07-Mec-B7, December 2016

National Examinations December 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. Marking scheme on page 2.
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) – 5 marks, Part (b) – 6 marks, Part (c) – 5 marks, Part (d) – 4 marks]

2. 20 marks total [Part (a) – 6 marks, Part (b) – 6 marks, Part (c) – 4 marks, Part (d) – 4 marks]

3. 20 marks total [Part (a) – 2 marks, Part (b) – 3 marks, Part (c) – 3 marks, Part (d) – 3 marks,

   Part (e) – 3 marks, Part (f) – 3 marks, Part (g) – 3 marks]

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

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

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

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

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QUESTION 1

(a) An aircraft with a mass of 6500kg is flying at a speed of 600km/hr at an altitude of 2500m in the standard atmosphere. The aircraft has a wing area of $33m^2$. The drag coefficient on the aircraft is given by $0.028+0.038C_L^2$ where C_L is the lift coefficient. Find the lift coefficient and the drag acting on the aircraft.

(b) Consider the aircraft described in Question number 1. If this aircraft is dived vertically downward find the maximum velocity it can achieve at an altitude of 1500m. Assume that in the vertical dive the lift coefficient is zero and that the engine is throttled back with the result that there is effectively no thrust on the aircraft.

(c) A small aircraft is flying at a speed of 340km/hr at an altitude at which the ambient pressure and temperature are 74kPa and 271K respectively. If a Pitot-static tube is fitted to this aircraft, find the difference between the Pitot pressure and the static pressure under these conditions.

(d) Explain what is meant by the "absolute ceiling" and discuss how it can be estimated for a given aircraft.

QUESTION 2

(a) An aircraft can fly at a maximum Mach number of 0.89. Find the highest speed it can fly at an altitude of 8000m in the standard atmosphere.

(b) An aircraft has a mass of 40,000 kg and a wing area of $120m^2$. The aircraft has a maximum lift coefficient of 1.3 with no high-lift devices deployed and a maximum lift coefficient of 2.3 with all high-lift devices deployed. Find the minimum speed at which this aircraft can fly at sea-level (a) with no high-lift devices deployed, and (b) with all high-lift devices deployed.

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

(d) Explain what are meant by the terms "compressibility drag" and "area rule"?

QUESTION 3

(a) Explain what are meant by the terms "pressure altitude" and "density altitude".
(b) Discuss what is meant by "induced drag" and what can be done to reduce the induced drag acting on an aircraft.
(c) Discuss why leading-edge slats and slotted flaps are used on the wing of an aircraft.
(d) Explain what is meant by a "spoiler" and why it is fitted to an aircraft.
(e) Discuss what are meant by the terms "skin-friction drag" and "pressure drag".
(f) Explain what is meant by a laminar flow airfoil and discuss why such airfoils are used?
(g) What methods are conventionally used to make an aircraft have static longitudinal (pitch) stability?

QUESTION 4

(a) What does the term "by-pass ratio" refer to when applied to a turbo-fan engine?
(b) What are the advantages of a turbo-fan engine over a traditional turbo-jet engine?
(c) Explain the difference between a liquid propellant rocket engine and a solid propellant rocket engine.
(d) Explain what is meant by the term "afterburning" and explain why afterburning engines are used on some aircraft.
(e) Explain why variable-pitch propellers are used.
(f) Discuss how a ram-jet engine works and discuss its advantages and disadvantages as compared to a conventional jet engine.

QUESTION 5

An aircraft has the following characteristics and dimensions: (i) In-Flight Drag Coefficient, $C_D = 0.031 + 0.037C_L^2$, (ii) Maximum Total Thrust at Sea-level = 160kN, (iii) Mass = 50,500kg, (iv) Wing Area = $120m^2$. 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 1000m in the Standard Atmosphere and the speed at which the aircraft will be flying when gliding under these conditions.

(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.

(e) Find the maximum ceiling for this aircraft in the Standard Atmosphere.

QUESTION 6

Consider the aircraft whose characteristics are given in Question 5. For this aircraft:

(a) Find the speeds for maximum range and for maximum endurance at an altitude of 9000m in the Standard Atmosphere.

(b) If for this aircraft: (i) The landing mass is 40,000kg, (ii) the maximum C_L value in the landing configuration is 2.4, (iii) the landing speed is 1.15 times the minimum speed in the landing configuration, (iv) the thrust during the approach to landing is 0.002 times the maximum thrust, (v) the value of C_L during the landing ground run is -0.05, (vi) the thrust during the landing ground run is -0.15 times the maximum thrust, thrust reversers being used, (vii) the wheel-runway friction coefficient during the landing ground run is 0.08, find the landing distance from an altitude of 15m at sea-level in the Standard Atmosphere.

(c) 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 horizontal frontal gust having a velocity of 60 km/hr.

QUESTION 7

(a) Consider a two-stage rocket vehicle that is basically made up of two identical stages. The ratio of the initial to the final mass of each of these stages is 6.7 and each stage has an initial mass of 1500kg. The rocket exhaust velocity from each stage is 3800m/s. Ignoring the effects of gravity find the velocity achieved by this rocket vehicle.

(b) A non-lifting vehicle with a mass of 2200kg is in a circular orbit around the earth at an altitude of 550km above the surface of the earth. If this vehicle re-enters the earth's atmosphere at its orbital velocity and at an angle of 10.5° to the earth's surface find the maximum deceleration experienced by the vehicle during re-entry. The drag coefficient, C_D, for this vehicle is 1.05 based on its reference frontal area of $5m^2$. Assume that the density in the upper atmosphere is 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.

(c) Discuss what is meant by the terms "re-entry heating" and "heat shield" as applied to re-entering space vehicle.

(d) Explain what is meant by the term "escape velocity" as applied to space flight.