Introduction to Aircraft Design
July-2023

Assignment 6

Q 1	Which of the following categories of aircraft has the smallest Parasite Drag coeffcienct as per the equivalent skin friction method?	
MCQ (1 mark)	(A)	Propeller Seaplane
	(B)	General Aviation Single Engined Aircraft
	(C)	Military Cargo aircraft
	(D)	High speed aircraft
Solution: (D)		

Q 2	Which of the following is/are NOT component(s) of Subsonic Parasite Drag?	
MSQ (1 mark)	(A)	Skin Friction Drag
	(B)	Form Drag
	(C)	Wave Drag
	(D)	Induced Drag
Solution: (C), (D)		

Q 3	Read the following statements about Skin Friction Drag coefficient and choose the correct option: I. It depends on the freestream Reynolds Number. II. It is independent of freestream Mach Number. III. It is generally higher in Turbulent flow.	
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: (F)		

Q 4	During the estimation of Parasite Drag coefficient of a wing, the value of Form Factor (FF) depends on _____.	
MSQ (1 mark)	(A)	Freestream Reynolds Number
	(B)	Freestream Mach Number
	(C)	Chordwise location of maximum thickness
	(D)	Sweep of maximum thickness line
Solution: (B), (C), (D)		

Q 5	Which of the following statement(s) is/are TRUE about Interference Factor (Q)?	
MSQ (1 mark)	(A)	Its value is zero when the engines are mounted directly on the fuselage.
	(B)	Its value is unity for H-Tail configuration.
	(C)	Its value is 1.25 for wing tip mounted missiles.
	(D)	Its value is unity for a well filleted low wing.
Solution: (C), (D)		

Q 6	An aircraft wing is equipped with slotted flaps with flapped area of 35% of the wing reference area and 35% flapped chord length of the wing chord. It has been deployed at takeoff at an angle of 25 degrees. Calculate the value of additional Parastite Drag coefficient due to flap deflection. (Write your answer correct upto three decimal places)
NAT (1 mark)	Answer : 0.010 - 0.017
Solution: $F_{flap} = 0.0074,\ for\ slotted\ flaps$ $\Delta C_{Do,flap} = F_{flap}.\left(\frac{C_F}{C}\right).\left(\frac{S_F}{S}\right)\left(\delta_{flap} - 10\right)$ $\Delta C_{Do,flap} = 0.0074 * (0.35) * (0.35) * (25 - 10) = 0.013$	

Q 7	An airplane has wing reference area of 32 m^2, is cruising at 400 kmph at an altitude of 3 km AMSL under ISA conditions. The weight of this aircraft before Cruise is 5500 kg and it consumes 500 kg of fuel during Cruise. If the pilot maintains a constant lift coefficient, estimate the percentage change in the Cruise velocity of the aircraft. (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 4.00 - 5.00

Solution:

Density at 3 km AMSL under ISA = 0.9093 kg/m^3

Lift coefficient, $C_L = \frac{2W}{\rho V^2 S} = \frac{2*5500*9.81}{0.9093*111.11^2*32} = \frac{107910}{359222.4451} = 0.30039$

For maintaining the same lift coefficient, the new velocity will be:

$V = \sqrt{\frac{2W}{\rho S C_L}} = \sqrt{\frac{2*5000*9.81}{0.9093*32*0.30039}} = \sqrt{\frac{98100}{8.74062}} = 105.94\ m/s$

% Change in velocity; $= \frac{111.11-105.94}{111.11} * 100 = 4.65\ \%$

Q 8	Wing Aspect Ratio and Leading edge sweep of a subsonic military aircraft are 4 and 35 degrees, respectively. Estimate the Oswald's Efficiency Factor "e". (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 0.80 - 0.90

Solution:

