

National Exams December 2015

07-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 the answer paper, a clear statement of any assumptions made.
 2. This is an OPEN BOOK EXAM.
Any non-communicating calculator is permitted.
 3. Any SIX (6) of the questions constitute a complete exam paper.
The first six questions as they appear in the answer book will be marked.
 4. Each question is of equal value.
 5. Some questions require an answer in essay format. Clarity and organization of the answer are important.
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QUESTION 1

- (a) If an aircraft is flying at an altitude at which the ambient temperature is -38°C find, assuming that the conditions in the Standard Atmosphere exist, the altitude at which the aircraft is flying and the ambient pressure and density at the altitude at which it is flying.
- (b) Explain what is meant by the term “pressure altitude”.
- (c) An aircraft is flying at a velocity of 250m/s at an altitude of 8000m in the Standard Atmosphere. Find the Mach number at which it is flying.
- (d) Discuss the meaning of the terms “parasite drag” and “induced drag”.

QUESTION 2

- (a) A small aircraft is cruising at an altitude at which the ambient pressure and temperature are 85kPa and 280K respectively. A Pitot-static tube is fitted to the aircraft and the difference between the Pitot and static pressures is measured and found to be 3.4kPa . Use the perfect gas law to determine the ambient air density and then calculate the velocity at which the aircraft is flying.
- (b) An aircraft is flying at a speed of 310 km/h at an altitude at which the air density is 1.06kg/m^3 and the ambient pressure is 90kPa . If the mean velocities over the upper and lower surfaces of the wing are 110m/s and 75m/s respectively find the mean pressures acting on the upper and lower surfaces of the wing and then find the lift generated per m^2 of wing area and the coefficient of lift.

QUESTION 3

Discuss:

- (a) Why high-lift devices are fitted to an aircraft.
- (b) Why spoilers are fitted to the wings of an aircraft.
- (c) What is meant by the camber of an airfoil.
- (d) The factors that influence the magnitude of the induced drag.
- (e) Why swept-back wings are used.
- (f) What happens when a wing stalls and how do leading edge slats delay stalling until higher angles of attack.
- (g) How static longitudinal stability is conventionally obtained in an aircraft.

QUESTION 4

An aircraft has the following dimensions and characteristics:

- Mass = 14,000kg
- Wing Area = 74m²
- Maximum Thrust at Sea-level = 75kN
- In-Flight Drag Coefficient $C_D = 0.032 + 0.038C_L^2$
- Maximum C_L without High-lift Devices = 1.4
- Maximum allowable load factor = 4

For this aircraft determine, ignoring compressibility effects, the following:

- (a) The maximum and minimum speeds at which the aircraft can fly at an altitude of 7000m in the standard atmosphere
- (b) The maximum altitude that the aircraft can reach in the standard atmosphere
- (c) The minimum gliding angle at an altitude of 3000m in the standard atmosphere
- (d) The maximum rate of climb at sea-level
- (e) The minimum radius on which the aircraft can turn when flying horizontally at sea-level.

QUESTION 5

An aircraft has a mass of 12,000kg and a wing area 65m² and the following dimensions and characteristics:

- Maximum Thrust at Sea-level = 60kN
- 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 = 1.4
- Maximum C_L in Landing Configuration = 2.2
- C_L during Landing Run (Spoilers are used) = - 0.06
- Thrust during Approach to Landing = 0.001 of maximum thrust
- Thrust during Landing Run (Thrust reversers are employed) = -0.1 of maximum thrust
- C_D during Landing Run = 0.15
- Wheel-Runway Friction Coefficient during the Landing Run = 0.09
- 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 highest speed that it can attain in a vertical dive at an altitude of 4000m
- (b) The landing distance from an altitude of 15m at sea-level.
- (c) The load factor that will occur if, when the aircraft is flying horizontally at sea-level at a speed of 400km/h, it encounters a vertical upward gust having a velocity of 50km/h.

QUESTION 6

- (a) Discuss what is meant by a turbo-fan engine and what advantages this type of engine has over a traditional jet engine.
- (b) Explain what is meant by the by-pass ratio as applied to a turbo-fan engine.
- (c) Derive an expression for the propulsion efficiency of a turbo-fan engine.
- (d) Explain what is meant by the specific fuel consumption of an aircraft engine and discuss how the specific fuel consumption of a turbo-fan engine varies with altitude.
- (e) Discuss what is meant by afterburning and why it is used in some types of aircraft engines.
- (f) Explain what is meant by turbocharging as applied to a reciprocating engine.

QUESTION 7

- (a) Explain what are meant by the terms ballistic re-entry and glide re-entry.
 - (b) Consider a two-stage rocket in which the first stage has an initial mass of 2000kg which is equal to 7 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 1700kg which is equal to 9 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 3000 m/s, find, ignoring gravitational and air drag effects, the burnout velocity of this rocket.
 - (c) A non-lifting space vehicle which has a drag coefficient of approximately 1 enters the earth's atmosphere at a velocity of 13 km/s at an angle of 12° below the horizontal. The vehicle has a mass of 1500kg and a reference frontal area of 4m^2 . If it is assumed that in the upper atmosphere $\rho / \rho_0 = e^{-0.000118h}$ where h is in m, find the maximum deceleration that occurs during this vehicle's re-entry and the velocity of the vehicle when it reaches the surface of the earth.
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Marking Scheme

1. 20 marks total [Part (a) – 6 marks, Part (b) – 4 marks, Part (c) – 5 marks, Part (d) – 5 marks]
2. 20 marks total [Part (a) – 10 marks, Part (b) – 10 marks]
3. 20 marks total [Part (a) – 2 marks, Part (b) – 2 marks, Part (c) – 2 marks, Part (d) – 4 marks, Part (e) – 3 marks, Part (f) – 4 marks, Part (g) – 3 marks]
4. 20 marks total [Part (i) – 3 marks, Part (ii) – 4 marks, Part (iii) – 4 marks, Part (iv) – 4 marks, Part (v) – 5 marks]
5. 20 marks total [Part (i) – 5 marks, Part (ii) – 8 marks, Part (iii) – 7 marks]
6. 20 marks total [Part (a) – 4 marks, Part (b) – 3 marks, Part (c) – 4 marks, Part (d) – 3 marks, Part (e) – 3 marks, Part (f) – 3 marks]
7. 20 marks total [Part (a) – 3 marks, Part (b) – 8 marks, Part (c) – 9 marks]

Since six questions are to be answered, full marks for the examination are 120 and therefore the percentage grade obtained will be equal to $[(\text{mark obtained} / 120) * 100]$.