MANIPAL INSTITUTE OF TECHNOLOGY
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**V SEMESTER B.TECH. (AERONAUTICAL/AUTOMOBILE ENGINEERING)**

**END SEMESTER EXAMINATIONS, NOV/DEC 2022**

SUBJECT: AIRCRAFT DESIGN [AAE -3155]

**REVISED CREDIT SYSTEM**

**(XX/11/2022)**

Time: 3 Hours MAX. MARKS: 50

**Instructions to Candidates:**

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

| Q No | Question | Marks | CO attained | BT level |
|---|---|---|---|---|
| **1A** | Evaluate the internal structural members of the wing and explain its main purposes also classify the wing under internal structural members. | **5** | **CO4** | **3** |
| **1B** | Describe the followings:<br>a) Balanced Field Length<br>b) Design Take-off Weight<br>c) Advanced Ratio<br>d) Wide Body Configuration<br>e) Differentiate between H-Tail and V-Tail | **5** | **CO4** | **2** |
| **2A** | Consider a twin turboprop passenger airplane carrying 40 passengers on board with cruise velocity of 420km/hr at altitude of 4km. Aspect ratio=9, S=52m$^2$, range=900km, Alternate airport is 250km away from destination, consider 4 crews in airplane.<br>$\eta_{cruise} = 0.85, \eta_{loiter} = 0.75, BSFC_{cruise} = \frac{2.7N}{kw.hr}, BSFC_{loiter} = \frac{2.85N}{kw.hr}$,<br>$\frac{W_{warmup+taxiing+take-off}}{W_{take\ off\ weight}} = 0.98, \frac{W_{climb}}{W_{warmup+taxiing+takeoff}} = 0.99$,<br>$\frac{W_{landing+taxiing}}{W_{descent}} = 0.98$, $C_D = 0.03354 \cdot s^{-0.1} + \frac{1.356}{\pi A} C_L{}^2$<br>i) Calculate fuel fraction for cruise (consider forward gust with 12m/s) and loiter<br>ii) Calculate empty weight ratio(constant values A=0.92, c=-0.05)<br>iii) Calculate take-off weight (guess $W_0$=15000kgf and number of crew=4), fuel weight and empty weight through iterative process (maximum 3 iterations) | **5** | **CO3** | **3** |
| **2B** | 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 4000N/m$^2$, $V_{max}$ = 600kmph, H = 4.5km, density= 0.8668kg/m$^3$, $(R/C)_{max}$ = 450m/min, $W_0$ = 23480kgf, $\eta$ = 0.85, $C_D = 0.03234 + 0.38\ CL^2$<br>Also determine which engine is best for this aircraft:<br>i) first engine has 6% lower SFC but it 11% heavier<br>ii) second engine is 7% lower SFC but is 14% heavier | **5** | **CO1** | **3** |

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|---|---|---|---|---|
| | iii) third engine is 5% lower SFC but it is 8% heavier | | | |
| **3A** | Consider subsonic jet airplane with the following parameters and design the wing under consideration of a) airfoil selection, b) aspect ratio, c) sweep angle, d) taper ratio, e) twist, f) incident angle, g) consider at trailing edge 30% cranked wing ($\Lambda_{TE}$=25deg). Draw the wing diagram with full specifications.<br><br>Given parameters are : $W_0$=99000kgf, p=6500N/m$^2$, $V_{cr}$=850km/h, A=12, $\lambda$=0.26 $\Lambda_{c/4}$=31.5deg, $\Lambda_0$=39deg, $\rho_{11}$=0.414kg/m$^3$, speed of sound at altitude=295m/s, initial twist angle= -3deg, | **5** | **CO2** | **5** |
| **3B** | Consider a turbo propeller passenger aircraft with following parameters and calculate the engine rating required at Rate of climb with minimum power and maximum velocity at altitude.<br>W/S=3500N/m$^2$, $V_{MAX}$=500km/h, $\rho_{cruise}$=0.7768kg/m$^3$, $(R/c)_{climb}$=485m/min, $\eta$=0.83, $W_0$=19500kgf, (thrust at cruise / thrust at sea level)=0.72, $C_D$=0.02224+0.038 $C_L^2$. | **3** | **CO1** | **3** |
| **3C** | How to determine the fuselage cabin width? Also explain how this width influencing the overall diameter of the fuselage. | **2** | **CO4** | **3** |
| **4A** | Consider twin-engine subsonic jet airplane with an initial estimate of gross weight 72000kgf and wing loading of 6200N/m$^2$. Given parameters are: A=11, $\lambda$=0.33. $\Lambda_{c/4}$=31$^0$, thickness of airfoil=0.16, diameter of fuselage=4m, $S_{HT}/S$=0.33, $S_{VT}/S$=0.25, $S_{WET}/S$=6,<br>$(S_{wet})_{wing} = 2 * S_{exposedwing} * (1 + 0.2\left(\frac{t}{c}\right))$,<br>$C_D = 0.02686 \cdot s^{-0.1} + \frac{1}{\pi A}\left(1 - 0.447 + \frac{0.2078}{\cos^2 \Lambda_{\frac{c}{4}}}\right) C_L{}^2$<br>i) Calculate drag polar in terms of constants $F_1$, $F_2$ and $F_3$<br>ii) Obtain wing loading under consideration of absolute ceiling | **5** | **CO2** | **3** |
| **4B** | Write down methods and procedure to obtain the diameter of the propeller | **3** | **CO1** | **2** |
| **4C** | Briefly explain the aircraft design process | **2** | **CO2** | **2** |

