TECHNICAL UNIVERSITY OF MOMBASA

FACULTY OF APPLIED AND HEALTH SCIENCES

DEPARTMENT OF MATHEMATICS & PHYSICS

UNIVERSITY EXAMINATION FOR THE SECOND YEAR DEGREE OF BACHELOR OF SCIENCE IN MATHEMATICS AND COMPUTER SCIENCE.

AMA 4419: FLUID MECHANICS III

SPECIAL/ SUPPLIMENTARY EXAMINATIONS

SERIES: SEPTEMBER- 2018

TIME: 2 HOURS

Instructions to Candidates

You should have the following for this examination

-*Answer Booklet, examination pass and student ID*

This paper consists of five (5) questions. Attempt Question One and any other Two Questions.

Use SMP four figure mathematical tables and non-programmable electronic calculators.

Do not write on the question paper.

Question ONE (30 MARKS) compulsory

a) State the Buckingham's π (Pi) theorem. 2 marks

b) The boundary layer thickness at a distance of 1m from the leading edge of a flat plate kept over zero angle of incidence to the flow direction is 1mm. The velocity outside the boundary layer is 25m/s, determine the boundary layer thickness at a distance of 4m if it is entirely laminar. 3 marks

c) In an oil field a well is sunk into a reservoir of a spherical sphere, the oil is coming from oil bearing rocks into the reservoir. Assuming that pressure P_1 in the rocks is much higher than the pressure P_0 in the reservoir and the permeability of the rocks is $k = k_0 r^3$ where r is the radial distance from the centre of the reservoir. Find what would be the radius of the reservoir so that uninterrupted supply of oil at the rate q can be obtained from the well. 7 marks

d) Define the following non dimensional parameters:

i) Froude number. 1 mark

ii) Weber number. 1 mark

iii) Mach number. 1 mark

e) A geometrically similar model of an air duct is built to $\frac{1}{50}$ scale and tested with water which is 75 times more viscous and 1200 denser than air. When tested under dynamically similar conditions the pressure drop is $400 KN/m^2$ in the model. Find the corresponding pressure drop in the full scale prototype. 6 marks

f) In a step bearing of breadth b, with the step centrally positioned.

i) Show that the volumetric flow rate Q through the bearing is given by $Q = \frac{V(1+H^2)}{2(1+H^3)} b h_1$ where $H = \frac{h_1}{h_2}$. 4 marks

ii) The bearing has the following dimensions; h_1=0.5mm, h_2=0.25mm, L=100mm, b=100mm, while it is used in conjunction with an oil of relative density 0.87 and kinematic viscosity $2 \times 10^{-4}\ m^2 s^{-1}$. The relative velocity between the bearing surfaces is $10 m.s^{-1}$, determine the volumetric flow rate of oil. 2 marks

iii) Determine the load supported by the step bearing. 3 marks

<u>Question TWO (20 MARKS)</u>

a) A model of submarine is scaled down to 1/20 of the prototype and is to be tested in a wind tunnel where free stream pressure is 2.0MPa, absolute temperature is 50^0C and the speed of the prototype is 7.72m/s. Determine the free stream velocity of air and the ratio of the drag between model and prototype. Assume kinematic viscosity of sea water as $1.4 \times 10^{-6}\ m^2/s$ and viscosity of air as $0.0184 Ns/m^2$. 6 marks

b) Show that the mass flux in a porous annulus of radii r =a and r =b where b>a in which the pressure $P = P_0$ when r=a and $P = P_1$ when r =b if permeability k is a constant will be $q = \frac{2\pi k}{\mu}\left(\frac{P_1 - P_0}{\ln a/b}\right)$. 7 marks

c) Obtain an expression for the ratio of displacement thickness to momentum thickness, for a steady Poiseuille flow in a cylindrical pipe of radius R given that the velocity distribution is $u = -\frac{1}{4\mu} \cdot \frac{\partial p}{\partial x}\left(R^2 - y^2\right)$ where y is the distance measured perpendicularly inside the pipe from the centre line. 7 marks

Question THREE (20 MARKS)

a) If the velocity distribution in the boundary is given by $\frac{u}{U} = \left(\frac{y}{\delta}\right)^{1/7}$, δ being boundary layer thickness.

Calculate: i) Displacement thickness. 2 marks

ii) Momentum thickness. 2 marks

iii) Shape factor. 1 mark

iv) Energy thickness. 3 marks

v) Energy loss due to boundary layer if at a particular section, the boundary layer thickness is 25mm and the free stream velocity is 15m/s. 2 marks

vi) If the discharge through the boundary layer region is $6m^3/s$ per metre width, express this energy loss in terms of metres of head. Take $\rho=1.2kg/m^3$. 1 mark

b). A plane bearing plate is traversed by a wide inclined slipper of 15cm in length moving at 2 m/sec. The clearance between the slipper and bearing plate is 0.03mm at the toe and 0.09mm at the heel. If the bearing has to carry a load of 30,000 kgf per metre width; i) Determine the viscosity of lubricating oil. 4 marks

ii) The maximum pressure in the lubricant. 2 marks

iii) The power consumed per metre width of bearing. 3 marks

Question FOUR (20 MARKS)

a) The performance for a spillway of an irrigation project is to be studied by means of a model constructed to a scale of 1:9 neglecting the viscous and surface tension effects determine:

i) Rate of flow in model for a prototype discharge of $1200m^3/s$. 3 marks

ii) The dissipation of energy in the prototype hydraulic jump, if the jump in the model dissipates 0.25kW. 3 marks

b) The velocity distribution in the boundary over the face of an open channel was observed to be $\frac{u}{U} = \left(\frac{y}{\delta}\right)^{0.22}$, the free stream velocity U is 20m/s and boundary layer thickness 5cm at a certain section. The discharge $5m^3/s$ per meter length of the open channel. Calculate: i) Displacement thickness. 3 marks

ii) Energy thickness. 4 marks

iii) Loss of energy up to the Section under consideration. 3 marks

c) State any four uses of dimensional analysis. 4 marks

Question FIVE (20 MARKS)

a) A plate 450mm×150mm has been placed longitudinally in a stream of crude oil of specific gravity 0.925 and kinematic viscosity of 0.9 stoke, which flows with velocity of 6m/s. Calculate

i) Friction drag on the plate. 5 marks

ii) Thickness of the boundary layer at the trailing edge. 2 marks

iii) Shear stress at the trailing edge. 4 marks

b) A 1:40 model of an ocean tanker is dragged through fresh water at 2m/s with a total measured drag of 117.7N, the skin frictional drag coefficient f for model and prototype are 0.3 and 0.02 respectively in the equation $R_f = fAV^2$. The wetted surface area of the model is $25m^2$, taking densities for the prototype and model as $1030kgN/m^3$ and $1000kgN/m^3$ respectively. Determine the total drag on the prototype.

. 6 marks

c) State Darcy's law and write its formula in the usual symbols. 3 marks

THE END