KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION

SMA 333: FLUID MECHANICS I

DATE: Monday, 5th December, 2011 TIME: 8.00 a.m. – 10.00 a.m.

INSTRUCTIONS: Answer question **ONE** and any other **TWO**.

QUESTION ONE (30 MARKS)

a) Define the following terms:
   i. Dimensional analysis (2 marks)
   ii. Specific weight (2 marks)
   iii. Bulk modulus of compressibility (2 marks)
   iv. Boundary layer (2 marks)
   v. Kinematic viscosity (2 marks)

b) Given that the average velocity of flow in an open channel is given by $V = K\sqrt{RS}$ where V is the velocity, R the hydraulic radius and S is the slope of the change, find the units of K using the fundamental units. (3 marks)

c) Distinguish between a pathline and a streamline. Hence determine the equation of pathlines of a fluid flow whose velocity components are $u = -x + t + 2$ and $v = y - t + 2$ (7 marks)

d) A liquid compressed in a cylinder has a volume of $0.396cm^3$ at a pressure of $6.8x10^7 N/cm^2$. Calculate the bulk modulus of the liquid. (3 marks)

e) Briefly discuss the continuum hypothesis (4 marks)

f) A plate at a distance of $0.2cm$ from a fixed plate moves at $1cm/\text{sec}$ and requires a force of $40N$ to maintain that speed. Determine the coefficient of viscosity. (3 marks)

QUESTION TWO (20 MARKS)

a) A gas obeying Boyle's law is moving in a horizontal uniform tube of small cross section, prove that $\frac{\partial^2 \rho}{\partial t^2} = \frac{\partial^2}{\partial x^2}\left[\left(k + u^2\right)\rho\right]$ where s is the fluid density and u is the velocity at a distance x from a fixed point at time t. (8 marks)

b) Determine whether or not the fluid flow whose velocity components are

$$u = \frac{-2xyz}{x^2 + y^2},\ v = \frac{z\left(x^2 - y^2\right)}{x^2 + y^2} \text{ and } w = \frac{y}{x^2 + y^2} \text{ is irrotational.} \quad (12 \text{ marks})$$

QUESTION THREE (20 MARKS)

a) State the First Law of Thermodynamics (2 marks)

b) By expressing entropy S and thermal energy Q in terms of pressure P and volume V show that

i. $\left(\frac{\partial S}{\partial V}\right)_P = \frac{C_P}{\alpha V T}$ (4 marks)

ii. $\left(\frac{\partial S}{\partial P}\right)_V = \frac{C_V}{\alpha K T}$ (4 marks)

c) Given the complex velocity potential $w = \phi + i\psi$, show that the equipotential lines and the streamlines cut one another orthogonally. (6 marks)

d) Find the velocity components of a spherically symmetrical flow whose stream function is

$$\psi(r,\theta) = \frac{ua^3}{2r}\sin^2\theta - \frac{ur^2}{2}\sin^2\theta$$ (4 marks)

QUESTION FOUR (20 MARKS)

a) Prove that for an adiabatic process, $p\rho^{-\gamma}$ where $\gamma = \frac{C_P}{C_V}$ (8 marks)

b) From the definition of the bulk modulus of compressibility, determine its units dimensions. (3 marks)

c) Show that $\frac{x^2}{a^2}\tan^2 t + \frac{y^2}{b^2}\cot^2 t = 1$, is a possible boundary surface of a liquid (6 marks)

d) Air is introduced through a nozzle into a tank of water to form a stream of bubbles. If the bubbles are intended to have a diameter of $2mm$, calculate by how much the pressure of the air at the nozzle must exceed that of the surrounding water, taking $\delta = 72.7x10^{-3}\ Nm^{-1}$ (3 marks)

QUESTION FIVE (20 MARKS)

a) Determine the fundamental units of the kinematic viscosity (3 marks)

b) Prove that $C_P - C_V = R$, where R is the gas constant (7 marks)

c) If the bulk modulus of a fluid remains constant, then show that the variation of pressure with density is given by;

$$P = P_\circ + k \ln\left(\frac{\rho}{\rho_\circ}\right)$$ where $P_\circ$ and $\rho_\circ$ are respectively the reference pressure and density (3 marks)

d) Determine the equations of streamlines of the fluid flow whose velocity vectors in spherical coordinates are; $\vec{q} = 2mr^{-3}\cos\theta\hat{r} + mr^{3}\sin\theta\hat{\theta}$ (7 marks)