

Name:

Enrolment No:



UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2019

Course: Supersonic Aerodynamics
Program: B. Tech. ASE
Course Code: ASEG 411

Semester: VI
Time 03 hrs.
Max. Marks: 100

Instructions: Assume any missing data appropriately. The use of tables for isentropic flow properties, normal shock properties, Prandtl's Meyer function and θ - β - M chart is permitted.

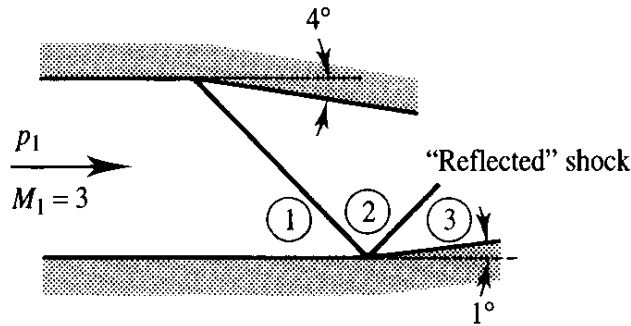
SECTION A

S. No.		Marks	CO
Q 1	A pitot tube is inserted into an airflow where the static pressure is 1 atm. Calculate the flow Mach number when the Pitot tube measures 12.06 atm.	04	CO1
Q 2	Discuss the qualitative aspects of hypersonic high temperature flows.	04	CO1
Q 3	Consider a flat plate at an angle of attack α to a Mach 2.4 airflow at 1 atm pressure. What is the maximum pressure that can occur on the plate surface and still have an attached shock wave at the leading edge?	04	CO2
Q 4	Consider an isentropic compression corner wherein the flow is turned through a total angle of 15° . The Mach number and pressure upstream of the wave are $M_1 = 10$ and $p_1 = 1$ atm., respectively. Calculate the Mach number and pressure in region 2 behind the compression waves.	04	CO2
Q 5	Consider a 15° half-angle wedge at zero angle of attack in a Mach 3 flow of air. Calculate the drag coefficient. Assume that the pressure exerted over the base of the wedge, the base pressure, is equal to the freestream pressure.	04	CO3

SECTION B

Q 6	A shock across which the pressure ratio is 1.18 moves down a duct into still air at a pressure of 100 kPa and a temperature of 30°C . Find the temperature and velocity of the air behind the shock wave. If instead of being at rest, the air ahead of the shock wave is moving towards the wave at a velocity of 75 m/s, what would be the velocity of the air behind the shock wave?	10	CO1
Q 7	Find the pressure, temperature and velocity in region 3 shown in figure below. The	10	CO2

pressure, temperature and Mach number in region 1 are 20 kPa, 20 °C and 3.0 respectively.



Q 8 Establish that the Prandtl - Glauert's transformation maps an irrotational isentropic flow in compressible space (x, y) to an irrotational, isentropic flow in an incompressible space (ξ, η) . Hence, find the P-G compressibility correction for pressure coefficient.

OR

Under low-speed incompressible flow conditions, the pressure coefficient at a given point on an airfoil is -0.36. Calculate the C_p at this point when the freestream Mach number is 0.62. If this point is the point of maximum suction on the airfoil, estimate the critical Mach number for the airfoil.

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CO4

Q 9 Consider a supersonic flow with an upstream Mach number of M_∞ . This flow moves over a wavy wall with a contour given by $y_w = h \cos(2\pi x/l)$, where y_w is the ordinate of the wall, h is the amplitude, and l is the wavelength. Assume that h is small. Using the small perturbation theory, derive an equation for the perturbed velocity potential and the surface pressure coefficient.

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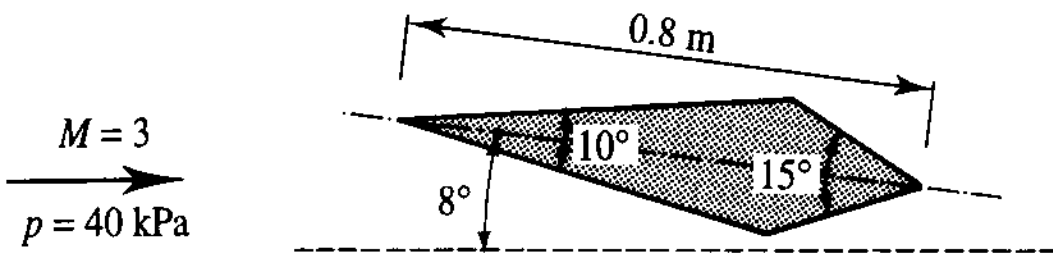
CO4

