Type: DES

Q1. Consider an aircraft with the following data: W = 5461 kg; S = 29.17 m^2; b = 12.49 m; maximum velocity at an altitude of 6 km = 190 m/s. At these conditions, the total drag coefficient is 0.00757. Calculate the profile drag coefficient for the wing. Assume that e = 0.9. (2)

Q2. Find out total drag of an airplane flying level at a speed of 320 kmph for which the total drag coefficient is given as $C_D = 0.0293 + 0.0398C_L^2$. Also given that the wing area is 12.5 m^2 and the mass of the airplane is 2000 kg.

Drag at any given speed,

$$D = \frac{1}{2} D_{min} \left[\left(\frac{V}{V_{D,min}} \right)^2 + \left(\frac{V_{D,min}}{V} \right)^2 \right] \quad (3)$$

Q3. Describe how drag must vary with airspeed to ensure that aircraft is statically stable with respect to the velocity. Indicate the stability status of the two reference flight conditions – thrust limited maximum airspeed and thrust limited minimum airspeed. Assume that the thrust is independent of airspeed. (5)

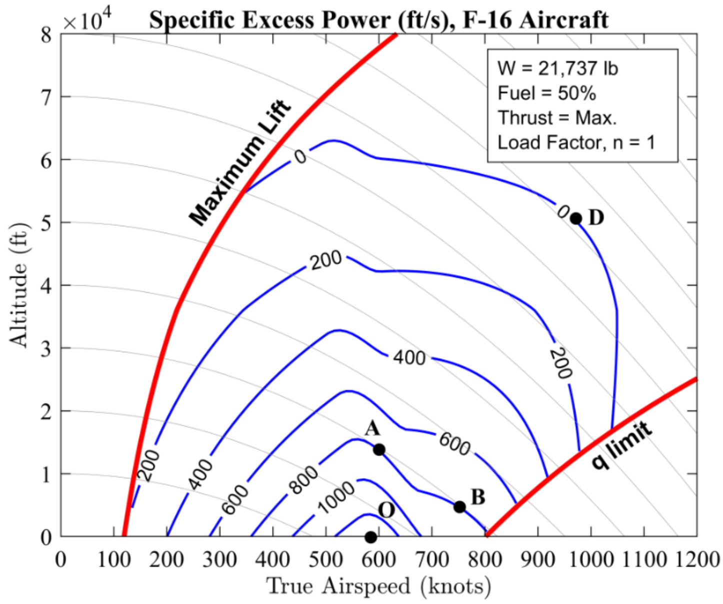
Q4. Draw the hodograph for unpowered flight in sink rate condition? (2)

Q5. An aircraft is performing a climbing flight at a true airspeed of 100 [m/s] and a climb rate of 20 [m/s]. The aircraft experiences a horizontal headwind of 15 [m/s]. Draw a clear free body diagram visualizing all forces and accelerations that act on the aircraft for this particular flight condition and calculate the ground speed of this aircraft. (3)

Q6. For F-16 aircraft whose specific excess power (P_s) diagram is depicted in the Figure 1. The aircraft parameters are: W = 96727 N; S = 27.87 m^2; Thrust at sea-level = 102109 N; maximum lift coefficient = 1.5; maximum dynamic load = 104043.24 N/m^2.

a. Demonstrate through calculations that the aircraft at Point **A** and Point **B**, as depicted in the figure, possess same energy height.
b. What is the aircraft's maximum 1-g level-flight (L = nW, where n = 1, i.e. 1-g) speed and at what altitude does it occur?
c. What is the aircraft's maximum zoom altitude?
d. What is the aircraft's best rate of climb at sea level, and at what velocity does it occur?
e. What is the aircraft's minimum level flight speed at sea level? What causes this limit?
f. What is the aircraft's maximum level flight speed at sea level? What causes this limit?
g. Draw the fastest path (trajectory of minimum time to climb) from point O to point D on this picture? And explain why is it the fastest?

