MACHAKOS UNIVERSITY COLLEGE

(A Constituent College of Kenyatta University)
University Examinations for 2015/2016 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

SECOND SEMESTER EXAMINATIONS FOR THE DEGREE IN
BACHELOR OF EDUCATION (SCIENCE)
BACHELOR OF EDUCATION ARTS

SMA 434: GAS DYNAMICS

Date: 5/8/2016 **Time: 2:00 – 4:00 PM**

INSTRUCTIONS

Answer question ONE and any other TWO questions

QUESTION ONE (30MKS) (COMPULSORY)

a) Argon is compressed adiabatically in a steady –flow compressor from $101 kPa$ and $25^0 C$ to $505 kPa$. If the compression work required is $475\, kJ/kg$, show that the compression process is irreversible. Assume that argon is an ideal gas.

$$\gamma = 1.67 \text{ , } molecular\ mass\ of\ \arg on\ is\ 39.944 \text{ , } \quad w_{12} = \frac{\gamma}{\gamma - 1} RT_1 \left[1 - \left(\frac{P_2}{P_1} \right)^{\frac{\gamma - 1}{\gamma}} \right]$$ (5 marks)

b) Air flows with a velocity of $800 m/s$ and has a pressure of $30\, psia$ and temperature of $600^0 R$. Determine the stagnation pressure. (5 marks)

$$gc = 32.2 \text{ , } R = 53.3 \text{ , } \gamma = 1.4 \text{ , } \quad p_t = p\left[1 + \left(\frac{\gamma - 1}{2} \right) M^2 \right]^{\frac{\gamma}{\gamma - 1}}$$

c) Oxygen flows into an insulated device with the following initial conditions. $p_1 = 20 psia$, $T_1 = 600^0 R$ and $v_1 = 2960 m/s$, $\gamma = 1.4$, $R = 48.3$, $gc = 32.2$. 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)

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

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

(5 marks)

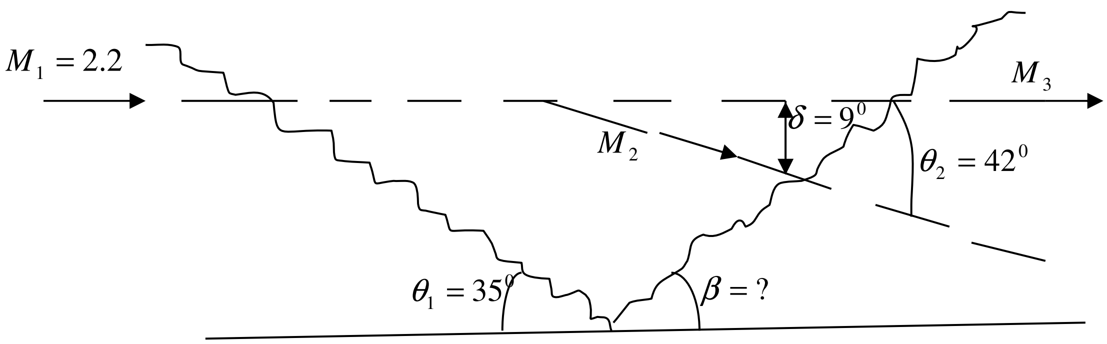
QUESTION TWO (20 MARKS)

a) 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.

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

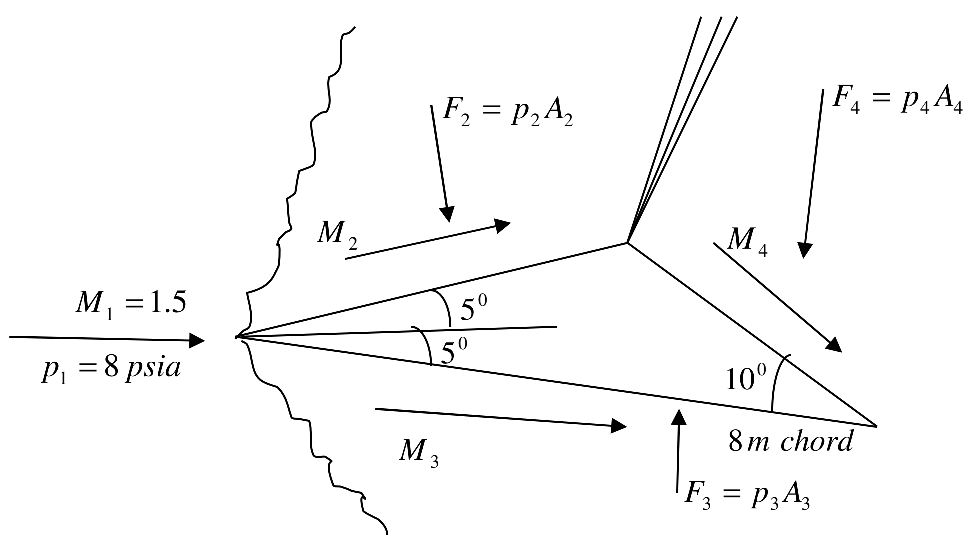
(7 marks)