SECTION-C

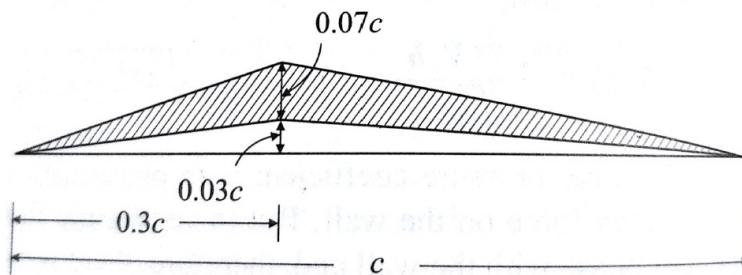
Q 10 For the double wedge airfoil shown in figure below, find the lift per meter span if the Mach number and pressure in the uniform flow ahead of the airfoil are 3 and 40 kPa respectively. Use shock-expansion theory.

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CO3

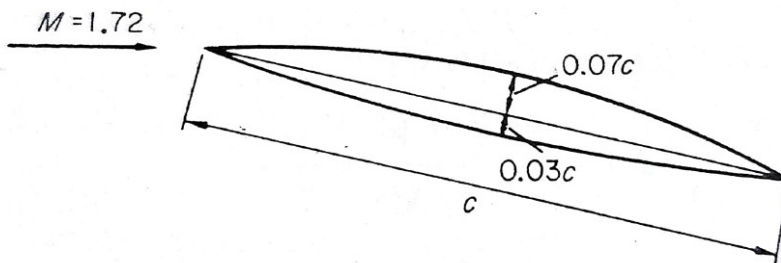


Q 11 A two-dimensional thin airfoil shown in figure below is placed in a stream with Mach number 3.0 and is at an angle of attack of 2° . Using linearized theory, estimate the pressure coefficients on the top and bottom surfaces. Also, find the lift and drag coefficients.



OR

Consider a biconvex airfoil section made up of two unequal circular arcs dimension as shown in figure below. The airfoil is placed in a freestream of Mach number 1.7 and angle of attack α . Using linearized theory; estimate the values of lift, and drag coefficients.



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CO4

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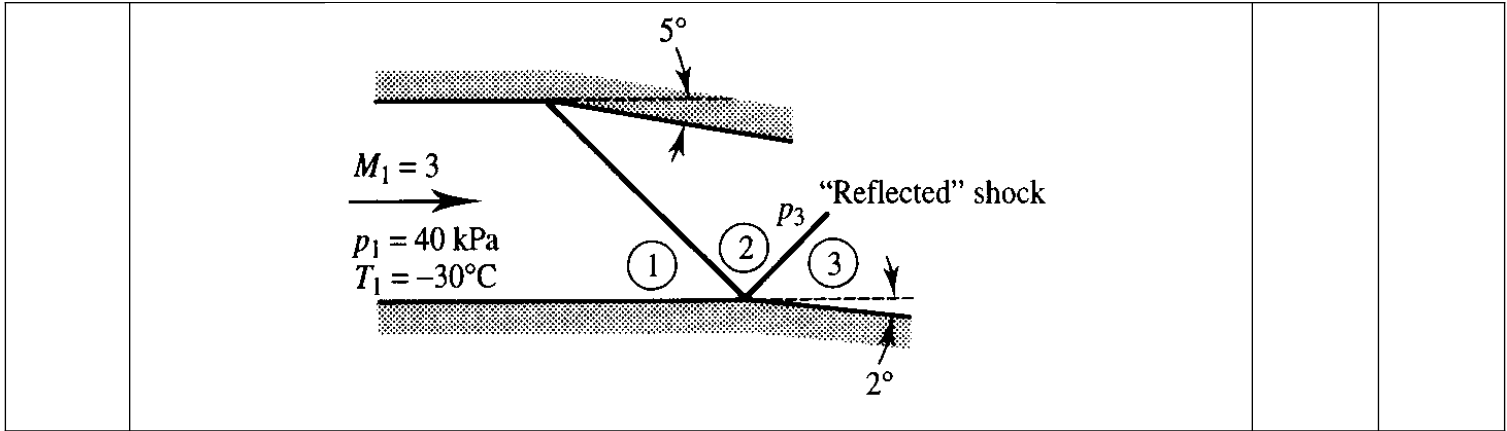
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SECTION A