$e = 4.61(1 - 0.045 * AR^{0.68})(Cos\,\Lambda_{LE})^{0.15} - 3.1$

$e = 4.61(1 - 0.045 * 4^{0.68})(Cos\,35)^{0.15} - 3.1$

$e = 0.85$

Q 9	A wing of an aircraft has quarter chord sweep of 35 degrees and the maximum thickness ratio is 5%. Calculate the Critical Mach Number. (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 0.83 - 0.86
Solution: Critical Mach Number for unswept wing: $M_{Unswept} = 1 - 0.065\left(100\frac{t_{max}}{C}\right)^{0.6} = 1 - 0.065(100 * 0.05)^{0.6} = 0.8292$ $M_{swept} = 1 - (Cos\,\Lambda_{c/4})^{0.6}(1 - M_{Unswept}) = 1 - (Cos\,35)^{0.6}(1 - 0.8292) = 0.84$	

Q 10	A low speed aircraft has wing Aspect Ratio of 10. Calculate the Span Efficiency Factor. (Write your answer correct upto two decimal places)
NAT (1 mark)	Answer : 0.51 - 0.55
Solution: $\Lambda_{tmax} = 30^0$ for a low speed aircraft $e = \frac{2}{2-AR+\sqrt{4+AR^2\left(1+tan\Lambda_{tmax}{}^2\right)}} = \frac{2}{2-10+\sqrt{4+10^2\left(1+tan30^2\right)}} = 0.53$	

Q 11	Which of the following parameter(s) affect(s) the Zero Lift Angle of Attack of an aircraft?	
MSQ (1 mark)	(A)	Airfoil Camber
	(B)	Twist distribution
	(C)	Wingspan
	(D)	Fuselage length
Solution: (A), (B)		

Q 12	Read the following statements and choose the correct option: I. Swept wings have higher value of Lift curve slope. II. Lower Aspect Ratio wings have lower value of Lift curve slope. III. Flow Reynolds Number and Surface Texture of the wing affects the value of maximum lift coeffcient.	
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 13-14	An airfoil cross section has lift curve slope of 6.5 per radians. A rectangular wing is constructed with this airfoil, having a span and chord of 5 m and 1m, respectively.
Q 13	Calculate the Lift curve slope of this wing. (Write your answer in per degrees and correct upto three decimal places)
NAT (1 mark)	Answer : 0.06 - 0.10

Solution:

Oswald's efficiency factor for a straight wing is given by:

$$e = 1.78(1 - 0.045 * AR^{0.68}) - 0.64 = 0.9$$

$$C_{L\alpha} = \frac{C_{l\alpha}}{1+\frac{C_{l\alpha}}{\pi e AR}} = \frac{6.5}{1+\frac{6.5}{\pi*0.9*5}} = 4.45\ per\ radians$$

$$C_{L\alpha} = 0.077\ per\ degrees$$

Q 14	If this wing is provided with a leading edge extension with surface area of 1 m^2. What will be the percentage change in the Lift curve slope of this wing with strakes. (Write your answer in per degrees and correct upto two decimal places)
NAT (1 mark)	Answer : 20

Solution:

$$C_{L\alpha(with\ strakes)} = C_{L\alpha(without\ strakes)} \frac{S_{strake}+S_{ref}}{S_{ref}} = 0.08\frac{1+5}{5} = 0.096\ per\ degrees$$

$$\%\ change = \frac{C_{L\alpha(with\ strakes)}-C_{L\alpha(without\ strakes)}}{C_{L\alpha(without\ strakes)}} * 100 = \frac{0.096-0.08}{0.08} * 100 = 20\%$$

Q 15	Which of the following statement(s) is/are TRUE about different types of Flaps?	
MSQ (1 mark)	(A)	$C_{L,max}$ increases by ~50% using Plain Flaps.
	(B)	$C_{L,max}$ decreases by ~40% using Split Flaps.
	(C)	$C_{L,max}$ increases by ~65% using Slotted Flaps.
	(D)	$C_{L,max}$ increases by ~90% using Fowler Flaps.
Solution: (A), (C), (D)		