UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2022

Module Number: ME7217 **Module Name: Aerospace Engineering**

[Three Hours]

[Answer **all questions**, each question carries twelve marks]

NOTE:
A data and formulae are given in page 4 and 5.
Use carefully labeled sketches to support your answers where necessary.
You may make additional assumptions, but clearly state them in your answers.

Q1. a) What is the value of lift coefficient of the airfoil NACA 23412 ?
For the same airfoil, express the location of camber and the maximum thickness as a percentage of chord length c.

[2.0 Marks]

b) What are the control surfaces used by a pilot during the landing phase of an aircraft? Describe your answer.

[5.0 Marks]

c) Explain how the lift coefficient & the drag coefficient of an airfoil could be estimated through a wind-tunnel test.

[5.0 Marks]

Q2. a) How can the flying speed and flying altitude be determined in an aircraft?

[1.0 Mark]

b) Differentiate between the absolute altitude and geometric altitude. With usual notations derive an expression for pressure variation with in the first sub layer of the stratosphere of the International Standard Atmosphere (ISA).

[5.5 Marks]

c) An aircraft cruising at 19.5 km in ISA, gives a pitot pressure reading of 0.8502 bar. Estimate the flying Mach number and the cruising speed of the aircraft.

[5.5 Marks]

Q3. a) Consider a small aircraft that flies proximity to a larger aircraft. Discuss possible adverse effects encountered by the small aircraft, due to the tip vortices generated from the large aircraft.

[2.0 Marks]

b) Describe stalling patterns of finite wings having rectangular, tapered & elliptic wings respectively.

[3.0 Marks]

c) The wings of a medium sized aircraft are made of NACA 2412 airfoil section. The tapered planform wings have a total span of 20 m; while the root chord length and the tip chord length of a single wing are 3.6 m and 1.2 m respectively. The aircraft having 4500 kg of gross weight cruises at an altitude of 10.3 km with a constant speed of 450 km/h. At the flying altitude density of air is 0.398 kgm^{-3}.

The lift coefficient and the drag coefficient variations for the NACA 2412 as a function of AoA are presented in Table 3.1. Further the induced drag factor as a function of taper ratio and the aspect ratio is given Fig. Q3. Assume $\delta = \tau$ and determine;

i) Lift curve slope (a_1) of the wings,

ii) The required AoA during the cruise,

iii) Induced drag and profile drag of the wings,

iv) If the total drag on the aircraft is 1.28 times that of the wings and the propulsion efficiency is 0.85; calculate the total propulsive power needed for the aircraft.

[7.0 Marks]

Q4. a) Write down key steps involved in a pitch-down manoeuvre of an aircraft.

[2.0 Marks]

b) An aircraft performs a pure longitudinal flight with an equilibrium angle of attack (AoA) α_e . Suppose due to a sudden guest its AoA has been changed. Describe how the original AoA is restored in each of following cases.

i) α_e is increased by $\delta\alpha$,

ii) α_e is decreased by $\delta\alpha$.

[3.5 Marks]

c) "Increasing the distance between the aerodynamic center and the center of gravity is not a viable option to enhance the stability of an aircraft." Comment on this statement.

[3.0 Marks]

d) Describe "pitch rate damping" mechanism of an aircraft.

[3.5 Marks]

Q5. a) With an aid of suitable sketches, indicate the bank angle (ϕ) and the side slip angle (β) of an aircraft.

[1.5 Marks]

b) Draw the variations of drag and thrust of an aircraft with its cruising speed in a same plot.

[2.5 Marks]

c) On schematic diagram marked all the forces acted on an aircraft in a pure longitudinal flight. Drive all the modelling equations in a longitudinal flight. You may take all the relevant angles to be small. Hence,

i) Drive symbolic expressions for the equilibrium angle of attack (α_e), the equilibrium velocity (V_e) and the equilibrium flight path angle (γ_e).

[2.5 Marks]

ii) Obtain expressions for changes in, equilibrium angle of attack ($\Delta\alpha_e$), equilibrium velocity (ΔV_e) and the equilibrium flight path angle ($\Delta\gamma_e$) for an input command by the pilot.