| | | | | |
|---|---|---|---|---|
| **5A** | Consider a passenger twin turboprop engines airplane with following parameters: $S_{wing}=65m^2$, $S_{HT}=13.7m^2$ (T-tail), $S_{VT}=15.2m^2$, $W_0=30000kgf$, $W_{empty}/W_0=0.56$, $W_{fuel}/W_0=0.16$, $W_{payload+crew}=8525kgf$,(In diagram (Figures 1&2) all dimensions all are in meters and all passengers are accommodated in fuselage mid-section)<br><br>Weight of 1 engine=430kgf, length of engine=2.1m, engine boss is 1.2m ahead of wing LE and C.G location of engine=44% of its length and engines are placed on the wing. | **10** | **CO3** | **4** |

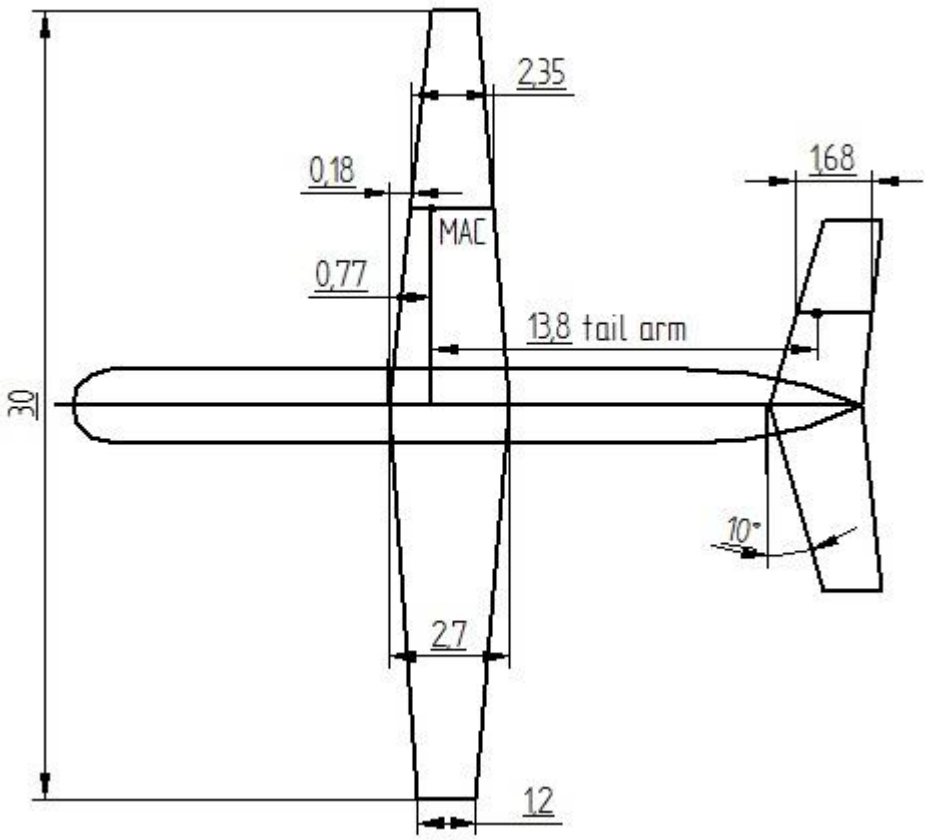


Figure – 1 Top View

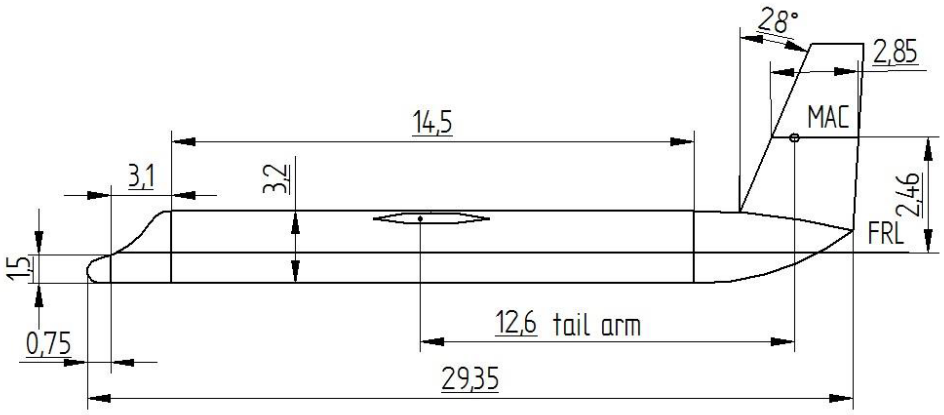


Figure – 2 Side View

Landing gear(LG) wheel base=10.15m, WLG/W0=0.045

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 | $S_{wetted}$ | 45% of its length |
| Landing gear | 0.097 | $W_0$ | |
| Installed Engine | 1.3 | Empty Weight | |

1) Calculate the weights and center of gravity locations of each structures
2) Find the center 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.