National Examinations May 2005
98-Mec-B7 Aerodynamics of Flight

Three 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. 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. FIVE (5) questions constitute a complete examination paper. Only the first five questions as they appear in the answer book will be marked
5. All questions are of equal value

QUESTION 1

(a) An aircraft is flying at a speed of 100m/s sea-level. The mean pressure on the upper and lower surfaces are 2kPa below and 1.2kPa above the ambient pressure respectively. Estimate the mean velocity over the upper and lower surfaces of this airfoil. If the wing area is $60m^2$ estimate the lift being generated. Assume standard atmospheric conditions and that the flow is incompressible.
(b) An aircraft is flying at a speed of 250m/s at an altitude of 7000m. Estimate the highest pressure acting on the surfaces of this aircraft. Assume standard atmospheric conditions.
(c) Air at standard sea-level pressure and temperature flows over a body at a velocity of 220m/s. Can the flow be assumed to be incompressible?
(d) Measurements indicate that at the pressure and temperature outside an aircraft are 28kPa and -57°C respectively. Find the density and pressure altitudes at which this aircraft is flying.
(e) Discuss what is meant by the absolute ceiling and the service ceiling of an aircraft.
(f) Explain the difference between the static and dynamic stability of an aircraft.

QUESTION 2

(a) An aircraft has a mass of 4000kg has a wing area of $19m^2$. The maximum coefficient of lift without high-lift devices is 1.6 and with high-lift devices it is 2.8. Find the minimum speed at which this aircraft can fly at standard sea-level conditions with and without high-lift devices.
(b) Discuss the meaning of the following terms: (i) a high-lift device (ii) induced drag.
(c) On what factors does the induced drag depend?
(d) Explain what happens when an airfoil stalls.
(e) Discuss why spoilers are used.

QUESTION 3

An aircraft has the following dimensions and characteristics:

Mass = 50,000 kg

Wing Area = 110 m^2

Maximum Thrust at Sea-level = 155 kN

In-Flight Drag Coefficient $C_D = 0.033 + 0.039{C_L}^2$

Maximum C_L without High-lift Devices = 1.3

Rate of change of Coefficient of Lift of wings without High-lift Devices with angle of attack = 0.13 per degree

For this aircraft, assuming standard atmospheric conditions, determine the following:

(a) The maximum speeds at sea-level and at an altitude of 5000m ignoring compressibility.
(b) The maximum rates of climb at sea-level and at an altitude of 5000m and the speeds at which they occur.
(c) The speed for maximum range at an altitude of 11000 m.
(d) The minimum gliding angle at an altitude of 5000m and the speed at which it occurs.
(e) The coefficient of lift and drag when the aircraft aircraft is flying at an altitude of 5000m at a speed that is 90% of the maximum speed at this altitude.

QUESTION 4

Consider the aircraft described in Question 3 above:
(a) Find the thrust required if the aircraft is descending at an angle of 5^o to the horizontal at a velocity of 300 km/hr at an altitude of 5000m.
(b) If the aircraft is operating at an altitude of 5000m with the engine delivering 5% of the maximum thrust at this altitude and if it is flying at 80 per cent of the maximum speed at this altitude, find the angle at which it is descending.
(c) If this aircraft when flying at an altitude of 5000m is dived at an angle of 45^o to the horizontal using 20% of the maximum thrust at this altitude, find, ignoring compressibilty effects, the speed that the aircraft attains. Based on this answer, is the neglect of compressibility effects justified.

QUESTION 5

If, for the aircraft described in Question 4 above:

Maximum C_L in Take-off Configuration = 1.7
Take-off speed = 1.15 x Minimum speed in take-off configuration
C_L during take-off Ground Run = 0.2
Wheel-runway friction coefficient during Take-off Ground Run = 0.05

then for this aircraft determine the take-off distance at sea-level to clear a 10m high obstacle.

QUESTION 6

(a) If for the aircraft considered in Questions 3 and 4 above:

Rate of change of Coefficient of Lift of wings without
High-lift Devices with angle of attack = 0.13 per degree
Maximum Allowable Load Factor = 2.8

then for this aircraft, assuming standard atmospheric conditions, determine the load factor that will occur if, when flying horizontally at 350 km/hr at sea-level, the aircraft suddenly encounters (i) a vertically upward gust with a velocity of 60 km/hr (ii) a horizontal frontal gust with a velocity of 80 km/hr.

(b) Discuss the factors that determine the minimum radius on which an aircraft can turn.

(c) Discuss the advantages and disadvantages of afterburning.