AAE 2256 Flight Mechanics
Overall Scope of Group Projects*
(21 Feb to 30 Apr 2023)

1. Draw drag polar of given aircraft for 3 aircraft weights ($0.95W_{TO}$, $0.85W_{TO}$ & $0.65W_{TO}$/ $0.9W_{TO}$, $0.8W_{TO}$ & $0.6W_{TO}$) at 6 altitudes (SL, 2.5, 5, 7.5, 10 & 11km/0.5, 3, 5.5, 8.5,10.5 & 11.5 km). On this draw stall boundary (V_{stall}) and M_{crit} boundary. Show also minimum drag value (D_{min}) and flight speed at which minimum drag (V_{Dmin}) occurs at various altitudes. Comment on the significance of stall boundary and M_{crit} boundary on drag polar.
   Draw a) 3 sets of drag polar (at 6 altitudes on one graph) for 3 weight conditions bringing out effect of altitude and b) 6 sets of drag polar (for 3 weights on one graph) bringing out effect of aircraft weight. **(Due by 21 Feb 2023)**

2. Draw level flight envelope (h vs V) defined by V_1 and V_2 boundaries for a specified combinations of aircraft weight and throttle setting. On these flight envelopes, identify the absolute ceiling and compare the same with the value obtained by using $D_{min} = T_{SL}\sigma$ condition and $h = 44300(1 - \sigma^{0.234})$. Also include V_{stall}, M_{crit} and q_{max} boundaries on these envelopes. Draw these flight envelopes and (M_{crit} & q_{max}) boundaries a) for 3 aircraft weights ($0.95W_{TO}$, $0.85W_{TO}$ & $0.65W_{TO}$/ $0.9W_{TO}$, $0.8W_{TO}$ & $0.6W_{TO}$) & 100% Throttle setting and b) for aircraft weight $0.95W_{TO}$/$0.9W_{TO}$ and 3 Throttle settings (75%, 87.5% and 100%/70%, 82.5% and 95%).
   Comment on dependence of flight envelope and absolute ceiling on weight and engine throttle setting. Draw suitable plots - Absolute ceiling Vs aircraft weight with throttle setting as parameter to support your comments. **(Due by 28 Feb 2023)**

3. Draw climb performance curves (R/C vs V) at 6 altitudes (SL, 2.5, 5, 7.5, 10 & 11km/0.5, 3, 5.5, 8.5,10.5 & 11.5 km) for 2 aircraft weights ($0.95W_{TO}$ & $0.85W_{TO}$/ $0.9W_{TO}$ & $0.8W_{TO}$) and one Throttle setting of 100%. Show also stall boundary and M_{crit} boundary on these climb performance plots.
   Draw curve joining $(R/C)_{max}$ points at various altitudes on these plots and give your recommendation on flight speed for optimum climb performance to be adopted throughout the climb from sea level/0.5 km to 11 km/11.5 km and justify your choice. Plot h vs $(R/C)_{max}$ curve for 2 aircraft weights ($0.95W_{TO}$ & $0.85W_{TO}$/ $0.9W_{TO}$ & $0.8W_{TO}$) and 100% throttle setting. Show on this plot absolute ceiling and service ceiling. Using approximate linear fit for h vs $(R/C)_{max}$ (or tabulated data), calculate aircraft climb time from SL to 11 km/11.5 km altitude
   For $W = 0.95W_{TO}$/$0.9W_{TO}$ and 100% throttle setting obtain time and fuel to climb from sea level to 11 km/11.5 km altitude following tabular column method considering variation of thrust, aircraft weight, TSFC with altitude. Give suitable plots showing variation of aircraft weight and altitude with time**.** Compare the time to climb following optimum climb speed and considering variation of aircraft weight etc with altitude. **(Due by 14 March 2023)**

Data for 10 aircraft *have been provided* ***in Annexure 1,*** *to carry out performance estimation. Each aircraft will be assigned to 2 groups of 4 to 3 members each. Two combinations of weight / altitude / throttle setting are specified for one aircraft (in two colours -* ***black*** *&* ***red****). Individual Group Presentation/Discussion Q&A will be scheduled after submission of final report).*

4. Draw level turn performance curves n vs V (not V - n diagram!), for given Propulsive (Thrust available), Aerodynamic (C_{Lmax}) and Structural (n=2.5g) boundaries for 2 aircraft weights ($0.95W_{TO}$ & $0.85W_{TO}$/ $0.9W_{TO}$ & $0.8W_{TO}$), two altitudes of SL & 4 km/0.5 & 5 km and one Throttle setting of 100%. Show on these plots, maximum load factor possible from propulsive boundary for level turn, level turn rate attainable, aircraft corner velocity and comment on its (V_{corner}) dependency on aircraft weight and feasibility of sustaining level turn at the corner velocity. **(Due by 28 March 2023)**

5. Obtain take off distance (at SL/0.5 km altitude) following step by step integration approach for ground acceleration distance, adding distances for 3 sec rotation and climb segment clearing 10.7 m high obstacle, for 2 aircraft take off weights (W_{TO} & $0.85W_{TO}$/ $0.9W_{TO}$ & $0.8W_{TO}$) and one throttle setting 100%/100%.

