UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: October 2019

Module Number: CE3303 **Module Name: Fluid Mechanics (C-18)**

[Three Hours]

[Answer all questions. Each question carries FIFTEEN marks]
All standard notations denote their usual meanings.

Q1. a) State the conditions under which the following equations are applicable to pipe flow.

(i) $\frac{u}{U_{max}} = \left(1 - \frac{r^2}{{r_o}^2}\right)$

(ii) $\frac{U_{max} - u}{u_*} = -2.5 \ln\left(\frac{y}{r_0}\right)$

[2 Marks]

b) A liquid of density $750\ kg/m^3$ and kinematic viscosity $2 \times 10^{-5}\ m^2/s$ flows in a pipe of inner diameter 1 cm. The velocity at the centreline of the pipe is measured to be 3 m/s. Select the appropriate equation from part (a) and determine volume flow rate through the pipe and the shear stress at the pipe wall.

[8 Marks]

c) Considering the velocity expression for u and $v = 0$, generate an expression for stream function Ψ along the vertical dashed line in Figure Q1. Consider $\Psi = 0$ along the bottom wall. What is the value of Ψ along the top wall? Compare and discuss your result to that obtained in part (b).

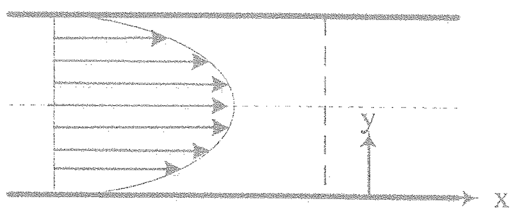


Figure Q1

[5 Marks]

Q2. a) Water (kinematic viscosity $=10^{-6}\ m^2/s$) is delivered through a pipe from an upper reservoir (A) to a lower reservoir (B) having water surface elevations of 40 m and 35 m, respectively. The pipe has a length of 3900 m and a diameter of 0.3 m with an absolute roughness of 0.26 mm. Find the flow rate in the pipeline. You may use the Moody diagram given in Page 3.

[4 Marks]

b) If the flow rate has to be increased to 0.1 m^3/s, calculate the head added to water by a pump attached to the system in (a).

[3 Marks]

c) The pump characteristic curve is given in Figure Q2 for the pump operating at 1200 rpm.

   (i) Derive an expression for system characteristic curve and plot it in Figure Q2 (Page 4).

   (ii) Find the operating speed of the pump added to the pipeline system for the flowrate of 0.1 m^3/s.

Detach page 4 of the question paper and attach it to the answer script.

[8 Marks]

Flow number, head number, and power number are Q/ND^3, gH/N^2D^2, and $P/\rho N^3D^5$, respectively.

Q3. A 0.5 m diameter bridge pier is subjected to the uniform flow of water at 4 m/s. Using the potential flow theory:

a) Describe how you can model the flow field around the bridge pier.

[2 Marks]

b) Derive the stream function representing the flow field around the bridge pier.

[5 Marks]

c) Determine the pressure distribution around the bridge pier.

[5 Marks]

d) Determine the maximum and minimum pressures exerted on the pier at a depth of 2 m.

[3 Marks]

