Code No: RR322105

Set No. 1

III B.Tech II Semester Supplementary Examinations,
November/December 2005
HIGH SPEED AERODYNAMICS
(Aeronautical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) What is the relationship between internal energy and enthalpy? Carbon dioxide expands isentropically through a nozzle from a pressure of 3.0 bar to 1.0 bar. If the initial temperature is 463 K , determine
   (b) The final temperature,
   (c) The enthalpy drop and
   (d) The change in the internal energy. [4x4=16]

2. (a) Prove the relation $M_2^* = \frac{1}{M_1^*}$
   (b) Hence show that $M_2^2 = \frac{1+\frac{\gamma-1}{2}M_1^2}{\gamma M_1^2-\frac{\gamma-1}{2}}$
   (c) And show that the downstream Mach number is function of the upstream Mach number alone.
   (d) Comment on the situation when M_1 is very large. [5+5+3+3]

3. A thin wedge of semi vertex angle θ is placed in a supersonic stream and the shock angle referenced from the axis of the wedge is β .The free stream Mach number is M_1 . Hence obtain the θ - β - M relation. [16]

4. The θ - β - M relation for an oblique shock wave is given by $\tan\theta = 2\cot\beta\frac{M_1^2\sin^2\beta-1}{M_1^2(\gamma+\cos 2\beta)+2}$ .Consider the θ - β - M diagram and explain the following situations;

   (a) If in a given physical problem $\theta < \theta_{\ max}$
   (b) if $\theta > \theta_{\ max}$. Make use of sketches and plots along with a drawn θ - β - M diagram on your answer sheet. [16]

5. Consider the equation of continuity under isentropic flow conditions and define the non-dimensional mass flow parameter .Obtain the relationship for the same in terms of Mach number as given below $\frac{m\sqrt{T_0}}{Ap_0}\sqrt{\frac{R}{\gamma}} = \left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/2(\gamma-1)} \frac{M}{\left(\frac{2}{\gamma+1}+\frac{\gamma-1}{\gamma+1}M^2\right)^{(\gamma+1)/2(\gamma-1)}}$ [16]

6. Describe the behavior of flow in a convergent-divergent nozzle when it is operated at

   (a) the design pressure ratio,

(b) pressure ratio higher than the design value,

(c) pressure ratio lower than the design value. Make use of sketches and plots to illustrate your answer. [16]

7. Explain why irrotational flows are often described by a velocity potential Φ. Define the velocity potential Φ for a two dimensional flow field. Hence obtain the velocity potential equation for a 2D irrotational flow under steady, compressible and isentropic conditions. State the utilities of this equation for analyzing flow field around an airfoil along with limitations if any. [16]

8. Consider an airfoil placed in a trisonic wind tunnel. Some systematic studies were made for studying flow over it up to sonic speed. Present the variation of lift and drag through plots and sketches with illustrations over this Mach number range. [16]

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Code No: RR322105 **Set No. 2**

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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Elaborate that entropy is an extensive property and
   (b) That for a real process occur only if the change is larger than the value of $\left(\frac{\delta Q}{T}\right)$.
   (c) Show that $\left(\frac{\partial U}{\partial S}\right)_V = T$, Thermodynamic temperature and $\left(\frac{\partial U}{\partial V}\right)_S = -p$ pressure. U is the internal energy of a system under equilibrium. [6+5+5]

2. (a) Illustrate with theory the phenomenon of Normal shock waves and that the Mach number behind a Normal Shock wave is always subsonic.
   (b) Develop the equation $M_1^* M_2^* = 1$ along with
   (c) The physics involved. [8+4+4]

3. A thin wedge of semi vertex angle θ is placed in a supersonic flow of free stream Mach number M_1 and the shock angle referenced from the axis of the wedge is β . Show that the θ - β - M relation is given by $\tan\theta = 2\cot\beta\frac{M_1^2\sin^2\beta - 1}{M_1^2(\gamma+\cos 2\beta)+2}$ [16]

