UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: February 2023

Module Number: CE3303 **Module Name: Fluid Mechanics**

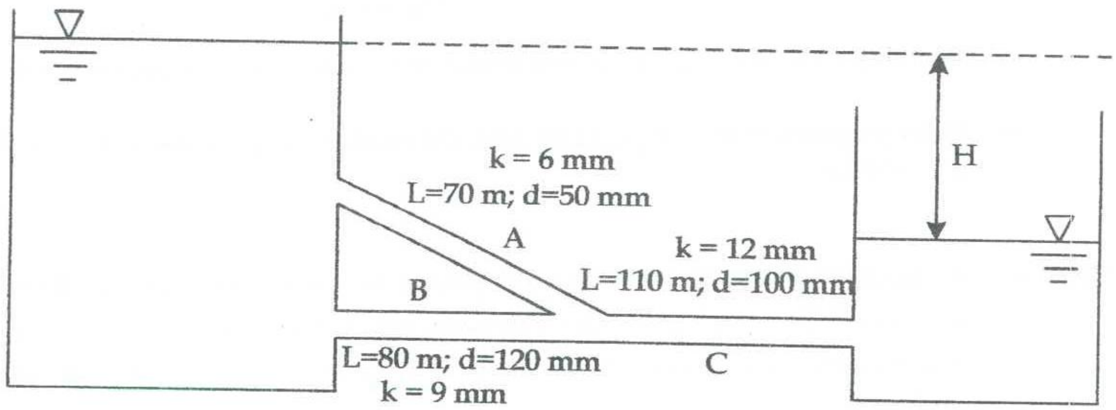
[Three Hours]

[Answer all questions. Each question carries FIFTEEN marks]

All standard notations denote their usual meanings.

Q1. Pipes are connected between two reservoirs as shown in Figure Q1. If $H = 11$ m, $\mu = 8 \times 10^{-3}$ Pa s and specific density of the liquid is 0.9, find the discharge through pipes A, B, and C.

You may consider that $\frac{1}{\sqrt{f}} = -2log\left[\frac{2.5}{Re\sqrt{f}} + \frac{k}{3.7D}\right]$.



L= length; d=diameter; k=pipe roughness

Figure Q1

[15 Marks]

Q2. a) The laminar boundary layer results obtained from the momentum integral equation are relatively insensitive to the shape of the assumed velocity profile. Consider the velocity profiles given below.

(i) $\frac{u}{U_\infty} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$

(ii) $\frac{u}{U_\infty} = 2\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^2 - 2\left(\frac{y}{\delta}\right)^3$

Which of the above expressions produces meaningful results when used with the momentum integral equation? Provide reasons for your answer.

[4 Marks]

b) Considering your answer in part (a),

(i) Determine the boundary layer thickness as a function of x.

[5 Marks]

(ii) A smooth thin flat plate with a length of 1 m and width of 3 m is immersed parallel to a stream of velocity 2 m/s. Calculate the boundary layer thickness at the trailing edge of the plate and the drag force on one side of the plate for air ($\rho = 1.23\ kg/m^3; \nu = 1.46 \times 10^{-5} m^2/s$).

[6 Marks]

Q3. A horizontal flow between the walls (Figure Q3) is defined by the stream function $\psi = \left[4r^{4/3}\sin\left(\frac{4}{3}\theta\right)\right]\ m^2/s$, where r is in meters.

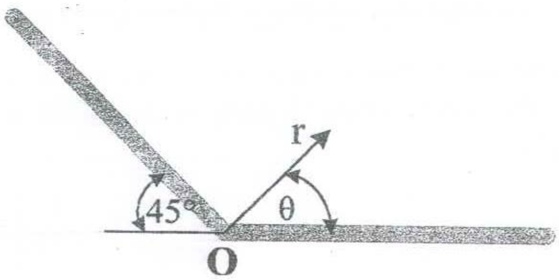


Figure Q3

a) Determine the flow rate between points A(r = 2 m, θ = 45°) and B(r = 4 m, θ = 45°).

[3 Marks]

b) If the pressure at the origin is 20 kPa, determine the pressure at $r = 2\ m, \theta = 45°$. $\rho = 900\ kg/m^3$.

