Reg. No.									

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

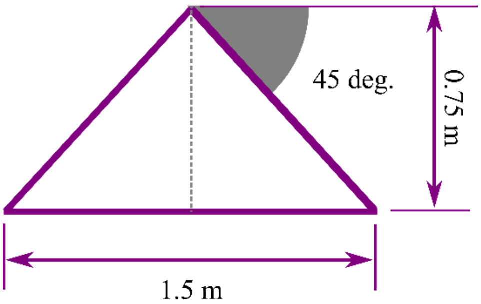
IV SEMESTER B.TECH. (AERONAUTICAL)
END SEMESTER EXAMINATIONS, APRIL/MAY 2024
AIRCRAFT PERFORMANCE [AAE 2224]
REVISED CREDIT SYSTEM

Time: 3 Hours | **Date: 05 May 2024** | **Max. Marks: 50**

Instructions to Candidates:

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

Q.NO	Questions	*Marks*	CO	BTL
1A.	The design lift coefficient required to trim the following wing at 3° is estimated as 0.334. Assume zero-lift angle of attack is -2° and e = 0.75. Find the following for an airfoil: lift coefficient at $\alpha = 0°$, zero-lift angle of attack (**assume that it is same as the wing**) and lift curve slope of the airfoil.	***(03)***	CO2	L03



Q.NO	Questions	*Marks*	CO	BTL
1B.	An aircraft flying at 610 m pressure altitude (P = 46602 N/m^2) has an indicated airspeed of 105.46 m/s. If the outside air temperature is 244.26 K, position error is -2.6 m/s, and there is a 20.6 m/s headwind, what is the aircraft's groundspeed? The calibrated airspeed correction factor (f) is given as 0.987.	***(03)***	CO1	L04
1C.	Obtain minimum power required for an airplane with W = 325200 N at 9000 m altitude (ρ = 0.4663 kg/m^3) and the corresponding level flight speed. Airplane data: Airplane data: Wing area (S) = 88.3 m^2; Aspect Ratio (AR) = 5.92; Maximum lift-coefficient (without flap), $C_{L_{max}}$ = 1.1; Drag polar = $0.015 + 0.08C_L^2$.	***(04)***	CO2	L04
2A.	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.	***(02)***	CO3	L04
2B.	An aircraft carries out a quasi-rectilinear symmetrical climbing flight at constant EAS in the troposphere of the ISA. Calculate at flight altitude H = 10 km the ratio between the actual rate of climb in the unsteady climbing flight and the rate of climb in the steady climbing flight at an instantaneous Mach number of M = 0.8 (attention M is not constant).	***(03)***	CO3	L04

$$1+\frac{V}{g}\frac{dV}{dh}=1+\frac{M^2\gamma}{2}\left[\frac{R}{g}\frac{dT}{dh}+1\right]$$

2C. For clearing obstruction in a confined aerodrome an airplane has to take an angle of climb 12°. The aerodrome is situated at an altitude where the relative density is 0.81. The airplane having a weight of 30000 kg and is designed to climb at 10° at sea-level. Taking power available and L/D ratio (L/D = 15) to be the same in both the cases, Calculate the maximum weight to which it should be loaded at that altitude for a climbing flight. ***(05)*** **CO3** **L04**

3A. Draw a free body diagram (FBD) and kinetic diagram (KD) visualizing all forces and accelerations that act on the aircraft for at least two views when it is flying a steady, horizontal and coordinated turn. These diagrams should contain all relevant forces and accelerations. ***(02)*** **CO3** **L03**

3B. Consider an airplane with the following data: W = 6000 N; S = 40 m^2; completes a vertical loop at 222 m/s constant speed with height range from top to bottom of a loop of 3000 m. Calculate the load factors at any three points at the end of vertical and horizontal diameter of the loop. Also, sketch a vertical loop and illustrate the forces acting on the aircraft at the end of vertical and horizontal diameter of the loop. ***(03)*** **CO3** **L04**

3C. Consider an aircraft with the following data: altitude = 7 km (ρ = 0.59 kg/m^3); T_{max} = 8670 N; zero-lift drag coefficient = 0.021; AR*e = 7; W = 60000 N; S = 30 m^2; $C_{L_{max}}$ = 1.2. Calculate maximum load factor and the corresponding airspeed. Also, find the radius of tightest turn and the corresponding airspeed. ***(05)*** **CO3** **L04**

$$n_{max}=\frac{T_{max}}{W}\left(\frac{C_L}{C_D}\right)_{max}$$

$$T=D=\left(C_{D_0}+kC_{L,max}^2\right)qS\Rightarrow q=\left(\frac{1}{S}\right)\frac{T_{max}}{\left(C_{D_0}+kC_{L,max}^2\right)}$$

4A. How to maximize the range and endurance of an aircraft at constant angle of attack flight schedule? ***(02)*** **CO3** **L03**

4B. Considering an aircraft with the following specifications: Maximum ramp weight: 216,817 kg; Maximum takeoff weight: 215,910 kg; Maximum landing weight: 165,561 kg; Maximum zero fuel weight: 154,222 kg; Operating empty weight: 108,500 kg; Number of passengers: 224; Weight per passenger: 95.25 kg; Maximum fuel capacity: 124,692 liters (density = 0.7911 kilograms per liter). The mission profile for this aircraft includes: Takeoff from sea-level; Climb to 11,278 meters to cruise a distance of 5,041 kilometers at Mach 0.85; Climb again to 12,497 meters altitude to cruise a distance of 9,714 kilometers at Mach 0.85; Descent to a holding altitude of 1,524 meters; Loiter for 30 minutes; Divert 370.4 miles to a diversion altitude of 6,741.3 meters at Mach 0.535; Approach and landing at sea-level. Reserve Fuel Fraction (RFF) = 5%. ***(05)*** **CO3** **L04**