   For the multi-engine aircraft, estimate take off distance required (TODR) and accelerate – stop distance required (ASDR) following an engine failure (OEI) at different phases of take ground run, with speeds ranging from 0.65 V_R to V_R. (choose 8 - 9 speeds at approximately $0.05V_R$ interval). For ASDR estimation, assume a response time of 3 seconds for cutting off working engine/s by the pilot and initiate application of brakes giving average deceleration of 0.25g. Using the plots of TODR and ASDR (Vs ground speed V), for OEI case, obtain Balanced Field Length (BFL) and decision speed V_1 (engine failure speed) for W_{TO}/$0.9W_{TO}$ at two altitudes (SL & 1 km/ 0.5 & 1.5 km). Following FAR obtain the take off distance for the aircraft for the one aircraft weight (W_{TO}/$0.9W_{TO}$) and 2 altitude cases (SL & 1 km/ 0.5 & 1.5 km).

   Also obtain landing distance following modified Pamadi's approach including distance for 3 sec de-rotation and final ground deceleration run distance limiting average deceleration levels at 0.25g, for 2 aircraft weights ($0.85W_{TO}$ & $0.65W_{TO}$/$0.8W_{TO}$ & $0.6W_{TO}$). **(Due by 15 April 2023)**

6. Draw Pay Load vs Range Trade off Diagram for your aircraft making the following assumptions: i) max take off weight is determined for the case with given empty weight, 100%/95% pay load and 100%/95% fuel onboard. ii) aircraft utilises some fuel to reach cruise altitude and needs some fuel to return and land. Fuel available at the beginning and end of the cruise segment may be assumed to be 0.95 and 0.07 respectively of initial fuel onboard iii) aircraft fuel tank has extra capacity to hold a total of 130% of normally loaded fuel for the mission. This extra fuel can be filled for special missions requiring longer range by reducing pay load onboard such that max take off weight does not exceed. A separate hand out provided describing Pay Load Vs Range Trade off Studies may be used and the questions raised there are to be addressed based on the studies carried out. **(Due by 30 April 2023)**

<u>Annexure 1</u>

11 Aircraft Data for 22 Groups**

A320, A300-600ER, A340-600, A380-600, E195B, 747-400ER, B777-300ER, B737-900ER, B787-10, B767-400ER and CRJ 1000

1. **Group Projects 01 and 02: Aircraft Data A320 M**
2. **Group Projects 03 and 04: Aircraft Data A300-600ERM**
3. **Group Projects 05 and 06: Aircraft Data A340-600M**
4. **Group Projects 07 and 08: Aircraft Data A380-800M**
5. **Group Projects 09 and 10: Aircraft Data E 195M (Embraer)**
6. **Group Projects 11 and 12: Aircraft Data B747 – 400ERM**
7. **Group Projects 13 and 14: Aircraft Data B777 – 300ERM**
8. **Group Projects 15 and 16: Aircraft Data B737 – 900ERM**
9. **Group Projects 17 and 18: Aircraft Data B787 – 10M**
10. **Group Projects 19 and 20: Aircraft Data B767 – 400ERM**
11. **Group Projects 21 and 22: Aircraft Data CRJ 1000M**

**** Group1 of 3 students (Roll Nos 1, 2 & 4), Groups 2 to 17 each of 4 students (Roll Nos 5 to 68), Groups 18 and 19 each of 3 students (Roll Nos 69 to 74) and Groups 20 - 22 each of 4 students (12 Re-Registered Students) have been formed assigning aircraft data 1 to 11.**

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Group Projects 07 and 08: Aircraft Data A380-800M

Take off weight W_{TO}= 6695 kN
W_{Empty} = 2725 kN
$W_{PayLoad}$ = 1480 kN
W_{Fuel} = 2490 kN
Thrust per Engine T = 350 σ kN (σ is density ratio at altitude h)
No of Engines:4
TSFC = 47.5$\sqrt{\theta}$ kg/hr/kN (θ is temperature ratio at altitude h)
Wing area S = 845 m^2
Wing aspect ratio AR = 7.53
Oswald's Efficiency factor e = 0.965
M_{crit} = 0.895
Maximum permissible dynamic head (Aeroelastic limit) = 55 kN/m^2
Parasite drag coefficient C_{D0} = 0.011
Aircraft C_{Lmax} without HLD (plain wing) C_{Lmax} = 1.15
ΔC_{Lmax} from full HLD for landing = 1.85
ΔC_{Lmax} from partial HLD for take off = 1.15
C_{Lmax} for climb segment of take off = 0.9 C_{LmaxTO}
$\Delta C_{D0Land\ Gear}$ =0.0042 & ΔC_{D0Flap} = 0.0034 for take off ground run and climb segments
$C_{LGround\ Run}$ = 0.12
Rolling friction coefficient μ = 0.02
Load factor n_{max}= 2.5.

Actual Aircraft Data
Seats: 3 Class 575 and 1 Class 853
Range: 14800 km;
Take off distance: 3000 m
A380 – 800 pay load and take off weight modified. Other data set built based on data available for similar aircraft/engines