[12 Marks]

Q4. a) A circular cylinder of diameter d is placed in a uniform stream of fluid as shown in Figure Q4a. Far from the cylinder, the velocity is V and the pressure is atmospheric. The gauge pressure is P at point A (θ = 170°) on the cylinder surface.

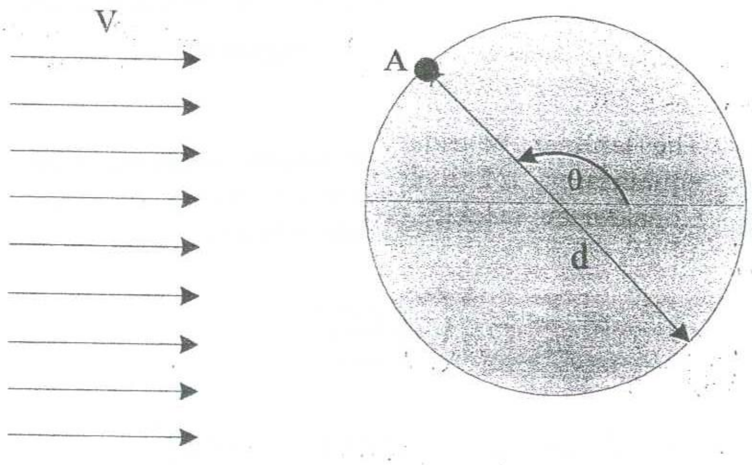


Figure Q4a

(i) Using dimensional analysis show that $\frac{P}{\rho V^2} = f\left(\frac{\rho V d}{\mu}\right)$

[5 Marks]

(ii) The gauge pressure P is to be determined from a model study for a 20 cm diameter prototype placed in an air stream having a speed of 2.5 m/s. A 1:12 scale model is to be used with water as the working fluid. Some experimental data obtained from the model are shown in Figure Q4b. Calculate the pressure at corresponding point A in the prototype.

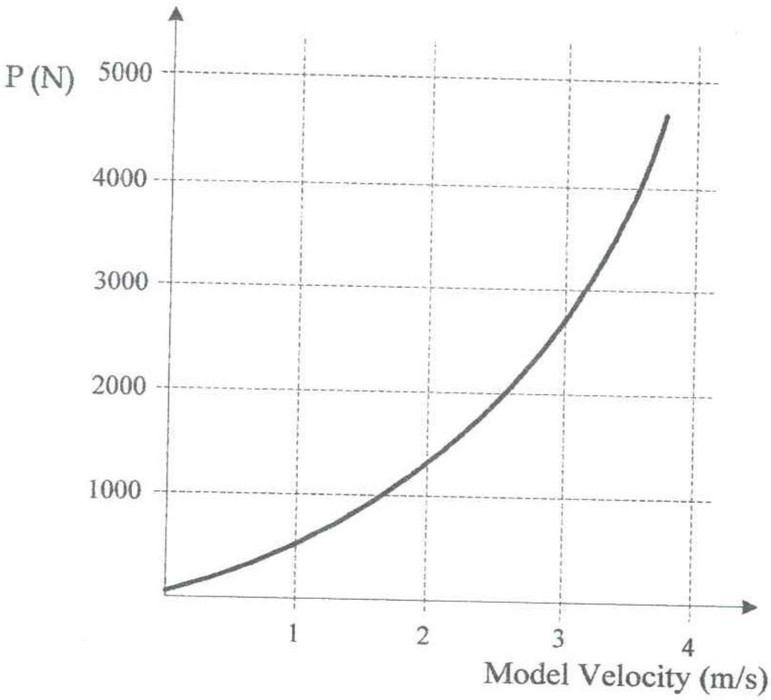


Figure Q4b

[5 Marks]

b) For ideal fluid flow passing a circular cylinder, radial and tangential velocity components are given by $U_r = U\left(1 - \frac{R^2}{r^2}\right)cos\theta$; $U_\theta = -U\left(1 + \frac{R^2}{r^2}\right)sin\theta$, respectively. By applying Bernoulli's equation show that $P = \frac{\rho V^2}{2}(1 - 4Sin^2\theta)$ and calculate the pressure at the corresponding point A in the prototype.

[5 Marks]