b) 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. $M_{2n} = 0.806$, $\delta_2 = 9^0$, $\theta_2 = 42^0$ (13 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 a 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 $M_1 = 1.5$ through air with pressure of $8\ psia, \theta = 48^0, M_{2n} = 0.900, \frac{p_2}{p_1} = 1.2838, v_2 = 6.7213, M_4 = 2.012$ (5 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.

$\gamma = 1.4$, $R = 287$, $gc = 1$

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

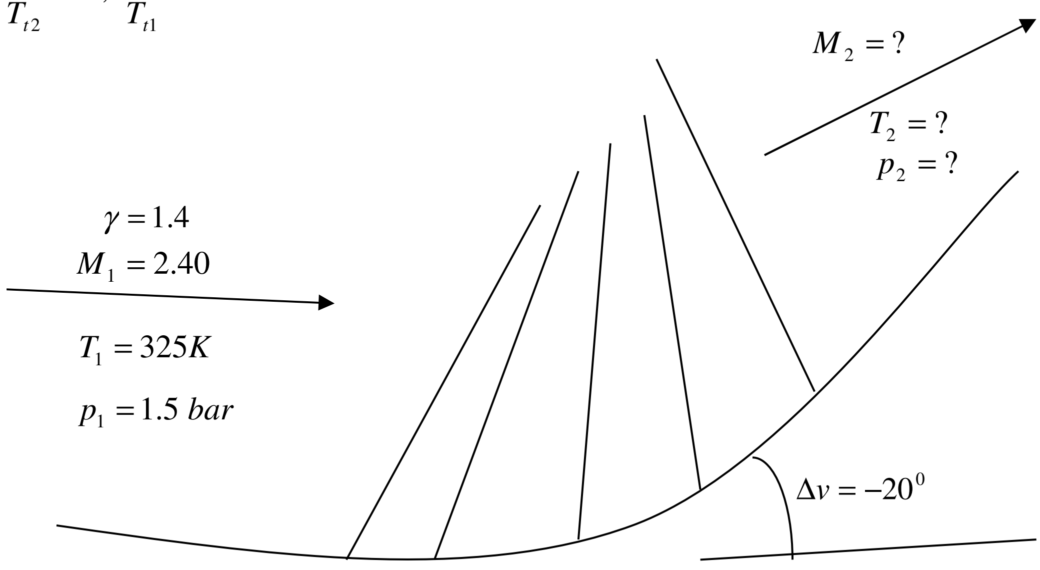
(5 marks)

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. $R = 287$, $\gamma = 1.4$, $gc = 1$; $\frac{p_2}{p_1} = 7.125$; $\frac{T_2}{T_1} = 2.1375$ (5 marks)

d) Air at $M_1 = 2.40$, $T_1 = 325K$, and $p_1 = 1.5\ bar$ approaches a smooth concave turn of 20^0 as below. Determine the properties in the flow after the turn.

$v_1 = 36.7465$, Δv *is negative* , $M_2 = 1.664$; $\frac{p_2}{p_{t2}} = 0.2139$; $\frac{p_{t1}}{p_{t2}} = 1$; $\frac{p_1}{p_{t1}} = 0.0684$; $\frac{T_2}{T_{t2}} = 0.6436$

$\frac{T_{t1}}{T_{t2}} = 1$; $\frac{T_1}{T_{t1}} = 0.4647$



Prandtl – Meyer Compression

(5 marks)

QUESTION FOUR (20MARKS)

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.

$a = \sqrt{\dfrac{\Delta p}{\Delta \rho}}$, $gc = 1, R = 287$ (5 marks)

b) Oxygen flows in a constant area horizontal, insulated duct. Conditions at section 1 are $p_1 = 50\,psia, T_1 = 600^0\,R\,and\;\; v_1 = 2860 m/s.$ 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) Sonic velocity through carbon dioxide is 275 m/s. Calculate the temperature in Kelvin. $\gamma = 1.29$, $gc = 32.2$, $R = 48.3$ (4 marks)

b) 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. (6 marks)

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

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

c) Methane gas at $140 kPa$ is compressed isothermally, and nitrogen gas at $100 kPa$ is compressed isentropically. Calculate the modulus of elasticity of;

i) Methane (4 marks)

ii) Nitrogen (4 marks)

iii) Which is more compressible? (2 marks)