MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF MATHEMATICS AND STATISTICS

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (STATISTICS AND PROGRAMMING)

BACHELOR OF SCIENCE (METHEMATICS)

BACHELOR OF EDUCATION(SCIENCE)

BACHELOR OF EDUCATION (ARTS)

SMA 333: FLUID MECHANICS I

DATE: **TIME:**

INSTRUCTIONS: Answer **question one** and **any other two** questions

QUESTION ONE (COMPULSORY)(30 MARKS)

a) Name and distinguish the two different points of view in analyzing problems in mechanics (4 marks)

b) Determine the density, specific gravity and mass of the air in a room whose dimensions are $4\ m$ by $5\ m$ by $6\ m$ at $100\ kPa$ and 25℃ (Take $R = 0.287\ kPa.m^3/(kg.K)$) (6 marks)

c) The viscosity of a fluid is to be measured by a viscometer constructed of two $40\ cm$ long concentric cylinders as shown in figure 1 below

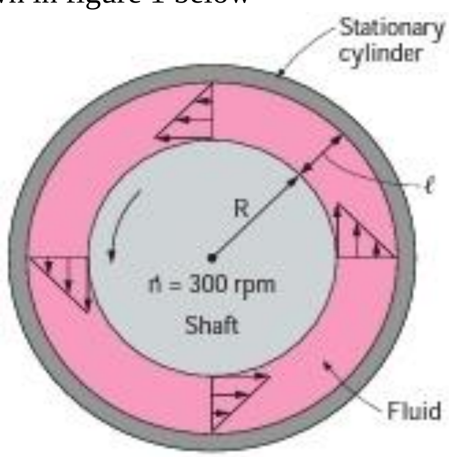

Figure 1. viscometer

The outer diameter of the inner cylinder is 12 cm and the gap between the two cylinders is 0.15 cm. the inner cylinder is rotated at 300 rpm and the torque is measured to be 1.8 Nm. Determine the viscosity of the fluid (4 marks)

d) Consider water initially at 20°C and 1 $atmosphere$. Determine the final density of water;

i. If it is heated to 50°C at a constant pressure of 1 $atmosphere$ (4 marks)

ii. If it is compressed to 100 $atmosphere$ pressure at a constant temperature of 20°C (Take $\rho_1 = 998.0\ kgm^{-3}, \beta = 0.337X10^{-3}\ K^{-1}\ and\ \alpha = 4.80X10^{-5}\ atm^{-1}$) (4 marks)

e) The velocity distribution for the flow of a Newtonian fluid between two wide, parallel plates as shown in figure 2 is given by the equation $u = \frac{3V}{2}\left[1 - \left(\frac{y}{h}\right)^2\right]$ where V is the mean velocity.

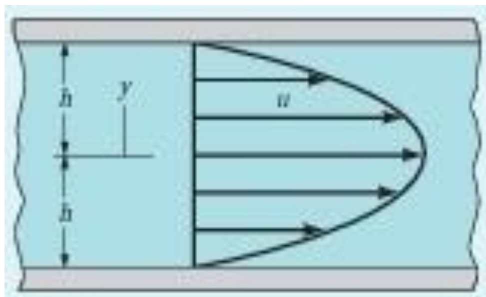

Figure 2. velocity distribution of a Newtonian fluid flow between two parallel plates

The fluid has viscosity of 0.04 $Ib.s/ft^2$, $V = 2\ ft/s$ and $h = 0.2\ inch$. Determine;

i. The shearing stress acting on the bottom wall (6 marks)

ii. The shearing stress acting on a plane parallel to the walls and passing through the centerline or midplane (2 marks)

QUESTION TWO (20 MARKS)

a) A jet aircraft flies at a speed of 550 mph at an altitude of 35000 ft where the temperature is -66°F and the Specific heat ratio is $k = 1.40$ determine the ratio of the speed of the aircraft, V to that of the speed of sound, c at the specified altitude given

