	(D)	≥ 156.2
<p>Solution: (B)</p>		

Q 5 - 8	<p>A military aircraft equipped with Turbojet engine (wet) is performing a $9g$ Subsonic combat turn. It is operating at Mach Number 0.9 at an altitude of 2000 m AMSL under ISA. It has already consumed 20 % of the fuel as compared to Take-off weight. It has a parabolic Drag Polar as $C_D = 0.0254 + 0.123 C_L^2$. If the constraint equation is expressed as:</p> $\left(\frac{T}{W}\right)_{TO} = \frac{A}{\left(\frac{W_{TO}}{S}\right)} + B \left(\frac{W_{TO}}{S}\right)$ <p>Please note that $\left(\frac{T}{W}\right)_{TO}$ is dimensionless and $\left(\frac{W_{TO}}{S}\right)$ is in N/m^2</p>
Q 5	<p>Estimate the Thrust Lapse Ratio. (Write your answer correct upto two decimal places)</p>
NAT (1 mark)	<p>Answer : 1.20-1.50</p>
<p>Solution:</p> <p>Air density at 2 km = $1.007 \text{ kg}/\text{m}^3$</p>	

$$\frac{T}{T_{SL}} = \alpha = \frac{\rho}{\rho_{SL}}(I + 0.7M) = \frac{1.007}{1.2256}(I + 0.7 * 0.9) = 1.33$$

Q 6	Estimate the value of constant "A" in the constraint equation. (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 840.00 - 900.00
Q 7	Estimate the value of constant "B" in the constraint equation. $B = x * 10^{-4}$ (Write the value of "x" correct upto two decimal places)
NAT (1 mark)	Answer : 0.90- 1.20

Solution:

Speed of sound at 2 km:

$$a = \sqrt{\gamma RT} = \sqrt{1.4 * 287 * 275.16} = 332.5 \text{ m/s}$$

$$V = Ma = 0.9 * 332.5 = 299.25 \text{ m/s}$$

$$q = 0.5 * \rho * V^2 = 0.5 * 1.007 * 299.25^2 = 45088.7 \text{ N/m}^2$$

$$\frac{T}{T_{SL}} = \alpha = \frac{\rho}{\rho_{SL}}(I + 0.7M) = \frac{1.007}{1.2256}(I + 0.7 * 0.9) = 1.33$$

$$\left(\frac{T}{W}\right)_{TO} = \frac{A}{\left(\frac{W_{TO}}{S}\right)} + B \left(\frac{W_{TO}}{S}\right)$$

$$\left(\frac{T}{W}\right)_{TO} = \frac{q}{\alpha} \left[\frac{C_{DO}}{\left(\frac{W_{TO}}{S}\right)} + k \left(\frac{n\beta}{q}\right)^2 \left(\frac{W_{TO}}{S}\right) \right]$$

$$\left(\frac{T}{W}\right)_{TO} = \frac{45088.7}{1.33} \left[\frac{0.0254}{\left(\frac{W_{TO}}{S}\right)} + 0.123 \left(\frac{9 * 0.8}{45088.7}\right)^2 \left(\frac{W_{TO}}{S}\right) \right]$$

$$\left(\frac{T}{W}\right)_{TO} = \left[\frac{861.09}{\left(\frac{W_{TO}}{S}\right)} + 1.063 * 10^{-4} \left(\frac{W_{TO}}{S}\right) \right]$$

Q 8	Which of the following can be possible combination(s) of W_o/S (in N/m^2) and T_o/W_o (dimensionless)?	
MSQ (1 mark)	(A)	3920 and 0.636
	(B)	2500 and 0.815
	(C)	3540 and 0.423
	(D)	1960 and 0.647
Solution: (A), (D)		

Q 9	For which of the following mission(s) is the Initial sizing methodology not applicable?	
MSQ (1 mark)	(A)	Air-to-Air Refueling
	(B)	Dropping of bombs
	(C)	Launching of a space shuttle mounted above the aircraft
	(D)	Transporting of passengers
Solution: (A), (B), (C)		

Q 10	In the estimation of fuel fractions in refined sizing, which of the following segment(s) has/have better/new formulae?	
MSQ (1 mark)	(A)	Accelerated Climb
	(B)	Level flight acceleration
	(C)	Combat Cruise or High Speed Dash
	(D)	Loiter
Solution: (A), (B), (C)		