4. The θ - β - M relation for an oblique shock wave is given by $\tan\theta = 2\cot\beta\frac{M_1^2\sin^2\beta - 1}{M_1^2(\gamma+\cos 2\beta)+2}$ .Consider the θ - β - M diagram and explain the following situations;
   (a) If in a given physical problem θ is fixed and M_1 is increased
   (b) if $\theta > \theta_{max}$. Make use of sketches and plots along with a drawn θ - β - M diagram on your answer sheet. [16]

5. Consider the equation of continuity under isentropic flow conditions and define the non-dimensional mass flow parameter .Obtain the relationship for the same in terms of Mach number as given below $\frac{m\sqrt{T_0}}{Ap_0}\sqrt{\frac{R}{\gamma}} = \left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/2(\gamma-1)} \frac{M}{\left(\frac{2}{\gamma+1}+\frac{\gamma-1}{\gamma+1}M^2\right)^{(\gamma+1)/2(\gamma-1)}}$ [16]

6. It I desired to expand air from $p_0 = 200$ kPa and $T_0 = 500$ K through a throat to an exit Mach number of 2.5. If the desired the desired mass flow is 3 kg/s, compute
   (a) the throat area , and
   (b) the exit conditions pressure, temperature, velocity and area . Assume isentropic flow. [16]

7. Make use of the partial differential equation for compressible subsonic irrotational and isentropicflow field, develop the linearized potential equation for subsonic compressible and isentropic flow as given below; $(1 - M_\infty^2)\phi_{xx} + \phi_{yy} = 0$ in usual nomenclature. [16]

8. The perturbation potential equation is given as $(1 - M_\infty^2)\frac{\partial^2 \hat{\phi}}{\partial x^2} + \frac{\partial^2 \hat{\phi}}{\partial y^2} = 0$. The independent variables x and y are transformed in to a new space $\xi =$ x and $\eta = \beta$y , where β=1-M^2 .Now show that the above equation get transformed into the Laplace equation . Hence explain that within limitations, results from incompressible flow can be converted into data for compressible flow. [16]

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Code No: RR322105 **Set No. 3**

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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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1. (a) Define the terms enthalpy, stagnation temperature and stagnation pressure. Air at a temperature of 288 K and a Pressure of 1 atm (101,325 kPa) flows isentropically at a velocity of 300 m/s. Assuming air to behave as a perfect gas of constant specific heats,
   (b) Calculate the enthalpy, stagnation temperature and stagnation pressure .
   (c) Explain the significance of stagnation properties. [6+6+4]

2. A Pitot-static tube is used in a subsonic compressible flow. The same tube was used in a stream of supersonic flow.
   (a) Compare the two results giving free stream Mach number and
   (b) provide your observations in these two cases. [12+4]

3. Write notes on
   (a) regular reflection of a shock wave from a solid boundary.
   (b) Interaction of right and left running shock waves at the end of a variable area duct. Present yourself with neat sketches providing all details [8+8]

4. Air at $M_1 = 2.3$ and at a pressure of 70 kPa flows along a wall which bends away at an angle of 12^0 from the direction of flow. Determine the Mach number and pressure after the bend. If in another case the flow experiences a compression over the concave wall which actually bends through the same angle, determine the Mach number and pressure with the same free stream conditions. Sketch the flow fields in both the cases. [16]

5. Consider the quasi-one dimensional form of the equation of continuity and derive the area-velocity relationship given by $\frac{dA}{A} = (M^2-1)\frac{dV}{V}$. Explain that this equation holds for flows at subsonic and supersonic Mach numbers .Further that a supersonic nozzle behaves as a subsonic diffuser and a subsonic nozzle acts as a supersonic diffuser. Make use of sketches and plots along with practical information from supersonic and subsonic wind tunnels. [16]

6. Air at a temperature of 284 K and atmospheric pressure flows isentropically through a C-D nozzle.The velocity at the inlet is 150 m/s and the inlet area is $10cm^2$ .If the flow at the exit of the nozzle is supersonic, find
   (a) M_{inlet},

(b) p_0 and T_0

(c) temperature and pressure at the throat ,

(d) the velocity and Mach number at exit if $T_2 = 220$ K, and

(e) area at the throat. Assume isentropic flow. [16]

