Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

M.E Sem-I Examination January 2010

Subject code: 711103 Subject Name: Fluid Mechanics and Gas Dynamics

Date: 25 / 01 / 2010 Time: 12.00 – 2.30 pm

Total Marks: 60

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Use of gas tables permitted.**

Q.1 **(a)** Define stagnation temperature and critical temperature of a gas. Also derive the equation $\frac{T^*}{T} = \left(\frac{2}{\gamma+1}\right)$ with usual notations. **06**

(b) The resistance force R of a supersonic plane during flight can be considered as dependent upon the length of the air craft l, velocity V, air viscosity μ, air density ρ and the bulk modulus of air K. Express the functional relationship between these variables and resisting force by dimensional analysis. **06**

Q.2 **(a)** Define Static and Stagnation enthalpies. Also prove that $h_0 = h\left[1+\left(\frac{\gamma-1}{2}\right)M^2\right]$ with usual notations. **06**

(b) The air at 4 bar and 550 K flows with velocity of 230 m/s in a duct of 35 cm diameter. Calculate (i) mass flow rate (ii) stagnation temperature (iii) Mach number (iv) stagnation pressure for compressible and incompressible flow. Take $C_p = 1.04$ kJ/kgK and $\gamma = 1.35$ for air. **06**

OR

(b) Derive continuity equation in cylindrical polar co-ordinates for a two dimensional fluid flow with usual notations. **06**

Q.3 **(a)** Explain Stream function for two dimensional fluid flow and give its properties. **06**

(b) In a two dimensional incompressible flow the fluid velocity components are given by $u = x - 4y$ and $v = -y - 4x$. Does the velocity potential exist? If yes, then derive its form. **06**

OR

Q.3 **(a)** Explain the difference between Source flow and Sink flow with figures. **04**

(b) An open circular cylinder of 30 cm diameter and 130 cm long contains water up to a height of 90 cm. It is rotated about its vertical axis. Find the speed of rotation when (1) no water spills and (2) Axial depth of water is zero. **04**

(c) A uniform flow of 10 m/s is flowing over a doublet of strength 16 m^2/s. The doublet is in the line of the uniform flow. Determine (1) Radius of Rankine circle (2) Value of stream line function at Rankine circle (3) Resultant velocity at a point on the Rankine circle at an angle of 30^0 from x-axis (4) Maximum velocity and location of the point on Rankine circle. **04**

Q.4 **(a)** Derive Rankine-Hugoniot Relation for a normal shock wave as follow: **08**

$$\frac{p_y}{p_x}=\frac{\left(\frac{\gamma+1}{\gamma-1}\right)\frac{\rho_y}{\rho_x}-1}{\left(\frac{\gamma+1}{\gamma-1}\right)-\frac{\rho_y}{\rho_x}}$$

(b) Air at $p_0 = 10$ bar and $T_0 = 400$ K is supplied to a 50 mm diameter pipe. The friction factor for the pipe surface is 0.002. If Mach number changes from 3.0 at the entry to 1.0 at the exit, determine the length of the pipe and mass flow rate of air. **04**

OR

Q.4 **(a)** Derive the following equation for maximum heat transfer $(Q_{\max})$ for Rayleigh flow with usual notations. **04**

$$Q_{\max} = C_p T_1 \cdot \frac{(1-M^2)^2}{2(1+\gamma)M^2}$$

(b) The gas at pressure of 0.69 bar and temperature of 278 K enters a combustion chamber at a velocity of 60 m/s. The heat supplied in the combustion chamber is 1400 kJ/kg. Determine the Mach number, pressure, temperature and velocity of the gas at the exit. Take $\gamma = 1.4$ and $C_p = 1.004$ kJ/kgK for gas. **08**

Q.5 **(a)** Define the following terms for an aerofoil with figure: **04**
(1) Drag force (2) Chord length (3) Angle of attack (4) Span

(b) A jet plane of total weight 20 kN has wing area of 25 m^2. It is flying at a speed of 200 km per hour. When the engine develops 600 kW, 70 % of this power is used to overcome the drag resistance of the wings. Calculate the co-efficient of lift and co-efficient of drag for the wings. Take air density 1.25 kg/ m^3. **04**

(c) Define the following model laws and give their fields of applications. **04**
(1) Reynold's model law (2) Froude model law (3) Euler model law
(4) Weber model law.

OR

Q.5 **(a)** Using equation $\frac{dC}{C}=\left(\frac{1}{M^2-1}\right)\frac{dA}{A}$, discuss the type of nozzles required for subsonic and supersonic flows. **04**

(b) A ship model of scale 1:50 is towed through sea water at a speed of 1 m/s. A force of 2 N is required to tow the model. Determine the speed of ship and the propulsion force on the ship. If prototype is subjected to wave resistance only. **04**

(c) Air at pressure of 6.5 bar and stagnation temperature of 300 K enters a convergent-divergent nozzle with flow in the divergent portion to be supersonic. A normal shock exists just at a plane on the exit of the nozzle. The exit to throat area ratio of the nozzle is 3.0. Find the Mach number just outside the normal shock. Take $\gamma = 1.4$ for air. **04**

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