S. No.		Marks	CO
Q 1	A pitot tube is inserted into an airflow where the static pressure is 1 atm. Calculate the flow Mach number when the Pitot tube measures 2.714 atm.	04	CO1
Q 2	Discuss the following phenomena associated with hypersonic flows. (a) Shock Layer (b) Real Gas Effects	04	CO1
Q 3	Discuss the phenomena of Mach reflection with the help of suitable sketches.	04	CO2
Q 4	List the effects of following in context to oblique shock waves a. Change in Mach number for given deflection b. Change in deflection for a given Mach number	04	CO2
Q 5	Define Critical Mach number. Discuss the effects of airfoil thickness and wing sweep on Critical Mach number.	04	CO4

SECTION B

Q 6	Consider motionless air with $p_1=0.1$ atm and $T_1=300$ K in a constant area tube. We wish to accelerate this gas to Mach 1.5 by sending a normal shock wave through the tube. Calculate the necessary value of the wave relative to the tube.	10	CO1
Q 7	Find the pressure, temperature and velocity in region 3 shown in figure below. The pressure, temperature and Mach number in region 1 are 40 kPa, -30 °C and 3.0 respectively.	10	CO2



Q 8 A simple wing may be modeled as a 0.3 m wide flat plate set at an angle of 3° to an airflow at a Mach number of 3, 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 wave formation on the wing.

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CO3

Q 9 A shallow irregularity of length l , in a plane wall, as shown in figure below, is given by expression $y=kx(1-x/l)$, where $0 < x < l$ and $k \ll 1$. A uniform supersonic stream with freestream Mach number M_∞ is flowing over it. Using linearized theory, derive an expression for the perturbation velocity potential and local pressure coefficient on the surface.

OR

Prove that the following transformations maps an irrotational isentropic flow in compressible space (x, y) to an irrotational, isentropic flow in an incompressible space (ξ, η) .

$$\begin{aligned} \xi &= x \\ \eta &= \beta y \\ \hat{\phi}(\xi, \eta) &= \beta \hat{\phi}(x, y) \end{aligned}$$

Also, establish that the shape of the airfoil is unaltered in the above transformation.

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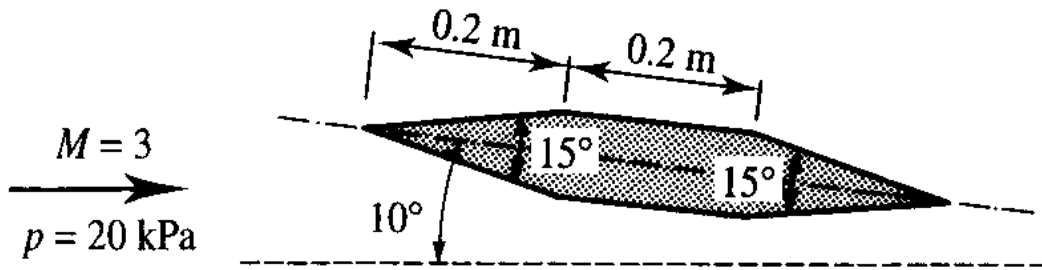
CO4

SECTION-C

Q 10 Consider two-dimensional flow over the double-wedge airfoil as shown in figure below. Find the lift and drag coefficients of the airfoil as well as the pressure variations on its surface.

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CO3

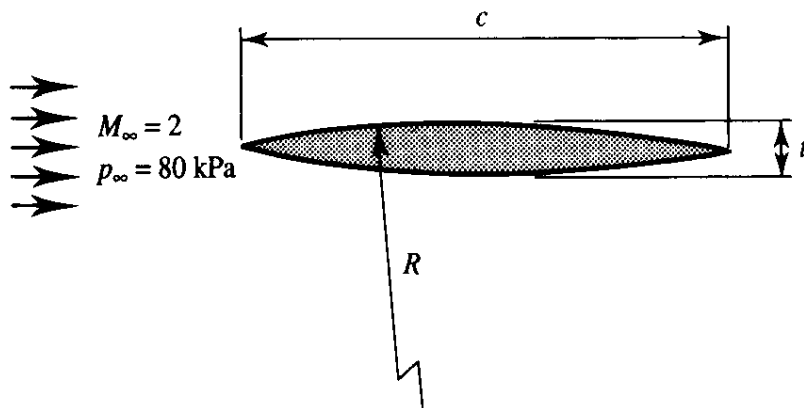


Q 11

Consider a diamond-wedge airfoil with a half-angle ϵ_0 . The airfoil is at an angle of attack α to a freestream with Mach number M_∞ . Using linear theory, derive expressions for lift and wave-drag coefficients of the airfoil. Estimate these coefficients if $\epsilon_0 = 15^\circ$, $\alpha = 10^\circ$ and $M_\infty = 3.0$

OR

An airfoil of the shape shown in figure below is placed in a flow at a Mach number of 2 and a pressure of 80 kPa. Derive expressions for the pressure variations along the upper and lower surfaces.



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CO4