[2.5 Marks]

iii) Suppose the pilot has increased the elevator command by an amount of δm. Plot the variations of V_e, α_e and γ_e with time, as the aircraft switches from the present equilibrium state to its new equilibrium state.

[3.0 Marks]

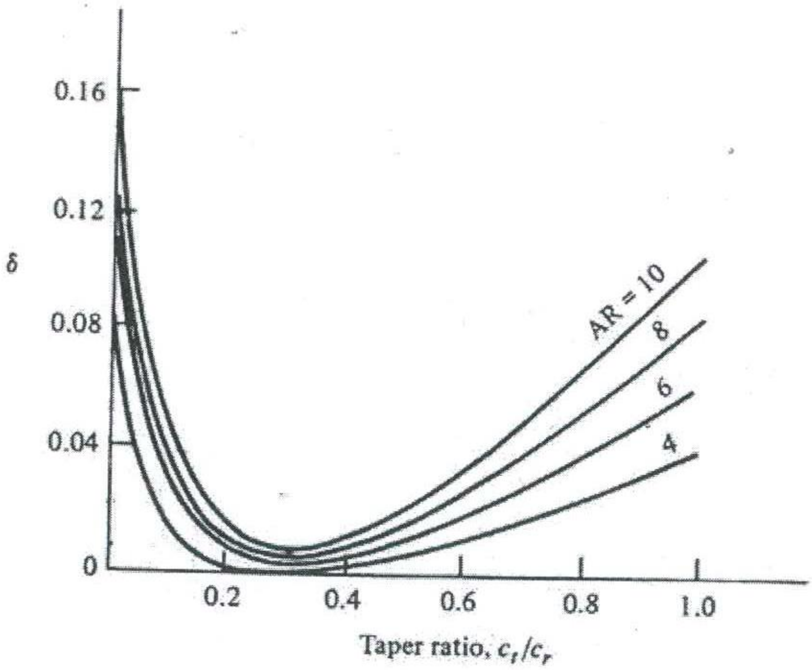

Fig. Q3: Induced drag factor variation

Table 3.1: NACA 2412 airfoil data

Angle of Attack (AoA) (degrees)	Lift coefficient - c_l	Drag coefficient - c_d
-4	-0.12	0.008
-2	0.12	0.006
0	0.36	0.006
2	0.6	0.006
4	0.84	0.007
6	1.08	0.0075
8	1.32	0.0092

a.) For sea-level atmospheric conditions use followings:

Static pressure (P_0) = 101325 Pa

Temperature (T_0) = 288.15 K

Density (ρ_0) = 1.225 kg.m^{-3}

Acceleration due to gravity (g_0)	=	9.81 m.s^{-2}
Specific heat ratio (γ)	=	1.4
Real gas constant (R_g)	=	287 J.kg^{-1}.K^{-1}
Dynamic viscosity	=	1.75 $\times$ 10^{-5} kg/ms

b.) In an ISA below 11 km, the static pressure (*P*) and the temperature (*T*) are given by,

$$P = P_0\left(1 - 2.2558\times10^{-5}h\right)^{5.2559} \text{ N.m}^{-2},$$

$$T = T_0 - 0.0065h \text{ K},$$

c.) For a steady, adiabatic, isentropic and inviscid flow, the total pressure (P_T), free stream pressure (P_∞) and free stream Mach number (M_∞) are related as,

$$P_T = P_\infty\left[1 + \frac{\gamma-1}{2}M_\infty^2\right]^{\frac{\gamma}{\gamma-1}}.$$

d.) Airfoil lift curve slope a_0 and 3-D wing lift curve slope a_1 are related as:

$$a_1 = \frac{a_0}{1 + \left(\frac{a_0}{\pi AR}\right)(1+\tau)}$$

e.) Atmospheric air can be treated as a perfect gas,

$$P = \rho R_g T$$

Speed of sound $a = \sqrt{\gamma RT}$.