ELIZADE UNIVERSITY, ILARA-MOKIN,
ONDO STATE, NIGERIA

DEPARTMENT OF MECHANICAL ENGINEERING

SECOND SEMESTER EXAMINATIONS

2017/2018 ACADEMIC SESSION

COURSE: MEE 502 – Fluid Dynamics (3 Units)

CLASS: 500 Level Mechanical & Automotive Engineering

TIME ALLOWED: 3 Hours

INSTRUCTIONS: Answer any 4 questions

HOD'S SIGNATURE

Date: July/August, 2018

Question 1

(a) Air is flowing through a duct and a normal wave is formed at a cross-section at which the Mach number is 2.0. If the upstream pressure and temperature are 105 bar and 15 °C, respectively, find the Mach number, pressure and temperature immediately downstream of the shock waves. Take $\gamma = 1.4$ **(4 Marks)**

(b) Calculate the maximum mass flow possible through a frictionless, heat-insulated, convergent nozzle if the entry or stagnation conditions are 5 bar and 15 °C and the throat area is 6.5 cm^2. Also calculate the temperature of the air at the throat. Take $C_p = 1.00\ kJ\ kg^{-1}K^{-1}$ **(4 Marks)**

(c) Show that for maximum discharge from a reservoir through a convergent-divergent duct, the throat velocity is $\bar{v} = \sqrt{(\frac{\gamma P_t}{\rho_t})}$, where P_t *is the throat pressure,* ρ_t *is the throat density* **(5 Marks)**

(d) How do the temperature and the pressure at the stagnation point in isentropic flow compare with reservoir conditions? **(2 Marks)**

Question 2

(a) Write short note on the following:
(i) Under-expanded nozzle (ii) Over-expanded nozzle (iii) Oblique shock wave
(iv) Normal shock wave **(4 Marks)**

(b) At a point upstream of the throat of a converging-diverging nozzle, the properties are $V_1 = 190\ m/s,\ T_1 = 305\ K\ and\ P_1 = 120\ kPa$. If the exit flow is supersonic, Compute, from isentropic theory, mass flow rate and inlet area. The throat area is 35 cm^2. **(4 Marks)**

(c) Air flows along a circular pipe with a diameter d of 50 mm. Assuming that conditions are adiabatic and that the Mach number at the entrance to the pipe is 0.2, calculate the distance

from the entrance of the pipe to the section at which the Mach number will be (a) 1.0. (b) 0.6
Take $f = 0.00375$

(4 Marks)

(d) List and explain four (4) factors affecting transition from laminar to turbulent flow regimes

(3 Marks)

Question 3

(a) Consider a supersonic flow of air through a stationery duct wherein a stationery shock in present. The Mach number ahead of the shock is 2.1 and the pressure and temperature are 101.3 kPa absolute and -37 °C. What is the velocity of propagation of the shock relative to the air ahead of the shock?

(4 Marks)

(b) Show that Bernoulli's equation $P + 0.5\rho U^2 + \rho gz$ *constant*, satisfies steady inviscid flow when the flow is irrotational. *Note that P is the pressure, U is velocity and ρ is density*

(4 Marks)

(c) State four (4) characteristics of inviscid flow.

(4 Marks)

(d) Determine whether these flows are rotational or irrotational:

(i) $u = -2y$, $v = 3x$
(ii) $u = 0$, $v = 3xy$
(iii) $u = 2x$, $v = -2y$

(3 Marks)

Question 4

(a) What do you understand by the term "turbulent modeling"? (2 Marks)

(b) Differentiate between K-Omega ($K - \omega$) and K-epsilon ($K - \varepsilon$) in relation to turbulent modelling.

(4 Marks)

(c) Oil with a free stream velocity of 3.0 m/s flows over a thin plate 1.25 m wide and 3 m long. Determine the boundary layer thickness and the shear stress at the mid-length and calculate the total, double-sided resistance of the plate. ($\rho = 860\ \frac{kg}{m^3}$, *kinematic viscosity*, $\vartheta = 10^{-5}\ m^2 s^{-1}$)

(5 Marks)

(d) A flow is defined by $u = 2x$ *and* $v = -2y$. Find the stream function and potential flow function for this flow.

(4 Marks)

Question 5

(a) Consider a uniform flow, $\emptyset = U_o\left(r + \frac{R^2}{2}\right)Cos\theta$ past a circular cylinder, where U_o is velocity, R is the radius and $\emptyset$ is the potential function. Obtain velocity components and pressure on the cylinder.

(4 Marks)

(b) A supersonic wind tunnel consists of a large reservoir containing gas under high pressure which is discharged through a convergent-divergent nozzle to a test section of constant cross-sectional area. The cross-sectional area of the throat of the nozzle is 500 mm² and the Mach number in the test section is 4. Calculate the cross-sectional area of the test section assuming $\gamma = 1.4$

(3 Marks)

(c) A smooth flat plate 3 m wide and 30 m long is towed through still water at 20 °C at a speed of 8 m/s. Determine the total drag on the plate and the drag on the first 3 m of the plate. (4 Marks)

(d) Show that Blasius equation for boundary layer thickness, δ in a laminar flow is given by $\frac{5.48x}{\sqrt{Re_x}}$

(4 Marks)