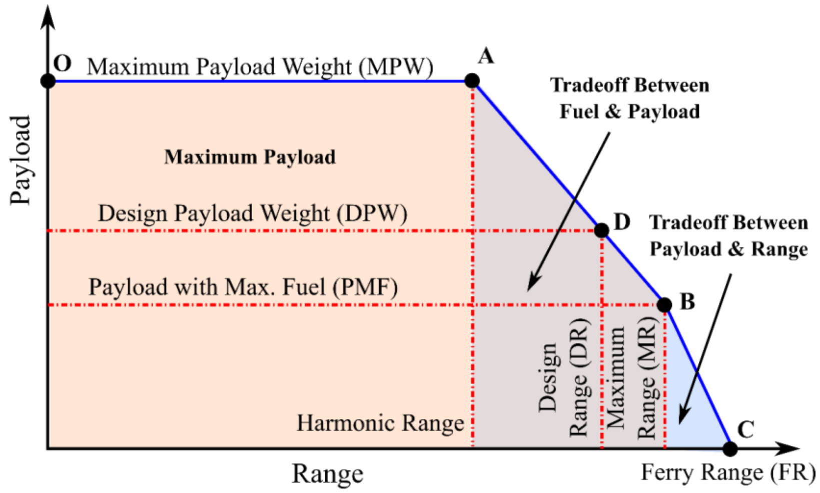


Figure 4A. Payload-range diagram

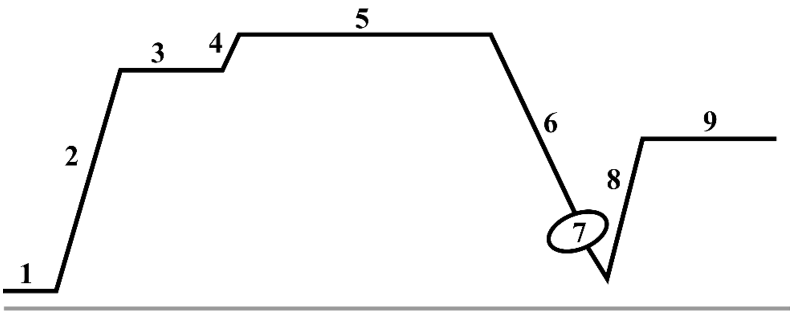


Figure 4B. Mission Profile

Segment	Time (min.)	Distance (nm)	Fuel (kg)
Warmup and Taxiing	10	0	907.2
Takeoff	1	0	208
Climb	27	176	4261
First Cruise	335	2722	28019.31
Step Climb	7	56	674.5
Second Cruise	645	5245	44601.3
Descent	21	129	198
Approach	2	0	149
Landing & Taxi-in	1	0	62.2
Total	**1050**	**8328**	**78174.3**
Diversion	39	200	2286
Holding	30	NA	1642

Formulate the payload weight, take-off weight, fuel weight, cruise fuel weight, cruise range and total range at point O, A, B, C, and D.

4C. Using the above data, find the value of the payload weight and range at the points **A**, **B**, and **D** shown in Figure 4A. ***(03)*** **CO4** **L04**

5A. The following data are given for a Boeing 747: Takeoff weight (W) = 3260 kN; Wing surface area (S) = 510 m^2; Zero-lift drag coefficient (C_{D_0}) = 0.036 (take-off configuration); Aspect Ratio (AR) = 6.7; Oswald efficiency factor (e) = 0.7; Maximum lift coefficient ($C_{L_{max}}$) = 1.8; Lift coefficient during ground run (C_{L_g}) = 0.7; Lift-off speed (V_{LO}) = 1.2*V_{stall}; Maximum thrust for one engine (T) = 165 kN; Number of engines = 4; Altitude = Sea-level condition. The take-off consists of a ground run and an airborne phase. This ***(03)*** **CO5** **L03**

aircraft requires 2500 m runway for the ground run. The thrust of the engines can be assumed independent of airspeed.

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 airborne phase of the take-off. 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.

5B. In case of the aborted take-off, calculate the ground run distance from the moment the engine fails until stand still. Full braking power is applied immediately and engine thrust is reduced to zero. The ground friction coefficient when braking (μ_{brake}) equals 0.4. It can be assumed that the mean deceleration occurs when the airspeed equals $\left(V_{LO}/\sqrt{2}\right)$.

(03) **CO5** **L04**

$$S_G = \frac{-1.44\left(\frac{W}{S}\right)}{\rho g C_{L_{max}}\left[\frac{\bar{T}}{W} - \frac{\bar{D}}{W} - \mu\left(1 - \frac{\bar{L}}{W}\right)\right]_{0.7V_{TO}}}$$

5C. Calculate the airborne distance from take-off to screen height (10.7 m). At screen height, the airspeed equals $1.3{*}V_{stall}$.

(04) **CO5** **L04**

$$S_A = \frac{\left(\frac{V_{SCR}^2 - V_{LO}^2}{2g}\right) + H_{SCR}}{\left(\frac{\bar{T} - \bar{D}}{W}\right)}$$