National Examinations, December, 2013

07-Mec-B7 Aero and Space Flight

Three 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. If the value of any required quantity appears to have been omitted, the candidate should assume a value and clearly state what has been assumed.
3. This is an OPEN BOOK EXAMINATION.
   Any non-communicating calculator is permitted.
4. Any SIX (6) questions constitute a complete examination paper.
   Only the first six questions as they appear in the answer book will be marked.
5. All questions are of equal value.

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QUESTION 1.

(a) An aircraft is cruising at an altitude of 10,000m. The ambient pressure and temperature are found to be 24.5kPa and -40°C respectively. Find the pressure and temperature altitudes. Then using the perfect gas equation for air and the temperature and pressure values given find the ambient air density and then find the density altitude.
(b) A small aircraft is cruising at a speed of 240km/h at an altitude of 2500m. A Pitot-static tube is fitted to the aircraft. What will be the difference between the Pitot and static pressures. The density can be assumed to be that in the Standard Atmosphere at this altitude.
(c) Air at standard sea-level ambient conditions flows over a blunt nosed body at a velocity of 70m/s. What is the highest pressure acting on the the body? Assume incompressible flow (i.e., ignore density changes).

QUESTION 2.

(a) An aircraft having a mass of 4000kg has a wing area of $19m^2$. The maximum coefficient of lift without high-lift devices extended is 1.6 and with high-lift devices extended it is 2.8. Find the minimum speed at which this aircraft can fly at sea-level with and without high-lift devices extended.
(b) An aircraft is flying at a velocity of 350km/h at an altitude of 2500m. If the mean velocity over the upper and lower surfaces of the wing are 410km/h and 305km/h respectively find the mean pressures acting on the upper and lower surfaces of the wing. and the lift generated per m^2 of wing area. In arriving at your answer use the properties of of the Standard Atmosphere at an altitude of 2500m.

QUESTION 3.

(a) Considering an aircraft designed to fly at transonic speeds, discuss what is meant by Compressibility Drag and explain the causes of this compressibility drag.
(b) Explain the meaning of the term Critical Mach Number.
(c) Explain what is meant by induced drag and discuss the factors that influence the value of the induced drag.
(d) Discuss why high-lift devices are fitted to an aircraft.
(e) Explain what is meant by inherent static stability.

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QUESTION 4.

An aircraft has the following characteristics and dimensions:

In-Flight Drag Coefficient, $C_D = 0.028 + 0.032\ C_L^2$
Maximum Thrust at Sea-level = 45kN
Mass = 11,500kg
Wing Area = $43m^2$

For this aircraft find:

(a) Ignoring compressibility, the maximum speed at sea-level and at an altitude of 6000m. Also find the induced and parasite drags acting on the aircraft when it is flying at these speeds at these altitudes.
(b) The speed at which the minimum drag occurs at sea-level and the parasite and induced drags when it is flying at this speed at this altitude.
(c) The speed at which minimum drag occurs at an altitude of 10000m.
(d) The maximum rate of climb at sea-level.

QUESTION 5.

An aircraft has the following dimensions and characteristics: Mass = 10,000 kg, Wing Area = $45m^2$, Maximum Thrust at Sea-level = 45kN, In-Flight Drag Coefficient $C_D = 0.025 + 0.035C_L^2$, Maximum C_L without High-lift Devices = 1.3, Maximum C_L in Landing Configuration = 2.2, Maximum C_L in Take-off Configuration = 1.8, C_L during Take-Off Ground Run = 0.25, C_L during Landing Ground Run (Spoilers are used) =-0.05, 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 = 0.06, Wheel-Runway Friction Coefficient during the Take-Off Run = 0.02, Wheel-Runway Friction Coefficient during the Landing Run = 0.08, Landing Speed = 1.2 x Minimum Speed, and Take-Off Speed = 1.25 x Minimum Speed. For this aircraft determine the the take-off distance to reach 15m at sea-level and the landing distance from 15 m at sea-level.

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QUESTION 6.

(a) Explain what is meant by the term load factor.
(b) Discuss the factors that determine the minimum radius on which an aircraft can turn at a particular altitude.
(c) Discuss why by-pass engines and afterburning are used.
(d) Explain the terms specific fuel consumption and propulsion efficiency as applied to a jet engine.

QUESTION 7.

A solid iron sphere with a diameter of 1.2 m enters the earth's atmosphere at a velocity of 11 km/s at angle of 14° to the local horizontal. Assuming a drag coefficient based on frontal area of 1 and that the density of iron is 7000 kg/m^3, find, assuming that the density in the upper atmosphere is approximately given by:

$$\frac{\rho}{\rho_0} = e^{-0.00012h}$$

where h is the altitude in m and ρ_0 is the air density at sea-level,:

(a) the altitude at which the maximum deceleration during reentry occurs
(b) the value of the maximum deceleration
(c) the velocity of the sphere when the maximum deceleration occurs
(d) the velocity with which the sphere reaches the earth's surface

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Marking Scheme

1. 20 marks total [Part (a) – 8 marks, Part (b) – 6 marks, Part (c) – 6 marks]

2. 20 marks total [Part (a) – 10 marks, Part (b) – 10 marks]

3. 20 marks total [Part (a) – 4 marks, Part (b) – 4 marks, Part (c) – 4 marks, Part (d) – 4 marks, Part (e) – 4 marks]

4. 20 marks total [Part (a) – 6 marks, Part (b) – 6 marks, Part (c) – 4 marks, Part (d) – 4 marks]

5. 20 marks total [Take-Off distance – 10 marks, Landing Distance 10 marks]

6. 20 marks total [Part (a) – 5 marks, Part (b) – 5 marks, Part (c) – 5 marks, Part (d) – 5 marks]

7. 20 marks total [Part (a) – 5 marks, Part (b) – 5 marks, Part (c) – 5 marks, Part (d) – 5 marks]