$R = 1716\ ft.Ib/slug.^0\ R$ (6 marks)

b) Pressures are sometimes determined by measuring the height of a column of liquid in a vertical tube. For water at 20°C, $\sigma = 0.0728\ N/m$ and $\gamma = 9.789\ k\ N/m^3$. Determine the diameter of clean glass tubing required so that the rise of water at 20°C in a tube due to capillary action as opposed to pressure in the tube is less than $h = 1.00\ mm$ (6 marks)

c) Find the change in volume of 1.00 ft^3 of water at 80°F when subjected to a pressure increase of 300 psi. Hence determine the bulk modulus of elasticity of water with the test data: 500 psi the volume was 1.000 ft^3 and at 3500 psi the volume was 0.990 ft^3

(Take $E = 325000\ psi\ at$ 80°F) (5 marks)

d) A sound wave is observed to travel through a liquid with a speed of $1500\ m/s$. The specific gravity of the liquid is 1.5 determine the bulk modulus for this fluid (3 marks)

QUESTION THREE (20 MARKS)

a) A velocity field in a plane flow is given by $\boldsymbol{V} = 2yt\boldsymbol{i} + x\boldsymbol{j}$. Find the equation of the streamline passing through $(4, 2)$ at $t = 2$ (6 marks)

b) Given the steady two-dimensional velocity distribution $u = \boldsymbol{K}x \quad v = -\boldsymbol{K}y \quad w = 0$ where $\boldsymbol{K}$ is a positive constant, compute and plot the streamlines of the flow, including directions, and give some possible interpretations of the pattern (6 marks)

c) For the velocity field $\boldsymbol{V} = 2xy\boldsymbol{i} + 4tz^2\boldsymbol{j} - yz\boldsymbol{k}$, find the acceleration, the angular velocity about the z-axis, and the vorticity vector at the point $(2, -1, 1)$ at $t = 2$ (8 marks)

QUESTION FOUR (20 MARKS)

a) Consider the flow of air around a bicyclist moving through still air with velocity V_0 as is shown in Figure 3 below.

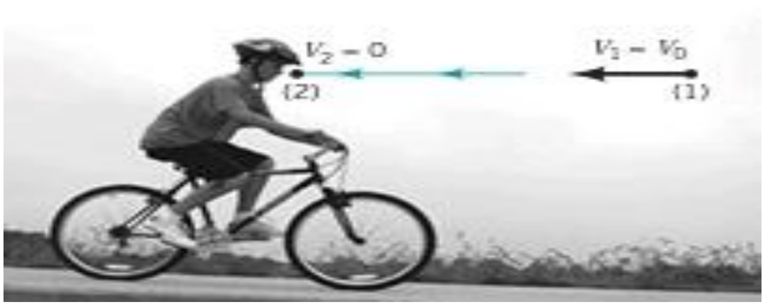

Figure 3. Bicyclist moving through still air

Determine the difference in the pressure between points (1) and (2) (4 marks)

b) The velocity components for a certain incompressible steady flow field in three dimensions are $u = x^2 + y^2 + z^2$, $v = xy + yz + z$ and $w = ?$ Determine the form of the $z-$ $component, w$ required to satisfy the continuity equation (6 marks)

c) A $10 - cm$ fire hose with a $3 - cm$ nozzle discharges $1.5\ m^3/min$ to the atmosphere as shown in Figure 4 below

