National Examinations, December, 2008

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.

/OVER

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. 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) An aircraft can fly at a maximum Mach number of 0.83. What is the highest speed at which it could fly at altitudes of 5000m and 10,000m?

QUESTION 2.

(a) A small aircraft is cruising at a speed of 80m/s. The ambient pressure and temperature are measured and found to be 78kPa and 277K respectively. A Pitot-static tube is fitted to the aircraft. What will be the difference between the Pitot and static pressures.

(b) An aircraft is flying at a velocity of 80m/s at an altitude of 3000m. If the mean velocity over the upper surface of the wing is 94m/s if the mean velocity over the lower surface of the wing is 73m/s and if the ambient pressure in the free-stream flow ahead of the aircraft is 70 kPa find the mean pressures acting on the upper and lower surfaces of the wing. Also find the lift generated per m^2 of wing area and the coefficient of lift.

QUESTION 3.

(a) Explain what happens when an airfoil stalls.

(b) Explain what are meant by the terms skin friction drag, induced drag, parasite drag and compressibility drag.

(c) Discuss how the drag coefficient for an aircraft varies with Mach number in the transonic velocity range.

(d) Explain the meaning of the term Critical Mach Number.

/OVER

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) The minimum gliding angle at an altitude of 8000m.

(b) The maximum rate of climb at sea-level and at an altitude of 8000m.

(c) The velocity for minimum drag at an altitude of 8000m. Also find the parasite and induced drags acting on the aircraft when it is flying at this minimum drag velocity at this altitude.

QUESTION 5.

(a) Discuss what factors determine the minimum radius on which an aircraft can turn at a particular altitude.

(b) Explain the difference between the static and dynamic stability of an aircraft.

(c) Consider a conventional subsonic aircraft. What means are usually used to ensure that such an aircraft has static lateral stability?

(d) Discuss why by-pass engines and afterburning are used.

/OVER

QUESTION 6.

Consider the aircraft whose characteristics are given in Question 4. For this aircraft find:

(a) The speed for maximum endurance and the speed for maximum range at an altitude of 8000m.

(b) If the maximum coefficient of lift for this aircraft when no high-lift devices are being used is 1.4 find the minimum speed at which this aircraft can fly in this no high-lift devices configuration at sea-level and at an altitude of 8000m. For the sea-level case, also find the drag force acting on the aircraft when flying at the minimum speed.

(c) If the rate of change of lift coefficient with angle of attack of the wings is 0.13 per degree, find the load factor that occurs when, while flying horizontally at a speed of 600km/hr at sea-level, the aircraft encounters a vertically upward gust with a velocity 40 km/hr.

QUESTION 7.

(a) A small single stage rocket has an initial mass before firing of the engine that is 8 times the mass of the rocket after all of the fuel is used. If the velocity of the exhaust from the rocket nozzle is 3000m/s, estimate, ignoring gravitational and air drag effects, the maximum velocity that this rocket can achieve.

(b) A non-lifting vehicle reenters the earth's atmosphere at a velocity of 10 km/s at an angle of 7° to the horizontal. The drag coefficient for this vehicle is 1.2 based on its frontal area of $4m^2$. 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, find the maximum deceleration experienced by the vehicle during reentry.

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Marking Scheme

1. 20 marks total [Part (a) – 12 marks, Part (b) – 8 marks]

2. 20 marks total [Part (a) – 8 marks, Part (b) – 12 marks]

3. 20 marks total [Part (a) – 5 marks, Part (b) – 7 marks, Part (c) – 5 marks, Part (d) – 3 marks]

4. 20 marks total [Part (a) – 6 marks, Part (b) – 7 marks, Part (c) – 7 marks]

5. 20 marks total [Part (a) – 6 marks, Part (b) – 4 marks, Part (c) – 5 marks, Part (d) – 5 marks]

6. 20 marks total [Part (a) – 5 marks, Part (b) – 7 marks, Part (c) – 8 marks, Part (d) – 5 marks]

7. 20 marks total [Part (a) – 10 marks, Part (b) – 10 marks]