MACHAKOS UNIVERSITY

University Examinations 2016/2017

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (COMPUTER AND MATHEMATICS)

BACHELOR OF SCIENCE (COMPUTER AND STATISTICS)

BACHELOR OF SCIENCE (MATHEMATICS)

SMA 434: GAS DYNAMICS

DATE: 28/7/2017 **TIME: 2:00 – 4:00 PM**

INSTRUCTIONS

Attempt question ***one (compulsory)*** and any other ***two questions***.

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Sonic velocity through carbon dioxide is $275m/s$. Calculate the temperature in Kelvin. $\gamma = 1.29$, $R = 189$ (3 marks)

b) Hydrogen has a static temperature of 25^0C and a stagnation temperature of 250^0C. Calculate the Mach number. $\gamma = 1.4$, (3 marks)

c) Air flows in a diabetic duct without friction. At one section, the Mach number is 1.5 and further downstream it has increased to 2.8. Calculate the area ratio. (4 marks)

d) A normal shock wave travels at $600m/s$ through stagnant 20^0C. Calculate the velocity induced behind the shock wave. $R = 287$, (5 marks)

e) Air enters a compressor at a stagnation state of $100kpa$ and $27^0 C$. If it has to be compressed to a stagnation pressure of $900kpa$. Calculate the power input to the compressor when the mass flow rate is $0.002kg/s$. assume the compression process to be isentropic. $R = 287m^2/s^2k,\ \ C_p = 1004.5$ (5 marks)

f) Determine the entropy increase caused by a bow shock in a Mach 7 air stream along the stagnation stream line, treating air as a perfect gas. (5 marks)

$\gamma = 1.4$, $S_2 - S_1 = R\ln\left(\frac{P_{01}}{P_{02}}\right)$, $R = 287$

$$\frac{P_{02}}{P_{01}} = \left[1 + \frac{2\gamma}{\gamma+1}\left(M_1^2 \sin\theta_{sw} - 1\right)\right]\left[\frac{(\gamma+1)M_1{}^2 \sin^2\theta_{sw}}{(\gamma-1)M_1{}^2 \sin^2\theta_{sw} + 2}\right]^{\frac{\gamma}{\gamma-1}}$$

g) Calculate the lift per unit span of a flat plate airfoil with a chord of $2m$ when flying at $M = 1.8$ and an angle of attack of 5^0. Ambient air pressure is $0.4bar$.

(5 marks)

QUESTION TWO (20 MARKS)

a) Helium is flowing at a mach number of 1.80 and enters a normal shock. Determine the pressure ratio across the shock. $\gamma = 1.67$,

$$M_2{}^2 = \frac{M_1{}^2 + \frac{2}{(\gamma-1)}}{\left(\frac{2\gamma}{\gamma-1}\right)M_1{}^2 - 1} \quad , \quad p_2\left(1+\gamma M_1{}^2\right) = p_1\left(1+\gamma M_2{}^2\right)$$

(6 marks)

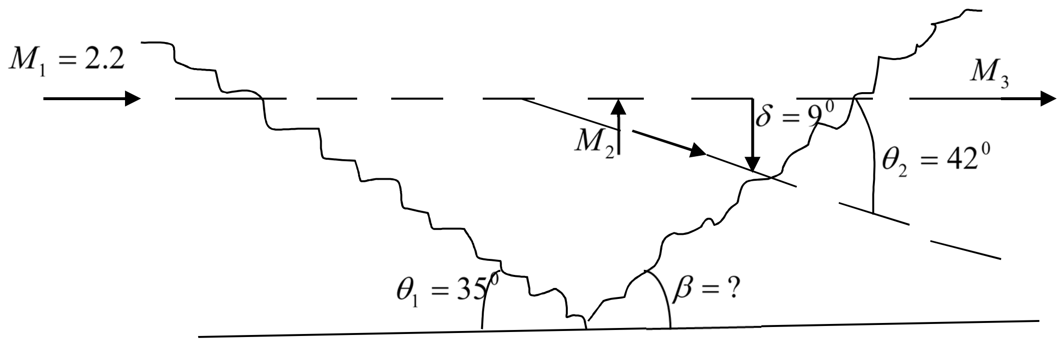
b) Observations of oblique shock in air reveals that a mach number of 2.2 flow at $550K$ and $2\,bar\ abs.$ is deflected by 14^0. Determine the conditions after the shock.

$$\theta = 40^0 \ \ and\ \ 83^0 (weak\ solution\ \ prevails), M_{2n} = 0.7339\ , \frac{T_2}{T_1} = 1.2638\ , \frac{p_2}{p_1} = 2.1660$$

(7 marks)

c) Air at mach 2.2 passes through an oblique shock at 35^0 angle. The shock runs into a physical boundary as below. Calculate the angle of reflection and compare the strengths of the two shock waves. $M_{2n} = 0.806$, $\delta_2 = 9^0$, $\theta_2 = 42^0$

