TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering & Technology

DEPARTMENT OF MECHANICAL & AUTOMOTIVE ENGINEERING

UNIVERSITY EXAMINATION FOR

THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

(SCHOOL-BASED PROGRAMME)

EMG 2307 FLUID MECHANICS III

END OF SEMESTER EXAMINATION

SERIES: AUGUST 2017

TIME: 2 HOURS

INSTRUCTIONS TO CANDIDATES:

1. You should have **Answer Booklet** for this examination.
2. This paper contains **FIVE** questions. Answer **ANY THREE** questions.
3. This paper consists of **FOUR** printed pages.

Question 1

(a) A steady, incompressible, two-dimensional velocity field is given by the following components in the *xy*-plane: $u = 0.523 - 1.88x + 3.94y$ $v = -2.44 + 1.26x + 1.88y$. Calculate:

(i) the acceleration field (i.e. find expressions for acceleration components a_x and a_y)

(ii) the acceleration at the point $(x, y) = (-1.55, 2.07)$. **(6 marks)**

(b) Consider steady, incompressible, two-dimensional flow for which the velocity field is $\vec{V} = (u,v) = (4.35 + 0.656x)\vec{i} + (-1.22 - 0.656y)\vec{j}$, where *x*- and *y*- coordinates are in metres and the magnitude of the velocity in m/s.

(i) Obtain an equation for the streamlines. **(6 marks)**

(ii) Sketch velocity vectors at several locations in the upper right quadrant for $x = 0$ m to 4 m and $y = 0$ m to 4 m; qualitatively describe the flow field. **(4 marks)**

(c) Consider the following steady, three-dimensional velocity field:

$$\vec{V} = (u, v, w) = (3.0 + 2.0x - y)\vec{i} + (2.0x - 2.0y)\vec{j} + (0.5xy)\vec{k}\,.$$

Calculate the vorticity vector as a function of space (x, y, z). Is the flow rotational or irrotational? Explain. **(4 marks)**

Question 2

(a) Starting with steady-flow energy equation for compressible flow in the form:

$$c_p T_1 + \frac{1}{2}V_1^2 = c_p T_2 + \frac{1}{2}V_2^2$$

derive the relations that describe temperature, pressure and density ratios. **(10 marks)**

(b) Air at approximately zero velocity enters a converging-diverging duct at a stagnation pressure and a stagnation temperature of 1000 kPa and 480 K, respectively. Throat area of the duct is 0.002 m^2. The flow inside the duct is isentropic, and the exit pressure is 31.7 kPa. For air, k = 1.4 and R = 287 J/kg. Determine,

(i) the exit Mach number,

(ii) the exit temperature,

(iii) the exit area of the duct, and

(iv) the mass flow rate through the duct. **(10 marks)**

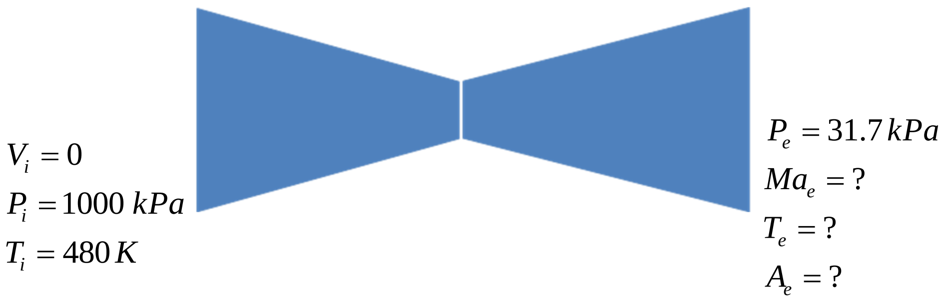

Figure Q 3(a): Convergent-divergent nozzle

Question 3

(a) The internal and external diameters of a centrifugal pump are 20 cm and 40 cm respectively. The pump is running at 120 rpm. The vane angle at inlet is 20^o. Water enters the impeller radially and velocity of flow is constant. Find the work done by the impeller per kg of water for β_2 = 30^o. **(10 marks)**

(b) A centrifugal pump rotates at n = 750 rpm. Water enters the impeller normal to the blades (α_1 = 0) and exits at an angle of 35° from radial (α_2 = 35°). The inlet radius is r_1 = 12.0 cm, at which the blade width b_1 = 18.0 cm. The outlet radius is r_2 = 24.0 cm, at which the blade width b_2 = 14.0 cm. The volume flow rate is 0.573 m^3/s. Take the density of water to be ρ = 998.0 kg/m^3. Assuming efficiency of the pump to be 100 percent, calculate,

(i) the net head produced by this pump in cm of water column height.

(ii) the required brake horsepower in Watts. **(10 marks)**

Question 4

(a) The power required for pumping is a function of the head developed and volumetric flow rate as well as pump size in terms of impeller diameter and its rotational speed, and the properties of the fluid in terms of density and viscosity. The power relationship can be expressed as: $P \propto Q^a (gH)^b N^c D^d \rho^e \mu^f$. Using fundamental dimensions M, L and T, show that the power relation can be expressed as:

$$\frac{P}{\rho N^3 D^5} = f\left(\frac{Q}{ND^3}, \frac{gH}{N^2 D^2}, \frac{\rho N D^2}{\mu}\right)$$

(8 marks)

(b) A model pump of 125 mm diameter develops 185 W at a speed of 800 rpm under a head of 760 mm. A geometrically similar pump 380 mm diameter is to operate at the same efficiency at a head of 15 m. What speed and power should be expected? **(4 marks)**

(c) A pump tested at 1800 rpm gives the following results: Capacity = 253 L/s, head = 48 m, power = 141.7 kW.

(i) Calculate the performance of this pump at 1600 rpm.

(ii) If along with the speed the diameter of the impeller is reduced from 380 mm to 356 mm, obtain the revised pump characteristics. **(8 marks)**

Question 5

The integral momentum equation for laminar boundary-layer flow over a flat plate may be expressed as:

$$\rho \frac{d}{dx}\int_0^{\delta}(u_\infty - u)u\,dy = \mu \frac{\partial u}{\partial y}\bigg|_{y=0}$$

If the velocity distribution of the boundary-layer as shown in Figure Q5 below is described by a third order polynomial function of the form: $u(y) = A + By + Cy^2 + Dy^3$

(i) By applying appropriate boundary conditions, develop an expression for velocity profile. **(5 marks)**

(ii) Obtain an expression for the boundary-layer thickness δ. **(10 marks)**

(iii) Show the relation for boundary-layer thickness and local friction coefficient. **(5 marks)**

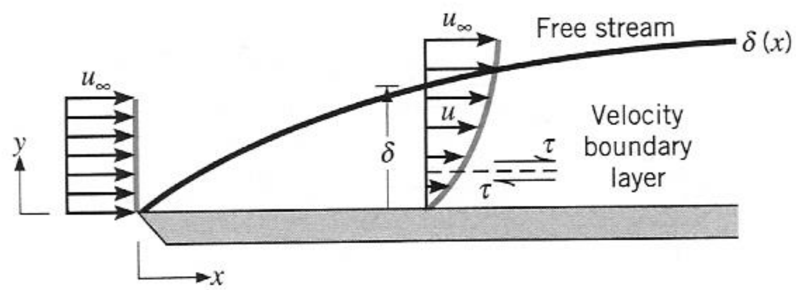

Figure Q5: Laminar boundary-layer on a flat plate