TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology

Department of Mechanical & Automotive Engineering

UNIVERSITY SPECIAL/SUPPLEMENTARY EXAMINATION FOR:

BSc. Mechanical Engineering

EMG 2417: GAS DYNAMICS & BOUNDARY LAYER THEORY

SPECIAL/SUPPLEMENTARY EXAMINATION

SERIES: SEPTEMBER 2018

TIME: 2 HOURS

DATE: Pick Date **Sep 2018**

Instruction to Candidates:

You should have the following for this examination

- *Answer booklet*
- *Non-Programmable scientific calculator*
- *Gas Dynamics Tables*

This paper consists of **FIVE** questions. Attempt question **ONE (Compulsory)** and any other **TWO** questions.

Maximum marks for each part of a question are as shown.

Do not write on the question paper.

Question ONE

a) Describe with the aid of sketches the development of a finite amplitude rarefaction wave. Show the directions of flow and the wave propagation **(8marks)**

b) Derive Prandtl- Meyer's relation for oblique shock wave. **(10 marks)**

c) Supersonic flow at M=3, P=100kPA and T= 300K is deflected through 20° at a compression corner. Determine;

i. the shock wave angle

ii. the flow properties downstream of the shock, P_2, T_2, P_{02}, T_{02}.

iii. the percentage loss in stagnation pressure. **(6 marks)**

d) Determine the displacement and energy thickness given that δ=0.4 mm for the boundary layer whose velocity profile is given by $\frac{u}{U_s} = \frac{3}{2}\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^3$ **(6 marks)**

Question TWO

a) Air ($\gamma = 1.4, R = 287 J/kg \cdot K, c_p = 1.004 kJ/kg \cdot K$) flows in a constant area duct of diameter 1.5cm with a velocity of 100m/s. static temperature of 320K and static pressure of 200kPa. Determine the rate of heat input to the flow necessary to choke the duct. Assume Rayleigh line flow assuming air to behave as a perfect gas with constant specific heat. **(10 marks)**

b) A convergent –divergent nozzle is operating under off-design conditions, resulting in the presence of a shock wave in the diverging portion. A reservoir containing air at 400kPa and 800K supplies the nozzle, whose throat are is 0.2m^2. The Mach No. upstream of the shock is M_1=2.44. The area at the nozzle exit is 0.7m^2.Find the area at the location of the shock and the exit temperature. Refer to Fig 3b

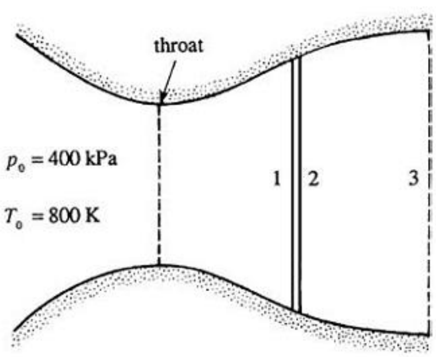

Fig 3b **(10 marks)**

Question THREE

a) For a steep compression wave derive the expressions for velocity when the wave passes through a stagnant gas. **(6 marks)**

b) At the exit of a supersonic nozzle, oblique shock waves appear as shown in figure 3b.Air is the working fluid. If the nozzle back pressure is 101kPa, the stagnation pressure of the flow is 500K, the nozzle throat area 50cm^2 and nozzle exit area is 120cm^2 determine;

i. the nozzle inlet stagnation pressure.
ii. the velocity at the nozzle exit plane
iii. the mass flow rate through the nozzle. **(14 marks)**

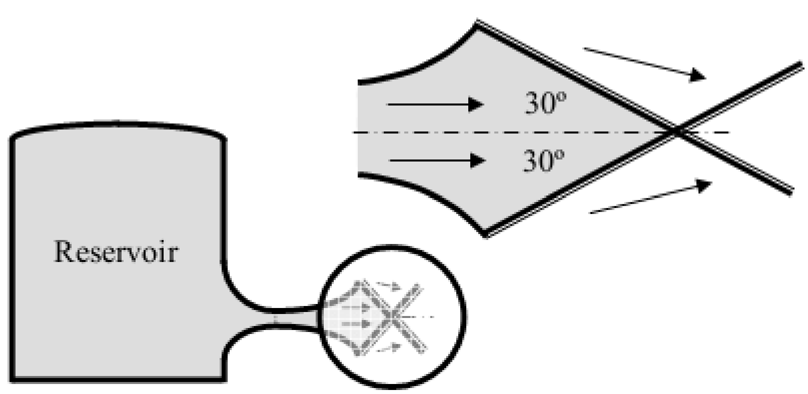

Fig 3b

Question FOUR

a) Explain the design of airfoil of a plane that facilitate that grant its aerodynamic properties. **(6 marks)**

b) A supersonic flow at Mach 3.0 and $\gamma = 1.4$ is to be slowed down via a normal shock in a divergent channel. For the conditions shown in Fig below, find p_2/p_1 and p_e/p_i.

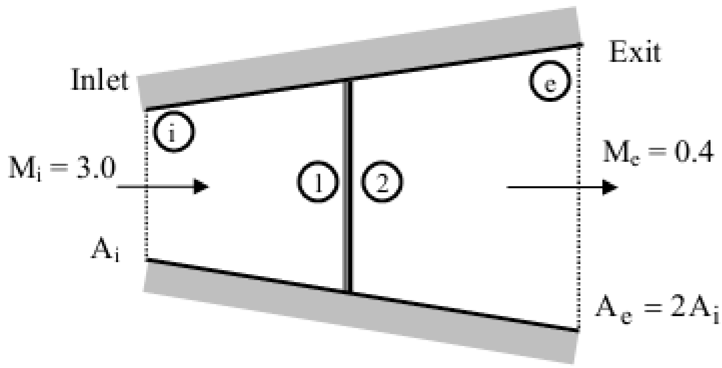

Fig 4b **(6 marks)**

c) Determine the ratio of momentum and displacement thickness of the boundary layer thickness δ when the velocity profile is given by $\frac{u}{U_s} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$ **(4 marks)**

d) State 4 assumptions used in deriving Rayleigh flow equations **(4 marks)**

Question FIVE

a) In an adiabatic compressible flow of a perfect gas in a round duct with constant diameter D, and interior skin friction coefficient C_f=4fdx/D, (the fanning friction factor) .Starting from the expression $\frac{\dot{m}}{A} dc = -dp - \frac{1}{2}\rho c^2 \left(4f\frac{dx}{D}\right)$ and $c = M \cdot a$ and

$\frac{T_0}{T} = 1 + \frac{a^2}{2c_p T} = 1 + \frac{\gamma - 1}{2}\frac{a^2}{\gamma RT} = 1 + \frac{\gamma - 1}{2} M^2$ derive an equation for $\frac{dM^2}{dx}$ where x is the distance along the duct in the direction of flow. **(15 marks)**

b) Flow parameters of the oblique shock can be derived by relations from the normal shock equations. Identify the relations that connect the property equations for the normal and oblique shocks. **(5marks)**