



B.E DEGREE EXAMINATIONS: NOV/DEC 2018

(Regulation 2015)

Fifth Semester

AERONAUTICAL ENGINEERING

U15AET501 : Aerodynamics II

COURSE OUTCOMES

- CO1:** To understand the basic concepts on compressible flow theory
CO2: To understand the flow physics of shock waves
CO3: To develop the industrial problem solving skills
CO4: To explore the application of compressible flow theory for solving real world problems

Time: Three Hours

Maximum Marks: 100

**Answer all the Questions:-
 (Use of Gas Table Permitted)
 PART A (10 x 1 = 10 Marks)**

1. Matching type item with multiple choice code

CO1 [K₂]

List I	List II
A. Compressible flow	i. Mach number > 5
B. Sonic flow	ii. $1 < \text{Mach number} < 5$
C. Supersonic flow	iii. Mach number > 0.3
D. Hypersonic flow	iv. Mach number = 1

- | | A | B | C | D |
|----|-----|----|-----|----|
| a) | ii | i | iii | iv |
| b) | iii | iv | ii | i |
| c) | ii | iv | iii | i |
| d) | iii | i | ii | iv |

2. For a given specific heat ratio, the exit Mach number of a choked CD nozzle is a unique function of _____

CO1 [K₂]

- | | |
|------------------------------------|---------------------------|
| a) Nozzle area ratio (A_e/A_t) | b) Upstream pressure |
| c) Downstream pressure | d) Nozzle throat diameter |

3. Aerodynamic forces depend on _____ CO1 [K₂]
1. Mach number 3. Prandtl number
2. Reynolds number 4. Nusselt number
- a) 1,3 b) 1,4
c) 1,2 d) 2,3
4. Normal shock waves can occur when the flight Mach number is _____ CO2 [K₂]
- a) Above one b) 0.3
c) 0.5 d) Zero
5. Assertion (A): Air is taken as a compressible fluid while solving the real world problems. CO4 [K₃]
Reason (R): When the changes in fluid density have significant effects on the solution, the fluid is considered as compressible.
- a) Both A and R are Individually true and R is the correct explanation of A b) Both A and R are Individually true but R is not the correct explanation of A
c) A is true but R is false d) A is false but R is true
6. The free stream Mach number at which the drag coefficient begins to increase rapidly is defined as _____. CO2 [K₂]
- a) critical Mach number b) drag-divergence Mach number
c) lower critical Mach number d) upper critical Mach number
7. Identify the flow Mach number variations from higher to lower sequence. CO1 [K₄]
(1) Hypersonic flow, (2) Subsonic flow, (3) Supersonic flow, (4) Sonic flow
- a) 2-4-3-1 b) 1-3-4-2
c) 3-4-2-1 d) 4-1-3-2
8. The Mach angle is a unique function of the _____. CO4 [K₂]
- a) local Mach number b) local pressure
c) velocity of sound d) local temperature
9. Assertion (A): The whole idea of sweeping an aircraft's wing is to delay the drag rise caused by the formation of shock waves. CO1 [K₂]
Reason (R): The sharp pressure increase across the shock wave creates a strong adverse gradient, causing the flow to separate from the surface, which can create substantial increases in drag.
- a) Both A and R are Individually true and R is the correct explanation of A b) Both A and R are Individually true but R is not the correct explanation of A
c) A is true but R is false d) A is false but R is true

10. Which one of the following is representing the linearized pressure coefficient, C_p , for small perturbations where u' is the perturbation velocity and V_∞ is the free stream velocity. CO1 [K₁]

a) $C_p = \frac{2u'}{\sqrt{1+V_\infty^2}}$

b) $C_p = -\frac{2u'}{V_\infty}$

c) $C_p = \frac{V_\infty^2}{\sqrt{1-u'}}$

d) $C_p = \frac{2u'}{1+V_\infty}$

PART B (10 x 2 = 20 Marks)
(Answer not more than 40 words)

