



MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

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University Examinations 2023/2024

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR THE DEGREE OF
BACHELOR OF SCIENCE IN EDUCATION

SMA 3404: FLUID MECHANICS II

DATE: APRIL 2024

TIME: 2 HOURS

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

QUESTION ONE (30 MARKS)

- a) For an incompressible fluid, the velocity components in x, y and z-directions are
 $u = 2x^2 + 3y, v = -2xy + 3y^3 + 3zy$, determine whether the continuity equation is
satisfied (6 marks)
- b) Discuss potential fluid flow (5 marks)
- c) For the function $\phi = ax^2y - y^3$ to represent velocity potential vector of an ideal fluid, find
the value of a and the corresponding stream function, ψ (7 marks)
- d) State the Cauchy-Riemann equations in terms of ϕ and ψ (2 marks)
- e) Describe the following fluid flows
- i) Plane Poiseuille flow (2 marks)
- ii) Generalized Couette flow (2 marks)

f) Test if the fluid flow with velocity field $\vec{q} = 2x\hat{i} + xyz\hat{j} + yz^2\hat{k}$ is irrotational

QUESTION TWO (20 MARKS)

- a) The stream function in x-y plane is given by $\psi = \frac{1}{2}x^2y^3$, determine the velocity vector \vec{q} of this stream (4 marks)
- b) State the Kutta-Joukowski lift theorem for a rotating cylinder, explaining its practical significance (6 marks)
- c) Explain any four characteristics of ideal fluids (4 marks)
- d) Discuss three differences between velocity potential and stream function (6 marks)

QUESTION THREE (20 MARKS)

- a) Show that the streamlines and equipotential lines form a net mutually perpendicular lines (8 marks)
- b) Determine the direction and amount of flow per unit width between two parallel plates when one is moving relative to other with a velocity of 3m/s in the negative direction, if $\frac{\partial p}{\partial x} = -100 \times 10^6 \text{ N/m}^3$ and $\mu = 0.04 \text{Ns/m}^2$ and the distance between the plates is 1 mm. (4 marks)
- c) Find the velocity potential, stream function and the complex velocity of a uniform flow inclined at an angle α to the x-axis (8 marks)

QUESTION FOUR (20 MARKS)

- a) Explain the following terms
- Circulation
 - Doublet flow
 - Conformal mapping
 - Stagnation point
- b) Find the velocity potential and stream function of a uniform flow along y -axis for which $u = 0$ and $v = V$ (6 marks)
- c) A uniform circular tube of bore radius R_1 has a fixed coaxial cylindrical solid core of radius R_2 . An incompressible viscous fluid flows through the annular passage under a pressure gradient $\left(-\frac{\partial p}{\partial x}\right)$. Determine the radius at which the shear stress in the stream is zero given that the flow is laminar under steady state condition. (5 marks)
- d) Explain the concept of superposition of complex potential, hence for a flow around a circular cylinder radius R with a uniform flow of magnitude U_0 and doublet strength μ , show that the complex potential function $f(z) = (U_0 r + \frac{\mu}{r}) \cos \theta + i(U_0 r - \frac{\mu}{r}) \sin \theta$ (5 marks)

QUESTION FIVE (20 MARKS)

- a) Test if the function $f(z) = z^3$ is analytic, take $z = x + iy$ (9 marks)
- b) For a uniform flow along the x -axis with velocity U , $v = 0$, find the complex potential $f(z)$ (11 marks)