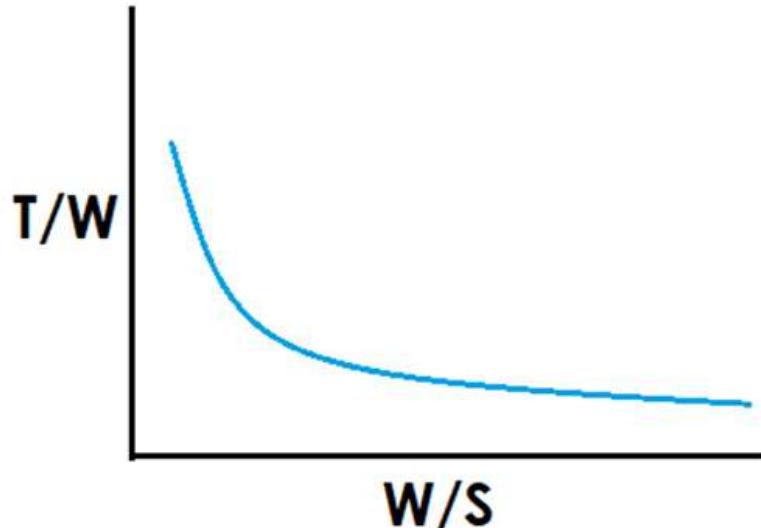
Q 11	The fuel weight fraction of an aircraft is 0.97 when it accelerates from Mach Number 0.1 to 0.85, and 0.93 when it accelerates from Mach Number 0.1 to 1.75. Estimate the fuel weight fraction when it accelerates from Mach Number 0.85 to 1.75. (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 0.94 - 0.98
Solution:	

$$\left(\frac{W_i}{W_{i-1}} \right)_{M=0.85 \text{ to } 1.75} = \frac{\left(\frac{W_i}{W_{i-1}} \right)_{M=0.1 \text{ to } 0.85} = 0.93}{\left(\frac{W_i}{W_{i-1}} \right)_{M=0.1 \text{ to } 1.75} = 0.97} = 0.96$$

Q 12	<p>For a fighter jet aircraft in a combat segment, it is given that:</p> <p>Weight ratio of combat segment = 0.85,</p> <p>$TSFC_{combat} = 18.4 \text{ mg/N-s}$,</p> <p>Combat duration = 15 min.</p> <p>What is the required Thrust to Weight ratio during this combat segment? (Write your answer correct upto two decimal places)</p>
NAT (1 mark)	Answer : 0.90- 0.95
<p>Solution:</p> $sfc_{combat} = tsfc_{combat} * \frac{9.807}{10^6} \text{ s}^{-1}$ $sfc_{combat} = 18.4 * \frac{9.807}{10^6} \text{ s}^{-1} = 1.8 * 10^{-4} \text{ s}^{-1}$ $\left(\frac{T}{W}\right) = \frac{I - \frac{W_i}{W_{i-1}}}{sfc * d} = \frac{I - 0.85}{1.8 * 10^{-4} * 900} = \frac{0.15}{0.162} = 0.92$	

Q 13	<p>Read the following statements about Rubber Engine Sizing and choose the correct option:</p> <ul style="list-style-type: none"> I. Engine is assumed to have a fixed value of Thrust or Power. II. Performance or Range is a fallout parameter. III. Used for designing around an existing engine. 	
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)	Only I and II are correct.
	(F)	Only I and III are correct.
	(G)	Only II and III are correct.
	(H)	All the statements are incorrect.
Solution: (H)		

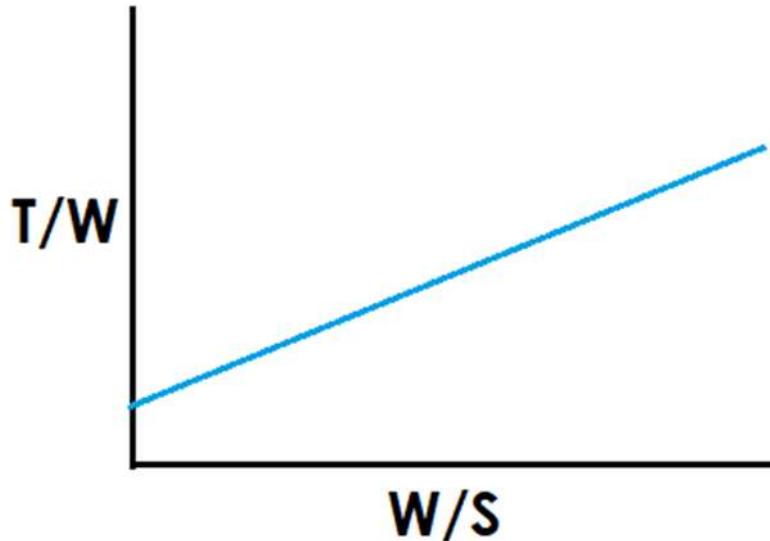
Q 14 Which of the following constraint(s) can yield a graph on the constraint diagram similar to the one as shown



MSQ (1 mark)	(A)	Maximum Mach Number
	(B)	Maximum Climb Rate
	(C)	Supersonic Turn
	(D)	Subsonic Turn
	(E)	Specific Excess Power
	(F)	Take-off
	(G)	Stalling Speed
	(H)	Instantaneous Turn

Solution: (A), (B), (C), (D), (E)

Q 15 Which of the following constraint(s) can yield a graph on the constraint diagram similar to the one as shown



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|-----------------|-----|-----------------------|
| MSQ
(1 mark) | (A) | Maximum Mach Number |
| | (B) | Maximum Climb Rate |
| | (C) | Supersonic Turn |
| | (D) | Subsonic Turn |
| | (E) | Specific Excess Power |
| | (F) | Take-off |
| | (G) | Stalling Speed |
| | (H) | Instantaneous Turn |

Solution: (F)