Roll No: -------------------------

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: M. Tech. CFD **Semester – I**
Subject (Course): Compressible Flow **Max. Marks : 100**
Course Code : ASEG 7004 **Duration : 3 Hrs**
No. of page/s: 03

The use gas tables/ *θ-β-M Chart* is permitted. Assume missing data, if any, appropriately. Use sketches to justify your answer wherever required.

Section A

Section A has five (05) questions of 04 marks each. These questions are of short answer type (maximum of 60 words) and all the questions in this section are compulsory.

1. Define the characteristic properties and the stagnation properties associated with a flow.
2. What would be speed of sound in a truly incompressible media? Justify your answer.
3. Discuss the form of governing equations particularly suited for the numerical solution of compressible flows.
4. Explain briefly the concept of time marching approach for the numerical solution of supersonic flow over a blunt body.
5. Why is the area of the second throat in a supersonic wind tunnel always greater than that of the first throat? Under what conditions would the two throats have the same area?

Section B

Section B has four (4) questions of 10 marks each. These questions are of long answer type (maximum 200 words for each question). All questions in this section are compulsory.

6. Air is expanded through a convergent-divergent nozzle from a large reservoir in which the pressure and temperature are 600 kPa and 40˚C respectively. The design back-pressure is 100 kPa. Find (a) the ratio of the nozzle exit area to the nozzle throat area, (b) the discharge velocity from the nozzle under design considerations and (c) the back - pressure for which there will a normal shock at the exit plane of the nozzle.

7. Consider an isentropic flow of air through a duct whose area is decreasing. Find the percentage changes in velocity, density, and pressure induced by a reduction in area for Mach number of 0.1 and 0.95.
8. Air flows out of a pipe with a diameter of 0.3 m at a rate of 1000 m^3 per minute at a pressure and temperature of 150 kPa and 293 K respectively. If the pipe is 50 m long, find assuming that f=0.005, the Mach number at the exit, the inlet pressure, and the inlet temperature.
9. Air flows through a constant area duct. The pressure and temperature of the air at the inlet to the duct are 100 kPa and 10˚C respectively and the inlet Mach number is 2.8. Heat is transferred to the air as it flows through the duct and as a result, the Mach number at the exit is 1.3. Find the pressure and temperature at the exit. If no shock waves occur in the flow, find the maximum amount of heat that can be transferred to the air per unit mass of air. Also, find the exit pressure and temperature that would exist with this maximum transfer rate. Assume that the flow is steady, that the effects of wall friction can be neglected and that the air behaves as a perfect gas.

Section C

Section C has two (02) question of 20 marks each. Both the questions are compulsory; however, one question has an internal choice. These questions are of long answer type (maximum 500 words for each question).

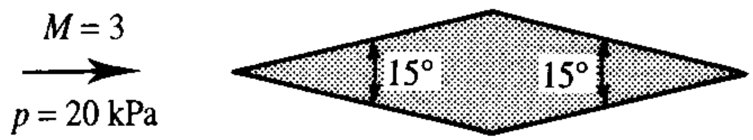
10. (a) Prove that the characteristic speed of sound, in an adiabatic flow across a normal shock, is equal to the geometric mean of the velocities ahead and behind the normal shock.

    (b) The Mach number ahead of a normal shock wave must be always greater than 1.0 and the Mach number aft of a normal shock wave is always subsonic. Justify this statement.

11. A simple wing may be modeled as a 0.3 m wide flat plate set at angle of 3˚ to an airflow at a Mach number of 3.0, the pressure in this flow being 40 kPa. Assuming that the flow over the wing is two-dimensional, estimate the lift and drag force per meter span due to the wave formation on the wing.

OR

A symmetrical double-wedge shaped body with an included angle of 15˚ is aligned with an airflow in which the Mach number is 3.0 and pressure is 20 kPa. Find the pressures acting on the surfaces of the body.



Roll No: --------------------------

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2017

Program: M. Tech. CFD	**Semester – I**
Subject (Course): Compressible Flow	**Max. Marks : 100**
Course Code : ASEG 7004	**Duration : 3 Hrs**
No. of page/s: 03	

Use of Gas Tables/ *θ-β-M Chart* is permitted. Assume missing data, if any, appropriately. Use sketches to justify your answer wherever required.