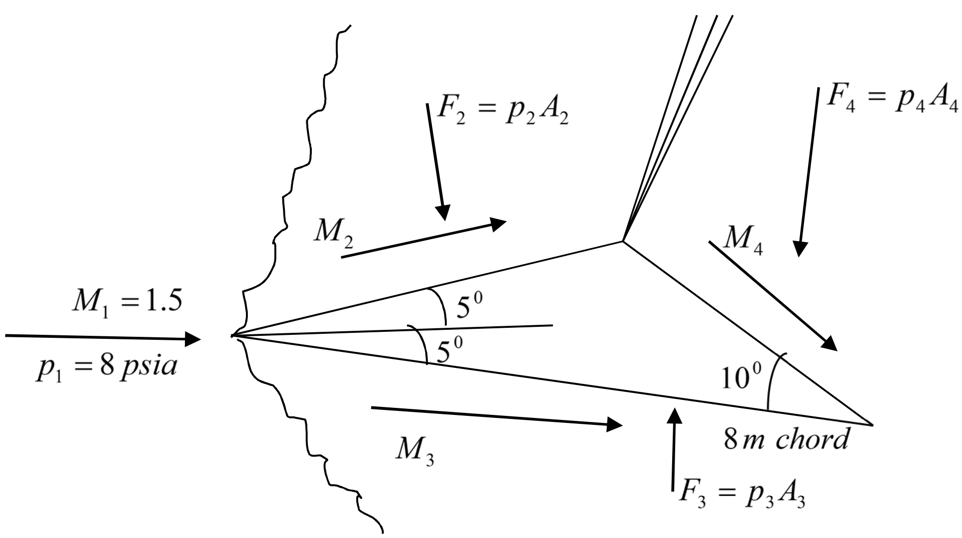
(7 marks)



QUESTION THREE (20 MARKS)

a) It has been suggested that a supersonic airfoil be designed as an isosceles triangle with 10^0 equal angles and an $8m$ chord. When operating at 5^0 angle of attack, the air flow appears as below. Calculate the pressure on the various surfaces and the lift and drag forces when flying at $M = 1.5$ through air with pressure of

$8\ psia, \theta = 48^0, M_{2n} = 0.900, \dfrac{p_2}{p_1} = 1.2838$, $v_2 = 6.7213$, $M_4 = 2.012$ (7 marks)



b) A converging diverging nozzle with an area ratio 3.0 of exhausts into a receiver where the pressure is $1\ bar$. The nozzle is supplied by air at $22^0\ C$ from a larger chamber. At what pressure should the air in the chamber be for the nozzle to operate at its design condition. Calculate the outlet velocity. $\gamma = 1.4$, $R = 287$, $gc = 1$

$\frac{A_2}{A_2^*} = 1$, $\frac{A_2^*}{A_3^*} = 1$, $M_3 = 2.64$, $\frac{p_3}{p_{t3}} = 0.0471$, $\frac{T_3}{T_{t3}} = 0.4177$, $\frac{p_{t1}}{p_{t3}} = \frac{T_{t1}}{T_{t3}} = 1$,

(7 marks)

c) Air has temperature and pressure of $300K$ and $2\,bar\ abs.$ respectively. It is flowing with a velocity of $868m/s$ and enters a normal shock. Determine the density before and after the shock. $R = 287$, $\gamma = 1.4$, $gc = 1$; $\frac{p_2}{p_1} = 7.125$; $\frac{T_2}{T_1} = 2.1375$ (6 marks)

QUESTION FOUR (20 MARKS)

a) Air at $1.2\,atm$ and $270\,K$ is accelerated isothermally to a state at which the pressure is $0.8\,atm.$. Calculate the speed of sound associated with this process. $a = \sqrt{\frac{\Delta p}{\Delta \rho}}$, $gc = 1$, $R = 287$ (5 marks)

b) Oxygen flows in a constant area horizontal, insulated duct. Conditions at section 1 are $p_1 = 50\,psia, T_1 = 600^0 R\ and\ v_1 = 2860m/s.$ At a downstream section the temperature is $T_2 = 1048^0\ R$. $\gamma = 1.4$, $gc = 32.2$, $R = 48.3$

i. Determine M_1 and T_{t1} (5 marks)

ii. Calculate $v_2\ and\ p_2$ (5 marks)

iii. Calculate the entropy change between the two sections (5 marks)

QUESTION FIVE (20 MARKS)

a) Methane gas at $140kPa$ is compressed isothermally, and nitrogen gas at $100kPa$ is compressed isentropically. Calculate the modulus of elasticity of Methane. (4 marks)

b) Oxygen flows into an insulated device with the following initial conditions. $p_1 = 20\,psia$, $T_1 = 600^0\,R\ and\ v_1 = 2960m/s$, $\gamma = 1.4$, $R = 48.3$, $gc = 32.2$. After a short distance, the area has converged from $6m^2\ to\ 2.5m^2$. Assuming steady –one dimensional flow and a perfect gas. $\frac{p_1}{p_{t1}} = 0.0509$, $\frac{T_1}{T_{t1}} = 0.4271$, $C_p = 0.218$ Calculate;

i. M_1 (5 marks)

ii. T_{t1} (3 marks)

iii. p_{t1} (3 marks)

iv. h_{t1} (4 marks)