Figure 1 P_s Contours



(5)

Q7. Define service and absolute ceiling? (2)

Q8. Estimate the maximum range for a constant altitude flight schedule at 9144 m and also the flight speed to achieve this range for the Gulfstream airplane when its maximum usable fuel is 131.42 kN and the TSFC of each engine (turbofan) at 9144 m is 0.69 N of fuel consumed per hour per N of thrust. The density at the given altitude is 0.458 kg/m^3. Airplane parameters: W = 325.22 kN; S = 88.26 m^2; AR = 5.92; $C_{D_0} = 0.015$; k = 0.08.

Range for constant altitude and constant angle of attack,

$$R = \frac{2}{c_t}\sqrt{\frac{2}{\rho S}}\frac{C_L^{1/2}}{C_D}\left(\sqrt{W_0} - \sqrt{W_1}\right) \text{ (3)}$$

Q9. A large transport aircraft with four engines is performing a cruise flight at 11 km altitude. At the start of the cruise flight, the following data are available for this aircraft: Aircraft weight (W_{start}) = 3500 kN; Fuel weight = 1340 kN; Wing surface area (S) = 520 m^2; Oswald efficiency factor (e) = 0.85; Zero-lift drag coefficient (C_{D_0}) = 0.018; True airspeed = 936 kmph (260 m/s); Air density at 11 km = 0.3648 kg/m^3; Temperature at 11 km altitude = 216.7 K; TSFC = 0.65 N/N/hr; Gas constant (R) = 287 m^2/s^{2}K. Calculate the minimum aspect ratio (AR) that will allow this aircraft to fly a distance (range) of 10000 km in the cruise phase with the amount of fuel given. calculate the required span of this aircraft and the Mach number at the start and end of the cruise flight. (5)

Q10. A transport aircraft weighing 40823 kg requires a take-off runway length of 1920 m. If the total thrust exerted by the engine is 4355 kg and average resistance to motion (drag + friction force) is 907 kg, calculate the take-off speed. (2)

Q11. Draw a clear Free Body Diagram (FBD) and Kinetic Diagram (KD) visualizing all forces and accelerations and also derive the equations of motion using the FBD and KD for the aircraft during the gliding phase. Clearly indicate all assumptions and draw the airspeed vector, all relevant angles, forces and accelerations in the two diagrams. The thrust vector can be assumed to act in the same direction as the airspeed vector. (3)

Q12. Using the Gulf Stream aircraft data set on mass, drag polar and wing geometry (Mass = 33152 kg, Drag Polar $C_D = 0.015 + 0.08\ C_L^2$, Wing Area S = 88.3 m^2 and AR = 5.92), determine its sink rate (rate of descent) for (a) maximum range flight with minimum glide path angle and (b) maximum endurance flight with minimum R/D, if both the engines of the aircraft fail at an altitude of 10km altitude. Density at 10 km altitude is 0.4127. (5)

Q13. The stalling speed of an aircraft in level flight is 70 kmph. Calculate the stalling speed when the aircraft executes a correctly banked turn, given that the angle of bank is 45°. (2)

Q14. An aircraft is flying at Mach 0.8 at 5000 m altitude (T = 255.65 K; ρ = 0.7361 kg/m^3). Calculate the energy height of this aircraft. Air traffic control asks the aircraft to maintain airspeed and to perform a rate one turn (180 deg./min). Calculate the corresponding turn radius and bank angle. (3)

Q15. An airplane is flying straight and level at a speed of 75 m/s at sea-level. It weighs 250000 N and requires thrust of 18000 N at an altitude of 4500 m (σ = 0.634). The aircraft engine produces a total thrust of 5 MW. Calculate the minimum radius of the horizontal banked turn that the airplane can make at that altitude. Assume that angle of incidence is same for both the cases of steady level flight at sea-level and horizontal turn at the given altitude. Also, estimate the time taken to turn through 180°. (5)