National Examinations December 2017

16-Mec-B7, Aero and Space Flight

3 Hours Duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with their answer paper a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAMINATION.
   Any non-communicating calculator is permitted.
3. Any SIX (6) questions constitute a complete examination paper. Only the first six questions as they appear in the answer book will be marked.
4. All questions are of equal value.
5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

Marking Scheme

1. 20 marks total [Part (a) – 6 marks, Part (b) – 4 marks, Part (c) – 4 marks, Part (d) – 6 marks]
2. 20 marks total [Part (a) – 6 marks, Part (b) – 7 marks, Part (c) – 7 marks]
3. 20 marks total [Part (a) – 3 marks, Part (b) – 3 marks, Part (c) – 2 marks, Part (d) – 2 marks, Part (e) – 2 marks, Part (f) – 3 marks, Part (g) – 2 marks, Part (h) – 3 marks]
4. 20 marks total [Part (a) – 4 marks, Part (b) – 4 marks, Part (c) – 4 marks, Part (d) – 4 marks, Part (e) – 4 marks]
5. 20 marks total [Part (a) – 10 marks, Part (b) – 10 marks]
6. 20 marks total [Part (a) – 3 marks, Part (b) – 3 marks, Part (c) – 3 marks, Part (d) – 2 marks, Part (e) – 2 marks, Part (f) – 4 marks, Part (g) – 3 marks]
7. 20 marks total [Part (a) – 7 marks, Part (b) – 7 marks, Part (c) – 6 marks]

Because there are six questions to be answered, full marks for the examination are 120 and therefore the percentage grade obtained will be equal to [(mark obtained / 120)*100].

QUESTION 1.

(a) In the Standard Atmosphere how is the temperature assumed to vary with altitude in the troposphere and in the stratosphere? How are these assumed temperature distributions in the Standard Atmosphere used to find the pressure variations with altitude in the troposphere and in the stratosphere?
(b) Explain what are meant by the terms pressure altitude, temperature altitude, and density altitude.
(c) If an aircraft can fly at a maximum Mach number of 0.82 what is the highest speed at which it can fly at an altitude of 10,000m in the Standard Atmosphere?
(d) An aircraft is flying at a velocity of 88m/s at an altitude of 2500m in the Standard Atmosphere. If the mean velocity over the upper surface of the wing is 99m/s and if the mean velocity over the lower surface of the wing is 71m/s find the mean pressures acting on the upper and lower surfaces of the wing.

QUESTION 2.

(a) Explain what are meant by the terms skin friction drag, induced drag, parasite drag, and compressibility drag.
(b) An aircraft which has a wing area of $45m^2$ is flying at a steady speed of 320km/hr at an altitude of 1500m in the Standard Atmosphere under such conditions that the lift and drag coefficients are 1.05 and 0.07 respectively. Find the thrust required under these conditions and the weight of the aircraft.
(c) An aircraft has a mass of 5000kg and the maximum coefficient of lift 1.4. If this aircraft is to be able to fly at a minimum speed of 220m/s at sea-level in the Standard Atmosphere find the wing area that is required.

QUESTION 3.

(a) Explain what is meant by a laminar flow airfoil.
(b) Explain what occurs when an airfoil stalls.
(c) Discuss what is meant by the term 'high-lift device'.
(d) Discuss why slotted flaps are used.
(e) Explain what are meant by the terms subsonic flow, transonic flow, and supersonic flow.
(f) Discuss why the drag coefficient increases at Mach numbers above the Critical Mach Number.
(g) Explain why swept-back wings are used.
(h) Discuss what is meant by the area rule and how its use influences the design of modern commercial jet aircraft.

QUESTION 4.

An aircraft has the following dimensions and characteristics:

Mass = 15,000kg
Wing Area = $55m^2$
Maximum Thrust at Sea-level = 67kN

If the drag coefficient for this aircraft is given by $C_D = 0.027 + 0.033\ C_L^2$ find:

(a) The parasite and induced drags acting on the aircraft when it is flying its the maximum speed at sea level in the Standard Atmosphere.
(b) The speed at which the minimum drag occurs when flying at sea-level and the ratio of the parasite drag to the total drag when flying under these conditions.
(c) The maximum angle of climb at an altitude of 8600m in the Standard Atmosphere.
(d) The minimum glide angle and the speed at which it occurs at an altitude of 1500m in the Standard Atmosphere.
(e) The speed for maximum range and for maximum endurance at an altitude of 8000m in the Standard Atmosphere.

QUESTION 5.

An aircraft has a mass of 13,500kg and a wing area 72m² and the following dimensions and characteristics:

Maximum Thrust at Sea-level = 59kN,
Mean Chord of Wings = 3.8m,
In-Flight Drag Coefficient $C_D = 0.031 + 0.039C_L^2$,
Maximum C_L without High-lift Devices = 1.3,
Maximum C_L in Landing Configuration= 2.3,
C_L during Landing Run (Spoilers are used) = - 0.07,
Thrust during Approach to Landing= 0.0015 of maximum thrust,
Thrust during Landing Run (Thrust reversers are employed) = -0.15 of maximum thrust
C_D during Landing Run= 0.15,
Wheel-Runway Friction Coefficient during the Landing Run= 0.085,
Landing Speed= 1.15 Minimum Speed in landing configuration,
Rate of Change of Coefficient of Lift of Wings with Angle of Attack = 6 per radian,

For this aircraft determine:

(a) The landing distance from an altitude of 15m at sea-level.

(b) The load factor that will occur if, when the aircraft is flying horizontally at sea-level in the standard atmosphere at a speed of 400km/hr, it encounters a vertical upward gust having a velocity of 50km/hr.

QUESTION 6.

(a) Explain what is meant by the stability of an aircraft and what the difference is between static and dynamic stability.
(b) For a typical subsonic aircraft discuss the means that are conventionally used to ensure that the aircraft has inherent stability about all three axes.
(c) Discuss why by-pass engines are used.
(d) Discuss why afterburning is used.
(e) Discuss what is meant by a ram-jet engine.
(f) Discuss what is meant by a liquid propellant rocket engine and give a sketch showing the main components of a conventional liquid propellant rocket engine.
(g) Discuss why shaped charges are used with solid-propellant rocket engines.

QUESTION 7.

(a) Consider a two-stage rocket in which the first stage has an initial mass of 2500kg which is equal to 7.5 times its final mass after all the fuel in it is consumed, i.e., its structural mass, and the second stage has an initial mass of 1900kg which is equal to 8 times its final mass after all the fuel in it is consumed, i.e., its structural mass. If the exhaust velocity from the rocket engines on both stages is 3200 m/s, find, ignoring gravitational and air drag effects, the maximum velocity that the rocket can achieve.

(b) Consider the reentry of a non-lifting vehicle into the earth's atmosphere. The velocity at which the vehicle enters the atmosphere is 10.5 km/s and it enters at an angle of 10^{o} to the horizontal. The drag coefficient for this vehicle is 1 based on its reference frontal area of $9m^2$. Assuming that the density in the upper atmosphere is approximately given by:

$$\frac{\rho}{\rho_0} = e^{-0.000118h}$$

where h is the altitude in m and ρ_0 is the air density at sea-level, find the maximum deceleration that will be experienced by the vehicle during reentry.

(c) A satellite is in an elliptical orbit around the earth. If the satellite altitudes at the perigee and apogee are 650km and 1500km respectively find the eccentricity of the orbit and the velocity of the satellite at the apogee. Assume that the radius of the earth is 6400km.