7. The equations of 2-D fluid motion in isentropic flow are given in indicial notation as below:
Continuity $\frac{\partial \rho}{\partial t} + \rho u_j \frac{\partial u}{\partial x_j} = 0$
Momentum $\rho \frac{\partial u_i}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = -\frac{\partial p}{\partial x_i}$
Isentropic relation $\frac{p}{p_0} = \left(\frac{\rho}{\rho_0}\right)^{\gamma}$
If the perturbation velocity components are given as u_1 = U + u and u_2 = v , then develop the equation of fluid motion in terms of perturbation velocity components and suggest how to apply B.C. for an elongated body. [16]

8. Define critical Mach number and plot lift and drag coefficient v/s Mach number for a conventional airfoil .Now describe a supercritical airfoil due to Whitcomb and plot the aerodynamic characteristics for this airfoil section on the same plot. Illustrate further with Cp plot. [16]

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Code No: RR322105

Set No. 4

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HIGH SPEED AERODYNAMICS
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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Define the term coefficient of Compressibility K of a fluid and
   $d\rho = \left(\frac{\partial\rho}{\partial T}\right) dT + \left(\frac{\partial\rho}{\partial p}\right) dp$
   (b) Now demonstrate that $E = \frac{1}{K - \beta\frac{dT}{dp}}$, where E Bulk modulus of elasticity and β = coefficient of volume expansion. [8+8]

2. (a) Define strong shock and weak shock wave in a compressible flow .
   (b) Illustrate with sketches and plots.
   (c) Hence develop the famous Prandtl relation for normal shock waves.
   (d) Provide detailed comments on this relation. [3+3+7+3]

3. Consider a thin wedge placed in a supersonic flow.
   (a) Explain difference between a shock wave and a Mach wave.
   (b) Hence prove for an oblique shock wave that $M_{n,2}^2 = \frac{1+[(\gamma-1)/2]M_{n,1}^2}{\gamma M_{n,1}^2-(\gamma-1)/2}$ where $M_{n,1}$ and $M_{n,2}$ are the normal components of the supersonic Mach numbers across the oblique shock waves.
   (c) Can you determine the down stream Mach number? [6+6+4]

4. The θ - β - M relation for an oblique shock wave is given by
   $\tan\theta = 2\cot\beta\frac{M_1^2\sin^2\beta-1}{M_1^2(\gamma+\cos 2\beta)+2}$ .Consider the θ - β - M diagram and explain the following situations;
   (a) If in a given physical problem θ is fixed and M_1 is increased
   (b) if $\theta > \theta_{max}$. Make use of sketches and plots along with a drawn θ - β - M diagram on your answer sheet. [16]

5. Consider the equation of continuity under isentropic flow conditions and define the non-dimensional mass flow parameter .Obtain the relationship for the same in terms of the area ratio as given below $\frac{m\sqrt{T_0}}{Ap_0}\sqrt{\frac{R}{\gamma}} = \left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/2(\gamma-1)}\frac{A^*}{A}$ [16]

6. Air flows isentropically through a nozzle of throat area $6cm^2$ and exit area $24cm^2$. If p_0 = 640 kPa and $T_0 = 200^0$C, compute the mass flow, exit pressure and exit mach number for
   (a) subsonic flow,

(b) supersonic flow. [16]

7. Consider a 2-D, irrotational isentropic flow over an arb. shaped object , given as below:
$$\left[1-\frac{1}{a^2}\left(\frac{\partial\phi}{\partial x}\right)^2\right]\frac{\partial^2\phi}{\partial x^2}+\left[1-\frac{1}{a^2}\left(\frac{\partial\phi}{\partial y}\right)^2\right]\frac{\partial^2\phi}{\partial y^2}-\frac{2}{a^2}\left(\frac{\partial\phi}{\partial x}\right)\left(\frac{\partial\phi}{\partial y}\right)\frac{\partial^2\phi}{\partial x\partial y}=0 \text{ where } \phi=\phi(x,y)$$
.Now $\phi = V_\infty x + \hat{\phi}$, introduces perturbation potential. Obtain the perturbation velocity equation. Present your work. [16]

8. Describe the effect of profile / shape of the object (streamlined or blunt) on the local flow over it when placed in a fluid stream. Hence consider the corresponding change in local Mach number over the profile by taking a circular cylinder and an airfoil. Now present your work through sketches and plots. [16]

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