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UNIVERSITY EXAMINATIONS 2019/2020

THIRD YEAR,SPECIAL/SUPPLEMENTARY EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS AND COMPUTER SCIENCE AND BACHELOR OF EDUCATION

SMA 3355 FLUID MECHANICS I

DATE: JANUARY 2021 **TIME: 2 HOURS**

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

QUESTION ONE (30 MARKS)

a) State any two characteristics of a fluid (2 marks)

b) Distinguish between ideal and real fluids (2 marks)

c) Briefly describe the effects of temperature and pressure on fluid viscosity (4 marks)

d) Examine whether the velocity components $u = -4ax\left(x^2 - 3y^2\right)$ and $v = 4ay\left(3x^2 - y^2\right)$ represent a physically possible two-dimensional flow (5 marks)

e) State the Eulerian description of fluid motion and hence show that for a three dimensional fluid flow, the acceleration component $a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t}$ (6 marks)

f) Identify each of the terms of the equation $\frac{\partial \vec{q}}{\partial t} + \vec{q}\cdot\nabla\vec{q} = \frac{-\nabla P}{\rho} + \frac{\mu}{\rho}\nabla^2\vec{q}$ (4 marks)

g) Verify whether the function $\phi = A\cos x$ is a valid potential function (5 marks)

h) State the Newton's law of viscosity (2 marks)

QUESTION TWO (20 MARKS)

a) Distinguish between each of the following pairs

i. Newtonian and non-Newtonian fluids (2 marks)

ii. Compressible and incompressible flows (2 marks)

iii. Steady and unsteady flows (2 marks)

b) Determine whether the flow with velocity field $\vec{q} = cyz\hat{i} + cxz\hat{j} + cxy\hat{k}$, where c is constant, is rotational or irrotational (5 marks)

c) The velocity of a two dimensional unsteady incompressible flow is $\vec{q} = \left(3 + 2xy + 4t^2\right)\hat{i} + \left(xy^2 + 3t\right)\hat{j}$. Compute the acceleration at point $(1,2)$ after 2 seconds. (9 marks)

QUESTION THREE (20 MARKS)

a) The velocity components in a two-dimensional fluid flow are given by $u = 2xy;\ v = a^2 + x^2 - y^2$. Derive the expression for the stream function (7 marks)

b) In a two dimensional incompressible flow, the fluid velocity components are given by $u = x - 4y;\ v = -y - 4x$.

i. Show that velocity potential exists (3 marks)

ii. Determine the expression for the velocity potential (5 marks)

iii. Determine also the expression for the stream function (5 marks)

QUESTION FOUR (20 MARKS)

a) Distinguish between Lagrangian and Eulerian methods of describing motion of fluid particles (4 marks)

b) Distinguish between Newtonian and plastic fluids, giving examples in each case (4 marks)

c) Verify whether the function $\phi = A\left(x^2 - y^2\right)$ is a valid potential function (5 marks)

d) In a three-dimensional incompressible flow, the velocity components in y and z directions are $v = ax^3 - by^2 + cz^2,\ w = bx^3 - cy^2 + az^2x$. Determine the missing component of velocity distribution such that continuity equation is satisfied (7 marks)

QUESTION FIVE (20 MARKS)

a) The potential for flow around a cylinder of radius R is given by $\phi = ux\left(1 + \frac{R^2}{x^2 + y^2}\right)$ where x and y are the Cartesian coordinates with the origin at the middle. Derive an expression for the stream function ψ (7 marks)

b) Given a two dimensional velocity field $u = \frac{-y}{r^2}$ and $v = \frac{x}{r^2}$

i. Show that the fluid flow satisfies the mass conservation (4 marks)

ii. Show that the velocity field can be described by a velocity potential (4 marks)

iii. Identify this velocity potential (5 marks)