Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

VII SEMESTER B.TECH. (AERONAUTICAL ENGINEERING)

END SEMESTER EXAMINATIONS, FEB 2021

SUB: HYPERSONIC AEROTHERMODYNAMICS [AAE 4003]

REVISED CREDIT SYSTEM
(01/02/2021)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

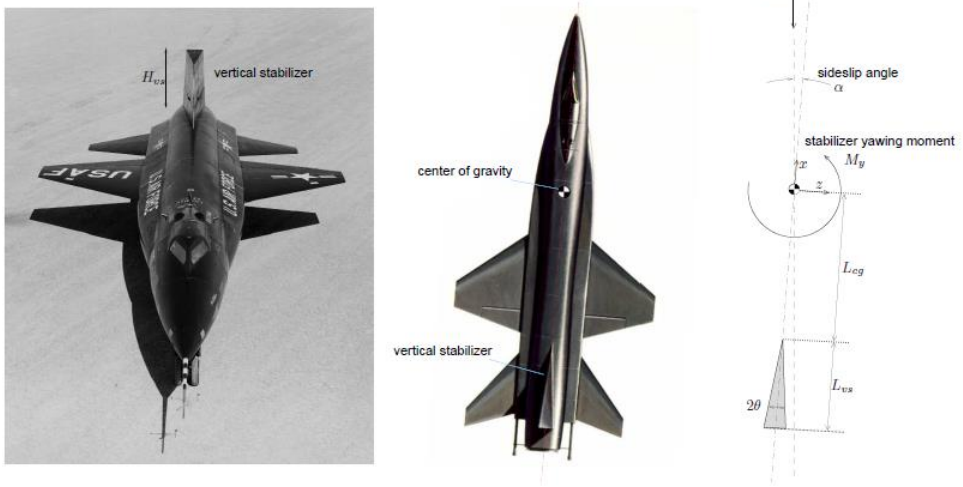
- Answer **ALL** the questions.
- Missing data may be suitable assumed.
- Data tables will be given.

1A.	What do you mean by 'momentum thickness' and 'energy thickness' in boundary layer flow?	**(2)**
1B.	Derive the expression for drag force on a flat plate due to boundary layer.	**(3)**
1C.	For the velocity profile for laminar boundary layer $\frac{u}{U}=\frac{3}{2}\left(\frac{y}{\delta}\right)-\frac{1}{2}\left(\frac{y}{\delta}\right)^3$. Determine the boundary layer thickness, shear stress, drag force and coefficient of drag in terms of Reynolds number.	**(5)**
2A.	What do you mean by 'Stream function' and also show the expression for stream function?	**(2)**
2B.	With the help neat diagrams describe the concept of viscous interaction in hypersonic flows.	**(3)**
2C.	With the help of neat diagram derive the expression for displacement thickness and energy thickness.	**(5)**
3A.	Write short note on physical significance of High temperature flows.	**(2)**
3B.	A jet of air at a Mach number of 2.1 is deflected inwards at the corner of a wall. The wave angle at the corner is 60°. Determine the deflection angle of the wall and the static pressure downstream of the shock if the stagnation pressure upstream of the shock was found to be 200 kPa.	**(3)**
3C.	With the help of velocity-altitude map from the fundamentals derive the expression for aerodynamic forces and aerodynamic heating.	**(5)**
4A.	Write the differences between tangent wedge and tangent cone methods.	**(2)**
4B.	Find the static temperature and velocity of air imparted to the fluid by the following normal shock conditions. Stagnant pressure 350 KPa, Stagnant temperature 297 K, shock moves with a velocity 1050 m/s into stagnant air.	**(3)**
4C.	With the help of neat diagrams derive the basic hypersonic shock relations.	**(5)**

5A. Determine the ratio of exit to the entry density value and limiting the wedge angle of the following conditions for a symmetric wedge experiment. Whose inlet Mach number is given as 5. **(2)**

5B. Derive the expression for Hypersonic shock relations in terms of the Hypersonic similarity parameter. **(3)**

5C. A vertical stabilizer is a rudder mounted on the aft end of the fuselage that provides directional stability to the aircraft when it sideslips with respect to the free stream. For instance, the X-15 hypersonic rocket plane used a vertical stabilizer that had the shape of a wedge of semi-angle θ. When the rocket plane side slipped by an angle α, the aerodynamic forces on the vertical stabilizer induced a yawing moment My around the center of gravity that restored the lateral attitude. In the notation below, Lcg is the distance from the vertical stabilizer's edge to the center of gravity, whereas Lvs and Hvs are, respectively, the length and height of the vertical stabilizer. **(5)**



$$C_y = \frac{2M_y}{\rho_\infty U_\infty^2 H_{vs} L_{vs} L_{cg}}$$

Assuming that the free-stream Mach number is $Ma_\infty = 8$, and the sideslip angle is $\alpha = 12^\circ$, calculate the yawing moment coefficient in the following cases:

a) $\theta = 20^\circ$.

b) $\theta = 8^\circ$.

c) Redo parts (a) and (b) using the Newtonian theory of hypersonic and compare the solutions.