Question Paper

Exam Date & Time: 31-Dec-2020 (02:00 PM - 05:00 PM)

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

FIFTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, DEC 2020 - JAN 2021

AIRCRAFT DESIGN [AAE 3155]

Marks: 50 **Duration: 180 min**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) Consider a high subsonic airplane with simple cruise mission with following specifications: (5)

A) V_{cruise} = 800 kmph, H = 11 km, $N_{passengers}$ = 130, Range = 5500 km, S = 94 m^2, A = 11, density at cruise = 0.414 kg/m^3, speed of sound at cruise= 295 m/s, quarter sweep angle = 44 deg,

W_0/W_1 = 0.98, W_2/W_1 = 0.98, W_5/W_4 = 0.98

C_D = 0:02686$S^{-0.1}$ + (1/πA) (1.0447 + 0.2078/cos^2 x quarter sweep angle) $C_L{}^2$

For empty weight consideration: values of A and C are 1.02 and -0.06 respectively and initial value of W_0 for guessing is 85000 kgf, if then calculate the followings:

- Obtain weights of payload and crew (consider 7 crews)
- Estimate of fuel fraction (consider head wind with 10m/s)
- Estimate empty weight fraction
- Solve take-off weight equation iteratively
- Mention fuel weight and empty weight in kgf
- If the number of passengers changes to 160 for the same aircraft then what will the new W_0?

B) Describe the internal structural members of the wing and explain their purposes and its classifications (3)

C) What is the purpose of cranked wing? (2)

2) Consider a high subsonic jet airplane with an initial estimate of gross weight 85000 kgf and wing loading of 7400 N/m2. (5)

A) Given parameters are: A=10, λ=0.32. quarter sweep angle=31, t/c of airfoil=0.14, diameter of fuselage=3.8m, S_{HT}/S=0.32, S_{VT}/S=0.28, S_{WET}/S=6.2, speed of sound at 11 km=295 m/s, density at 11 km=0.364 kg/m^3, M_{cr}=0.82, H_{cr}=11 km, R=4800 km, TSFC=0.78, (*Missing data, if any, may be suitably assumed*)

(□□□□)□=2∗□□□□□□□□□□□□□∗(1+0.2(□/□))
□□=0.02686·□$^{−0.1}$+1/□□(1−0.447+(0.2078/c□□^{2}Λ□/4))□□^{2}

- Calculate C_{fe} and drag polar in terms of constants F_1, F_2 and F_3
- Obtain wing loading under consideration of range
- Obtain wing loading with max rate of climb is 800 m/min

B) Describe the methods and procedures to determine a standard civil aviation passenger fuselage cabin layout dimensions. (3)

C) Distinguish between take off gross weight and operational empty weight of an aircraft. (2)

3) Calculate the diameter of propeller from the consideration of 40 seater twin turboprop airplane with following parameters: V_{cr}=450kmph, H_{cr}=4.5km, A=9, N=1300, wing loading=3100N/m2, S=52m2, assumed η=0.85, density at 4km=0.7768kg/m3, (5)

A)

$$C_D = 0.0335 \cdot s^{-0.1} + \frac{1.356}{\pi A} C_L{}^2$$

Choose appropriate values from the design chart:

C_S	β	J	η
2	30^0	1.4	0.81
2.3	35^0	1.6	0.84
2.5	40^0	1.75	0.84

B) Obtain the engine rating required for the aircraft under the consideration of V_{max} and rate of clime (R/C) with assumption of wing loading 4200N/m2. (3)

V_{max} = 610kmph, H = 4.5km, density= 0.8668kg/m^3, $(R/C)_{max}$ = 480m/min, W_0 = 24480kgf, η = 0.84,

C_D = 0.03234 + 0.38 $C_L{}^2$

Also determine which engine is best for this aircraft:

- first engine has 6% lower SFC but it 12% heavier
- second engine is 8% lower SFC but is 15% heavier
- third engine is 4% lower SFC but it is 10% heavier

Assume that the fuel fraction is 0.19 and the installed engine weight is almost 9% of gross weight of the aircraft.

Note: Missing data, if any, may be suitably assumed

C) What is decision speed and how it's influencing the runway length for the aircraft? (2)

4) Consider a turbo propeller airplane with followings parameters, W_0=21000kgf, wing loading=3000N/m2, V_{cr}=450kmph, H_{cr}=4.5km, leading edge sweep angle=16deg, density at 4.5km=0.777kg/m3, speed of sound at 4km=322.6m/s, A=12, λ=0.35, twist=ϵ=3 (5)

A)

$$C_{L\alpha} = \frac{2\pi A}{2+\sqrt{4+A^2(1-M^2)\left(1+\frac{\tan^2\Lambda_{c/2}}{(1-M^2)}\right)}}, \quad \overline{C_w} = \frac{2}{S_W}\int_0^{b/2} C^2\,dy,$$

- Calculate the design lift coefficient
- Design a simple tapered wing for this aircraft
- Calculate wing incident angle
- Draw the wing diagram with dimensions