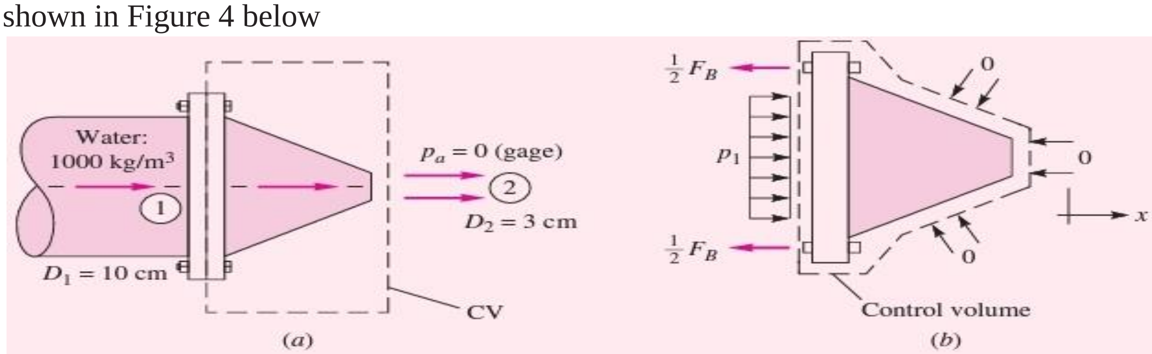

Figure 4. Fire hose with a nozzle

Assuming frictionless flow, use Bernoulli's equation and continuity to find the pressure P_1 upstream of the nozzle, and then we use a control volume momentum analysis to compute the bolt force as shown in Figure 4. Hence find the force F_B exerted by the flange bolts to hold the nozzle on the hose (10 marks)

QUESTION FIVE (20 MARKS)

a) In a two-dimensional incompressible flow, the fluid velocity components are given by

$$v_x = x - 4y \text{ and } v_y = -y - 4x$$

i. Show that the flow satisfies the continuity equation (4 marks)

ii. obtain the expression for the stream function (5 marks)

iii. If the flow is irrotational, obtain also the expression for the velocity potential (5 marks)

b) A Kelvin oval from Figure 5 has $K/U_\infty a = 1.0$

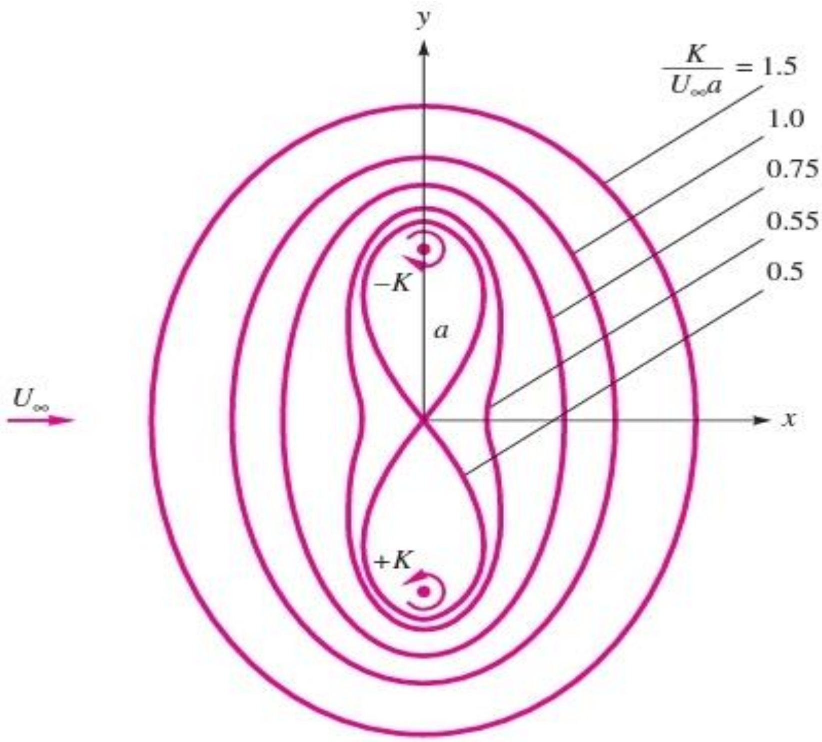

Figure 5. Kelvin oval body shapes as a function of the vortex strength parameter $K/U_\infty a$

Compute the velocity at the top shoulder of the oval in terms of U_∞ (6 marks)