Section A

Section A has five (05) questions of 4 marks each. These questions are of short answer type (maximum of 60 words) and all the questions in this section are compulsory.

1. List down with sketches the various models of fluid flows for application of conservation laws.
2. Discuss the effect of heat addition and subtraction on a supersonic flow through a one-dimensional duct.
3. Explain the numerical solution of conservation equations for inviscid supersonic flow using the concept of space marching.
4. Discuss the shock capturing and shock fitting approaches for the numerical solution of supersonic flow over arbitrary objects.
5. Calculate the isothermal compressibility and the isentropic compressibility of air at 0.5 atm. Assume air to be a perfect gas.

Section B

Section B has four (4) questions of 10 marks each. These questions are of long answer type (maximum 200 words for each question). All questions in this section are compulsory.

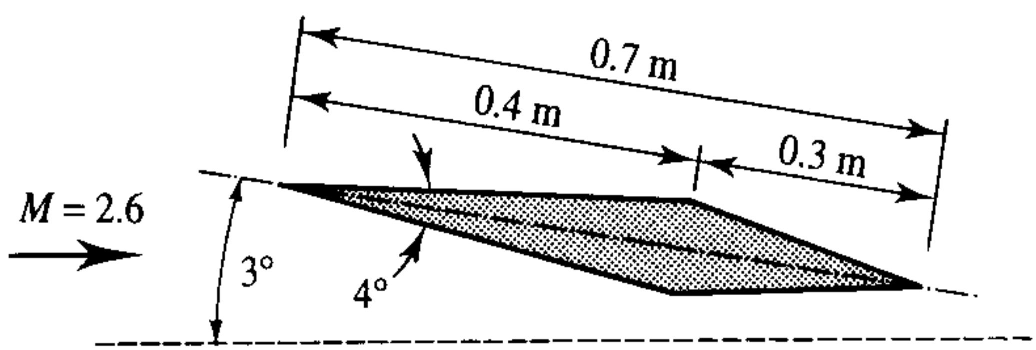
6. Air flows in a 5 cm diameter pipe. The air enters at M=2.5 and is to leave at M=1.5. What length of the pipe is required? What length of the pipe would give M=1 at the exit? Assume that f = 0.002 and that the flow is adiabatic.

7. Air flows along a flat wall at a Mach number of 3.5 and a preaaure of 100 kPa. The wall turns towards the flow through an angle of 25˚ leading to the formation of an oblique shock wave. A short distance downstream of this, the wall turns away from the flow through an angle of 25˚ leading to the generation of an expansion wave causing the flow to be parallel to its original direction. Find the Mach number and pressure downstream of the expansion wave.
8. Air flows through a constant area duct whose walls are kept at a low temperature. The air enters the pipe at a Mach number of 0.52, a pressure of 200 kPa, and a temperature of 350˚C. The rate of heat transfer from the air to the walls of pipe is estimated to be 400 kJ/kg of air. Find the Mach number, temperature, and pressure at the exit of the pipe. Assume that the flow is steady, that the effects of wall friction can be neglected and that the air behaves as a perfect gas.
9. What are pressure deflection diagrams? Discuss the application of pressure deflection diagrams in shock-shock interactions with a suitable example.

Section C

Section C has two (02) question of 20 marks each. Both the questions are compulsory; however, one question has an internal choice. These questions are of long answer type (maximum 500 words for each question).

10. Find the lift per meter span for the wedge shaped airfoil shown in figure below. The Mach number and the pressure ahead of the airfoil are 2.6 and 40 kPa respectively.



11. Consider a supersonic flow with Mach number, pressure and temperature of 3.0, 1 atm and 300 K respectively. The flow is deflected through an angle θ_1=14˚ by a compression corner at a point A on the lower wall, creating an oblique shock wave emanating from point A. This shock impinges on the upper wall at point B. Also precisely at point B the upper wall is bent through an angle θ_2 =10˚.The incident shock is reflected at point B, creating a reflected shock wave which propagates downward and to the right. Calculate the Mach number, pressure and temperature in the region behind the reflected shock wave.

OR

Consider an infinitesimally thin flat plate at a 5˚ angle of attack in a Mach 2.6 freestream. Calculate the lift and drag coefficients.