THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY – LEVEL 05
FINAL EXAMINATION– 2010/2011

MEX5230 – FLUID MECHANICS

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01 NOV 2011

DATE : 10th MARCH 2011
TIME : 0930 HRS. – 1230 HRS.
DURATION : THREE HOURS

ANSWER FIVE QUESTIONS ONLY. ALL QUESTIONS CARRY EQUAL MARKS.

Density of water = 1000kg/m^3. Acceleration due to gravity=9.81m/s^2

QUESTION 1

i. Figure Q1 shows an end elevation of a tank containing Benzene of specific gravity 0.85. Find the hydrostatic force on the inward semi-circular bulge ABC of the tank for a 1m length of the tank. Find also the location of this force on the bulge.

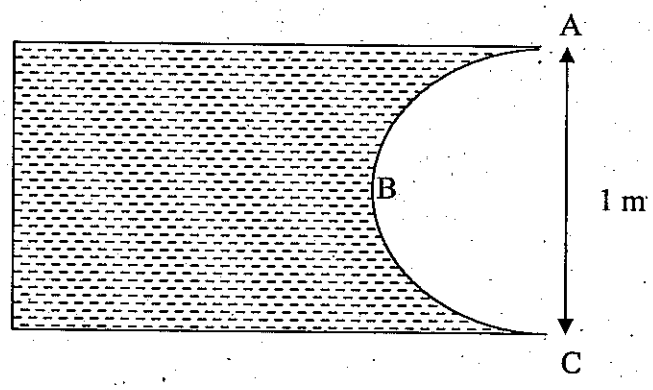


Figure Q1

ii. A lawn sprinkler has two identical nozzles of diameter 7.5mm each provided at the ends of the sprinkler rotor. Nozzles are fixed at right angles to the rotor and nozzles discharge water in directions opposite to the each other. The velocity of flow from each nozzle is 10m/s and the nozzles are at a radial distance of 200mm and 150mm from the centre of the rotor. Determine the speed of rotation of the arm if the rotor is free to rotate.

QUESTION 2

A plane surface is fixed and another plane surface rotates with angular velocity ω about an axis perpendicular to its plane and there is a film of oil fluid between them. Prove that the pressure p in the oil film satisfies the equation

$$h^3\left(\frac{\partial^2 p}{\partial r^2}+\frac{1}{r}\frac{\partial p}{\partial r}+\frac{1}{r^2}\frac{\partial^2 p}{\partial \theta^2}\right)+\frac{\partial h^3}{\partial r}\frac{\partial p}{\partial r}+\frac{1}{r^3}\frac{\partial h^3}{\partial \theta}\frac{\partial p}{\partial \theta}=6\mu\omega\frac{\partial h}{\partial \theta}$$

where (r,θ) are polar coordinates in the plane of the film, the origin being in the axis of the film of rotation, and h is the thickness of the film.
Equation of continuity for flow in the direction of y with velocity V along with the flow in the direction of x with velocity U is given by

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\partial p}{\partial y}\right)=6\mu\left(\frac{\partial}{\partial x}(hU)+\frac{\partial}{\partial y}(hV)\right)$$

and

$x=r\cos\theta\ , y=r\sin\theta,$

$$\frac{\partial}{\partial x}=\cos\theta\frac{\partial}{\partial r}-\frac{\sin\theta}{r}\frac{\partial}{\partial \theta}$$

$$\frac{\partial}{\partial y}=\sin\theta\frac{\partial}{\partial r}-\frac{\cos\theta}{r}\frac{\partial}{\partial \theta}$$

$$\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}=\frac{\partial^2}{\partial r^2}+\frac{1}{r}\frac{\partial}{\partial r}+\frac{1}{r^2}\frac{\partial^2}{\partial \theta^2}$$

QUESTION 3

The pressure rise Δp generated by a pump is a function of the impeller diameter D, rotational speed N, the fluid density ρ, viscosity μ and the rate of discharge Q. Using Buckingham's Pi theorem show that

$$\Delta p=\rho N^2D^2\oint\left(\frac{Q}{ND^3},\frac{\rho ND^2}{\mu}\right)$$

QUESTION 4

Rough turbulent flow occurs in a pipe of 300mm diameter with mixing length of 0.012m when it conveys water. Measurements indicate that the mean velocity and the velocity gradient at a distance 30mm from pipe wall are 2m/s and $10.5s^{-1}$ respectively. Determine the wall shear stress, roughness height, friction factor and the mean velocity of flow.

