MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF MATHEMATICS, STATISTICS AND ACTUARIAL SCIENCE

FOURTH YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

SMA 434: GAS DYNAMICS

DATE: 24/9/2019 **TIME: 2:00 – 4:00 PM**

INSTRUCTION: *Answer Question **ONE** which is compulsory and any other **TWO** Questions*

QUESTION ONE (COMPULSORY)(30 MARKS)

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

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

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

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

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. $\gamma = 1.67$, $M_2^{\ 2} = \dfrac{M_1^{\ 2} + \dfrac{2}{(\gamma - 1)}}{\left(\dfrac{2\gamma}{\gamma - 1}\right) M_1^{\ 2} - 1}$, $p_2\left(1 + \gamma M_1^{\ 2}\right) = p_1\left(1 + \gamma M_2^{\ 2}\right)$

(5 marks)

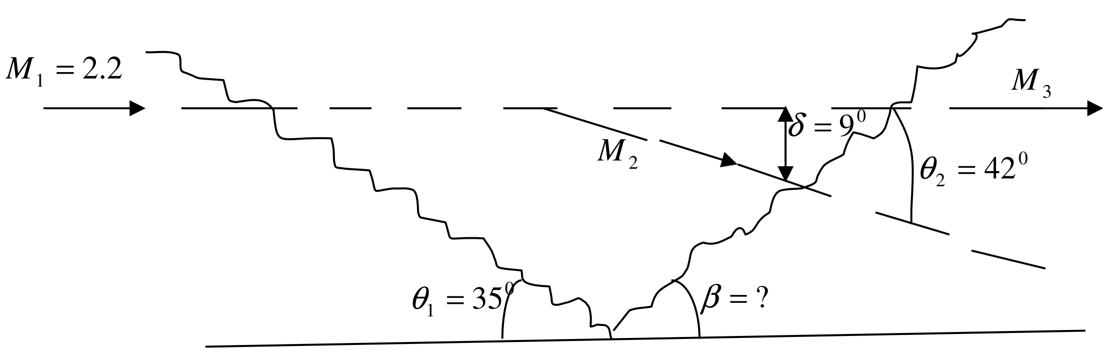
QUESTION TWO (20 MARKS)

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.

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

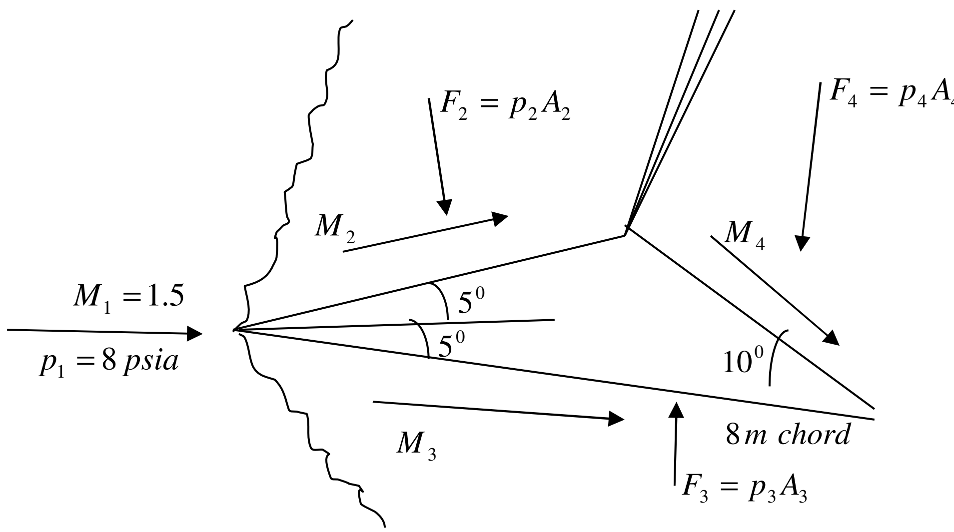
(7 marks)

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 $M = 1.5$ through air with pressure of $8\ psia, \theta = 48^0, M_{2n} = 0.900, \dfrac{p_2}{p_1} = 1.2838$, $v_2 = 6.7213$, $M_4 = 2.012$ (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.

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

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

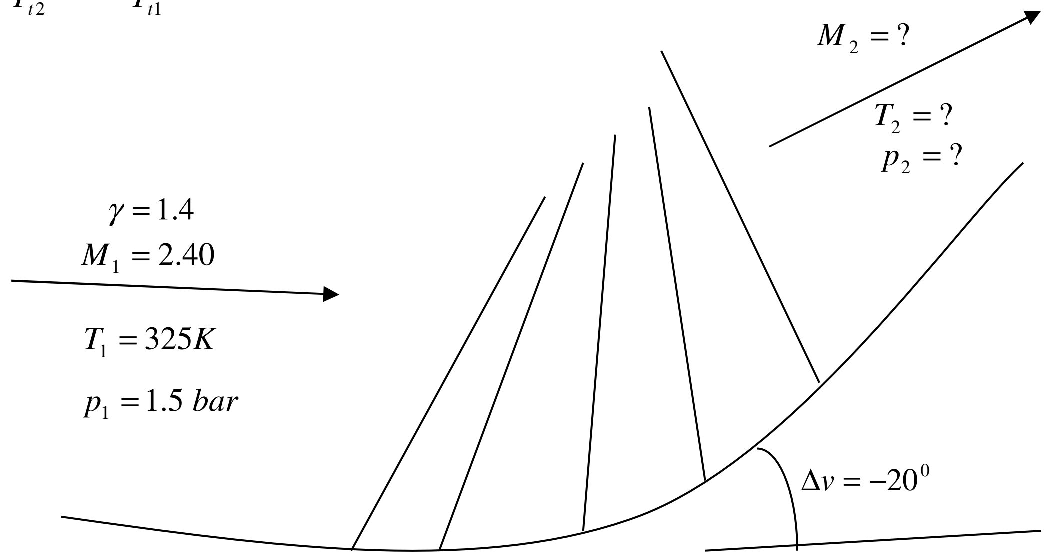
(5 marks)

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

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

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



$\text{Pr}\,andtl - Meyer\ Compression$

(5 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 $p_1 = 50\ psia, T_1 = 600^0\ R\ and\ v_1 = 2860 m/s.$ 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)

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

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

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

i) Methane (4 marks)

ii) Nitrogen (4 marks)

iii) Which is more compressible? (2 marks)