- | | | |
|--|-----|-------------------|
| 11. Define compressibility of the fluid | CO1 | [K ₂] |
| 12. Distinguish between the nozzle flow choking and the thermal choking | CO1 | [K ₂] |
| 13. Write down the steady one dimensional momentum equation | CO1 | [K ₂] |
| 14. Distinguish between viscous and inviscid flow | CO1 | [K ₂] |
| 15. Define the critical Mach number | CO4 | [K ₃] |
| 16. Sketch Rayleigh curve showing the Mollier diagram of one dimensional diabatic flow | CO4 | [K ₂] |
| 17. What really causes the entropy increase across a shock wave? | CO2 | [K ₂] |
| 18. Distinguish between normal shock and oblique shock waves | CO2 | [K ₂] |
| 19. What is the benefit of a supercritical airfoil in the transonic aircraft design? | CO4 | [K ₄] |
| 20. What is the purpose of winglets? | CO4 | [K ₁] |

Answer any FIVE Questions:-
PART C (5 x 14 = 70 Marks)
(Answer not more than 300 words)

Q.No. 21 is Compulsory

- | | | | |
|---|-----|-----|-------------------|
| 21. (i) Derive an expression for the speed of sound for calorically perfect gas. | (8) | CO1 | [K ₁] |
| (ii) Estimates the flight Mach numbers at a static pressure of 1 atm when the Pitot tube measures (i) 1.34 atm, and (ii) 15.35 atm at two different flight regimes. | (6) | | [K ₃] |
| 22. (i) Using the Euler equation derive an expression for the area-velocity relation of a convergent-divergent nozzle. | (7) | CO1 | [K ₃] |
| (ii) Using the isentropic relations formulate expressions relating to pressure ratio, density ratio and temperature ratio for the analyses of compressible flow problems. | (7) | | [K ₅] |

23. (i) Describe briefly the integral form of continuity equation. (7) CO1 [K₂]
(ii) An aircraft flies at 800 km/hr at an altitude of 10,000 meters ($T=223.15$ K, $p = 0.264$ bar). The air is reversibly compressed in an inlet diffuser ($\gamma = 1.4$, $R = 287$ J/kg K). The Mach number at the exit of the diffuser is 0.36. Determine (a) the entry Mach number and (b) velocity, pressure and temperature of air at the diffuser exit. (7) [K₃]
24. (i) Derive Prandtl relationship pertaining to the normal shock waves and prove that Mach number behind the normal shock is always subsonic. (8) CO2 [K₄]
(ii) How to estimate the flight Mach number using a Pitot tube at the subsonic and the supersonic flow regimes? (6)
25. (i) A normal shock wave is standing in the test section of a supersonic wind tunnel. Upstream of the wave, $M_1 = 3$, $P_1 = 0.5$ atm, and $T_1 = 200$ K. Find M_2 , P_2 , T_2 , and u_2 downstream of the wave. (7) CO3 [K₃]
(ii) Describe briefly with a sketch the working of a supersonic wind tunnel. (7) [K₆]
26. (i) Describe briefly on: (a) wave angle and the Mach angle, (b) attached and detached shocks, (b) Prandtl-Meyer expansion wave. (6) CO4 [K₂]
(ii) A uniform supersonic stream with $M_1 = 3.0$, $P_1 = 1$ atm, and $T_1 = 288$ K encounters a compression corner, which deflects the stream by a flow deflection angle (θ) of 20° . Calculate the shock wave angle (β), and P_2 , T_2 , M_2 , P_{02} , and T_{02} behind the shock wave. (8) [K₃]
27. (i) Using the small perturbation potential theory prove that the linearized pressure coefficient depends only on x component of the perturbation velocity. (8) CO4 [K₃]
(ii) Write short note on (a) Supercritical airfoil, (b) Transonic area rule, (c) Swept wing aircraft (6) [K₂]