You may use the following equations with usual notation:

$$\tau = \rho l_m^2 \left(\frac{du}{dy}\right)$$

$$\tau = \tau_0 \left(1 - \frac{y}{R}\right)$$

$$u^* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\frac{u}{u^*} = 8.5 + 5.75log\left(\frac{y}{k}\right)$$

$$\frac{1}{\sqrt{4f}} = 1.74 + 2log\left(\frac{r}{k}\right)$$

$$u^* = V\sqrt{\frac{4f}{8}}$$

QUESTION 5

A compound pipe consists of three pipes connected in series. The diameters and lengths of the three pipes are given below.
Pipe 1: 500mm diameter, 1900m long
Pipe 2: 450mm diameter, 1500m long
Pipe 3: 300mm diameter, 600m long

a) Find the diameter of the equivalent pipe 4000m long.
b) Find the length of the equivalent pipe 450mm in diameter.
c) If the three pipes are connected in parallel find the equivalent length of a 600mm diameter pipe.

QUESTION 6

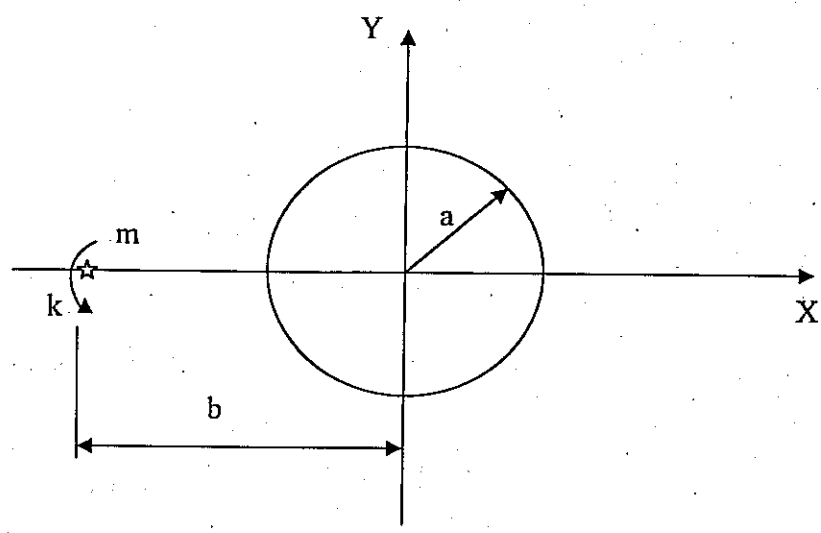


Figure Q 6

A cylinder of radius $|Z| = a$ is placed at the origin of a flow field consisting of a coincident source of strength m and a vortex of strength k located at $Z = -b$ where $b > a$. show that the cylinder is attracted by the singularities by a force

$$F = \frac{-2\pi\rho(m^2 + k^2)a^2}{b(b^2 - a^2)}$$

QUESTION 7

a) Water flows over a flat plate at a free stream velocity of 0.15m/s. There is no pressure gradient and the laminar boundary layer at a location is 6mm thick. Assuming a sinusoidal velocity profile with usual notation, given by

$$\frac{u}{U} = Sin\left(\frac{\pi y}{2\delta}\right),$$

calculate the shear stress on the plate at the point where $\delta = 6mm$. For water $\mu = 1.02\times10^{-3}$Pas and $\rho = 1000$ kg/m^3.

b) A plate 25m long and 1.25m wide is moving underwater in the direction of its length. The drag force on the two sides of the plate is estimated to be 8500N. If the drag coefficient if 0.002, calculate the velocity of the plate.

QUESTION 8

Two sources each of strength m are placed at the points (-a,0),(a,0) and a sink of strength $2m$ at the origin. Show that the stream function is given by

$$\left(x^2+y^2\right)^2 = a^2\left(x^2-y^2+\lambda xy\right)$$

where λ is a variable.

Also show that the speed at any point is $\dfrac{2ma^2}{(r_1 r_2 r_3)}$, where r_1, r_2 and r_3 are the distances of the point from the sources and the sink. You may use the following relationships.

$z = (x+iy)$ and $\ln(\alpha+i\beta) = \dfrac{1}{2}\ln\left(\alpha^2+\beta^2\right)+i\tan^{-1}(\beta/\alpha)$

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