National Examinations May 2016

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 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. Each question is of equal value.
5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

QUESTION 1.

(a) Measurements indicate that the ambient pressure and temperature outside an aircraft are 26kPa and -39°C respectively. Find the pressure, temperature, and density altitudes. In arriving at your answer, use the perfect gas equation for air and the temperature and pressure values given to determine the ambient air density.

(b) An aircraft can fly at a maximum Mach number of 0.86. What is the highest speed at which it could fly at sea-level and at an altitude of 9,000m in the standard atmosphere?

(c) An aircraft is flying at a speed of 210m/s at an altitude of 5000m in the standard atmosphere. Find the highest pressure acting on the surface of the aircraft.

QUESTION 2.

(a) An aircraft which has a wing area of $30m^2$ is flying at a steady speed of 280km/hr at an altitude of 1700m in the standard atmosphere under such conditions that the lift and drag coefficients are 1.1 and 0.08 respectively. Find the thrust required under these conditions and the weight of the aircraft.

(b) An aircraft has a mass of 5000kg and a wing area of $23m^2$. The maximum coefficient of lift without high-lift devices being used is 1.5 and with high-lift devices deployed is 2.8. Find the minimum speeds at which the aircraft can fly with and without high-lift devices at an altitude of 500m in the standard atmosphere.

(c) Explain what is meant by the terms: skin friction drag, induced drag, parasite drag, and compressibility drag.

QUESTION 3.

(a) Discuss how the drag coefficient for an aircraft varies with Mach number in the transonic velocity range and what is meant by the term Critical Mach Number.

(b) Discuss why swept-back wings are used on an aircraft.

(c) Explain what is meant by the term Area Rule.

(d) Explain what is meant by a Laminar Flow Airfoil.

(e) Discuss why slotted flaps used.

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QUESTION 4.

An aircraft has the following characteristics and dimensions:

In-Flight Drag Coefficient, $C_D = 0.031 + 0.034\ C_L^2$
Maximum Thrust at Sea-level = 85kN
Mass = 29,500kg
Wing Area = $65m^2$

For this aircraft find:

(a) Ignoring compressibility effects, the maximum speed of this aircraft at sea-level and at an altitude of 5000m in the Standard Atmosphere.
(b) The minimum gliding angle at an altitude of 2000m in the Standard Atmosphere and the speed at which it occurs.
(c) The maximum rate of climb at sea-level and at an altitude of 8000m in the Standard Atmosphere.
(d) 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.

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

(a) Find the speed for maximum endurance and the speed for maximum range at an altitude of 8000m in the Standard Atmosphere.
(b) If for this aircraft (i) the lift-off speed is 1.25 x the Minimum Speed, (ii) the Maximum C_L value in the take-off configuration is 1.7, (iii) the value of C_L during the take-off ground run is 0.25, (iv) the Wheel-Runway Friction Coefficient during the take-off ground run is 0.02, find the take-off distance to reach an altitude of 15m at sea-level in the Standard Atmosphere.
(c) If the rate of change of the Coefficient of Lift of the wings is 5.5 per radian, find the load factor that will occur if, when the aircraft is flying horizontally at an altitude of 500m in the Standard Atmosphere at a speed of 350 km/hr, it suddenly encounters a vertically upward gust having a velocity of 40 km/hr.
(d) Find the maximum ceiling for this aircraft in the Standard Atmosphere.

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QUESTION 6.

(a) Explain the difference between the static and dynamic stability of an aircraft.
(b) For a typical subsonic aircraft discuss the means that are usually used to ensure that the aircraft has static lateral stability.
(c) Discuss what factors determine the minimum radius on which an aircraft can turn at a particular altitude.
(d) Discuss the term propulsion efficiency as applied to a jet engine.
(e) Discuss why by-pass engines and engines with afterburning are used.
(f) Discuss the difference between solid and liquid propellant rocket engines.

QUESTION 7.

(a) Consider a single stage rocket which has an initial mass before the firing of the engine that is 8.3 times the mass of the rocket after all of the fuel is used. If the velocity of the exhaust from the rocket nozzle is 3300m/s, estimate, ignoring both 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 11 km/s at an angle of 10° to the horizontal. The drag coefficient for this vehicle is 1.1 based on its reference frontal area of $5m^2$. 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 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 500km and 1200km 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.

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Marking Scheme

1. 20 marks total [Part (a) – 8 marks, Part (b) – 7 marks, Part (c) – 5 marks]

2. 20 marks total [Part (a) – 7 marks, Part (b) – 7 marks, Part (c) – 6 marks]

3. 20 marks total [Part (a) – 5 marks, Part (b) – 3 marks, Part (c) – 4 marks, Part (d) – 4 marks, Part (e) – 4 marks]

4. 20 marks total [Part (a) – 5 marks, Part (b) – 3 marks, Part (c) – 4 marks, Part (d) – 4 marks, Part (e) – 4 marks]

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

6. 20 marks total [Part (a) – 3 marks, Part (b) – 4 marks, Part (c) – 4 marks, Part (d) – 3 marks, Part (c) – 3 marks, Part (f) – 3 marks]

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