B) Describe the effects of aspect ratio, taper ratio and sweep angle on tail designing of the aircraft? (3)

C) What are the aero dynamical and structural requirements in aircraft design? (2)

5) Consider a passenger twin turboprop engines airplane with following parameters: (7)

A) S_{wing}=60m^2, S_{HT}=13.6m^2 (T-tail), S_{VT}=14.6m^2, W_0=29000kgf, W_{empty}/W_0=0.56, W_{fuel}/W_0=0.16, $W_{payload+crew}$=8625kgf,(All dimensions all are in meters in Figure-1 & Figure-2 and all passengers are accommodated in fuselage mid-section only). Weight of 1 engine=450kgf, length of engine=2.15m, engine boss is 1.2m ahead of wing leading edge and centre of gravity location of engine=43% of its length and engines are placed on the wing. Landing gear (LG) wheel base=10.5m, W_{LG}/W_0=0.046

Approximate weight buildup:

Structures	Weight Factor	multiplier	C.G location
wing	49	$S_{exposed}$	40% of MAC
H.T & V.T	27	$S_{exposed}$	40% of MAC
Fuselage	24	S_{wetted}	43% of its length
Landing gear	0.045	W_0	
Installed Engine	1.3	Empty Weight	

Note: Missing data, if any, may be suitably assumed

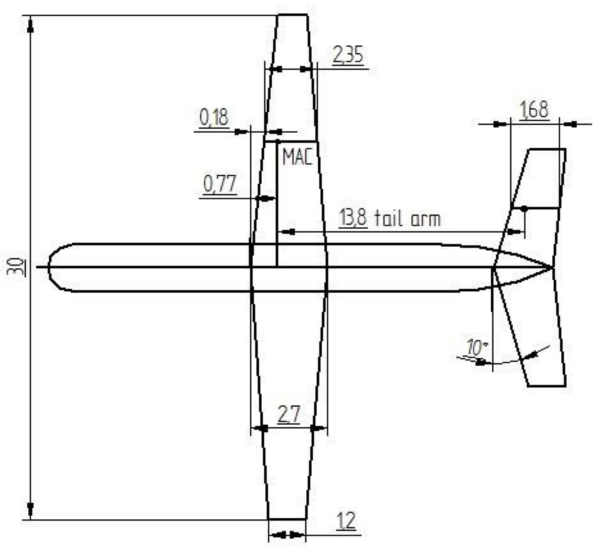
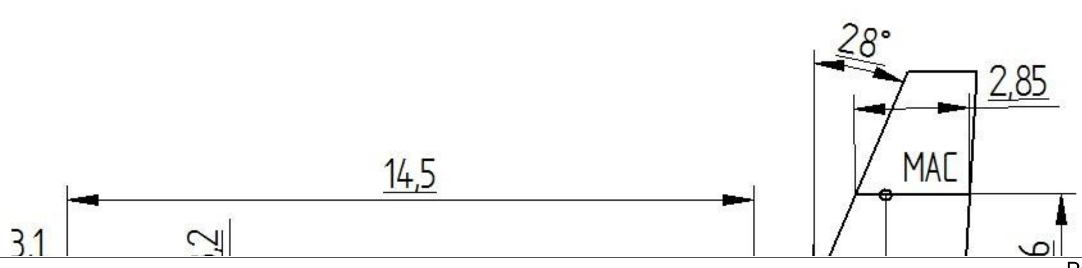


Figure - 1



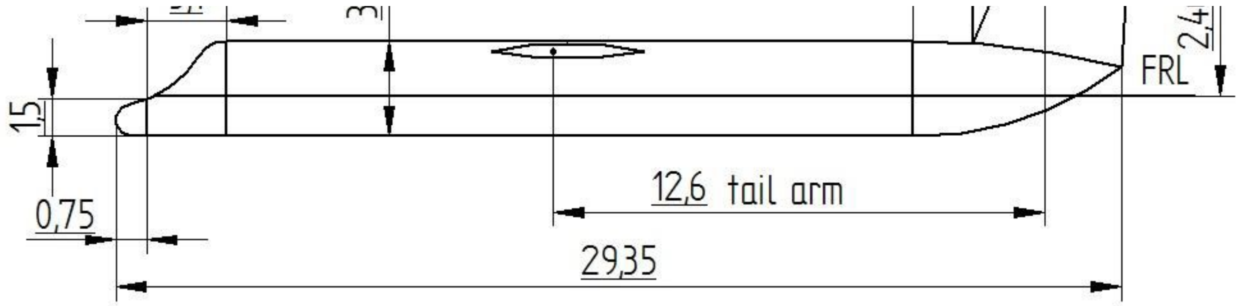


Figure - 2

- Calculate the weights and centre of gravity locations of each structures
- Find the centre of gravity location of the airplane from the nose section of fuselage under consideration of center of gravity is at 0.25% of wing MAC.

B) From previous question 5A (CG calculation) calculate the centre of gravity shift under the consideration of (3)

- Full payload but no fuel
- No payload and no fuel

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