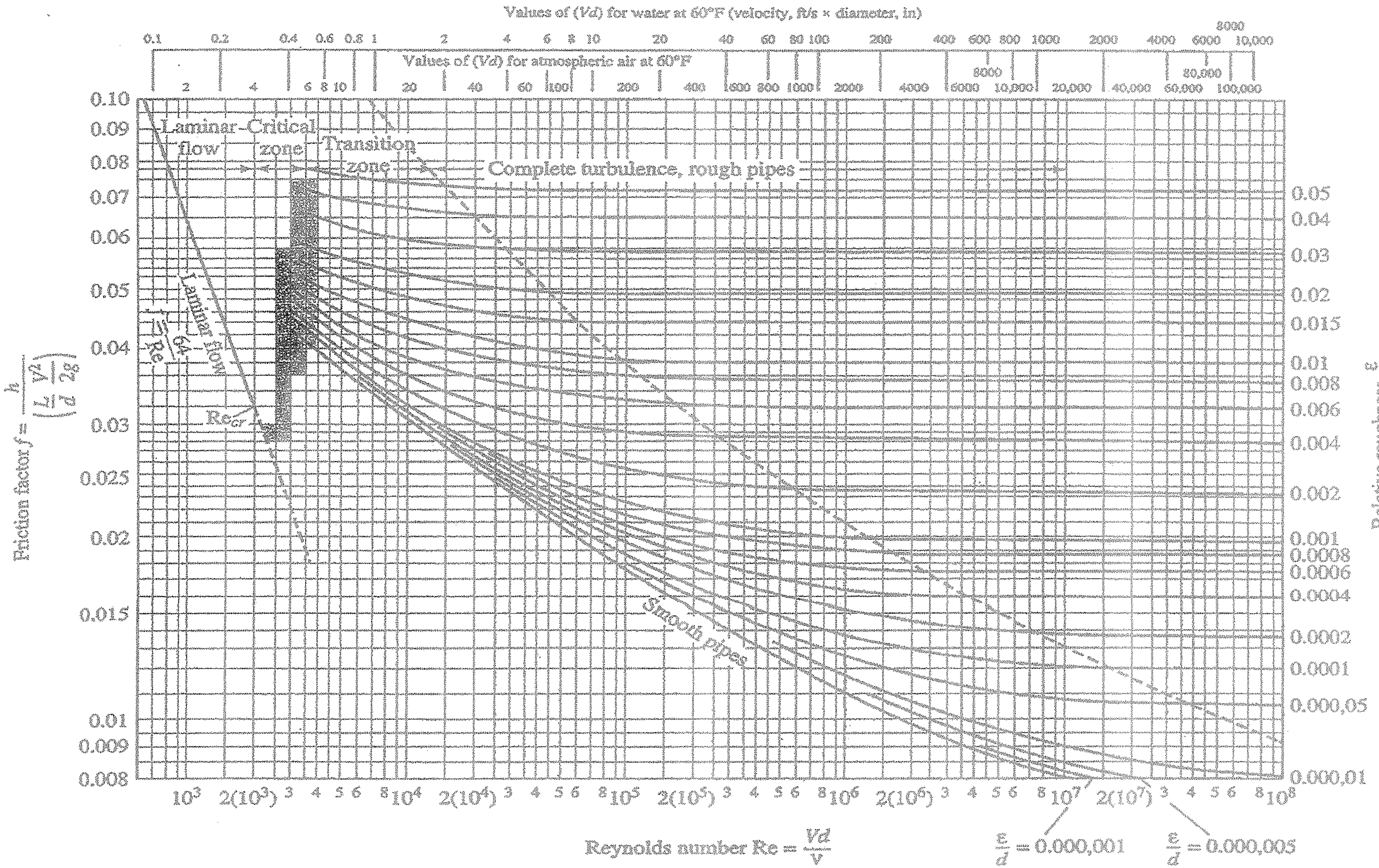
Stream function of a doublet can be represented as $\psi = -\frac{\mu}{2\pi}\left(\frac{\sin\theta}{r}\right)$

Q4. a) Consider steady flow over a thin flat plate. The boundary layer thickness δ at any downstream distance x is a function of x, free-stream velocity (U), and fluid properties density (ρ), and viscosity (μ). Use dimensional analysis to derive a functional relationship for δ.

[3 Marks]

b) Air of density 1.2 kg/m^3 and kinemetic viscosity 14.5 mm^2/s flows at 29 m/s past a 3 m long flat plate. At a distance of 0.5 m from the leading edge, a fine trip wire attached to the flat plate perpendicular to the flow induces abrupt transition in the boundary layer at that position and also there is a 15% increase in the momentum thickness. Assuming steady two-dimensional flow at constant pressure, calculate the drag force on the plate due to viscous shear. For the laminar boundary layer, $\theta = \frac{0.664x}{\sqrt{Re_x}}$ and for the turbulent boundary layer, $\theta = \frac{0.037x}{(Re_x)^{-1/5}}$.

[12 Marks]



Moody diagram

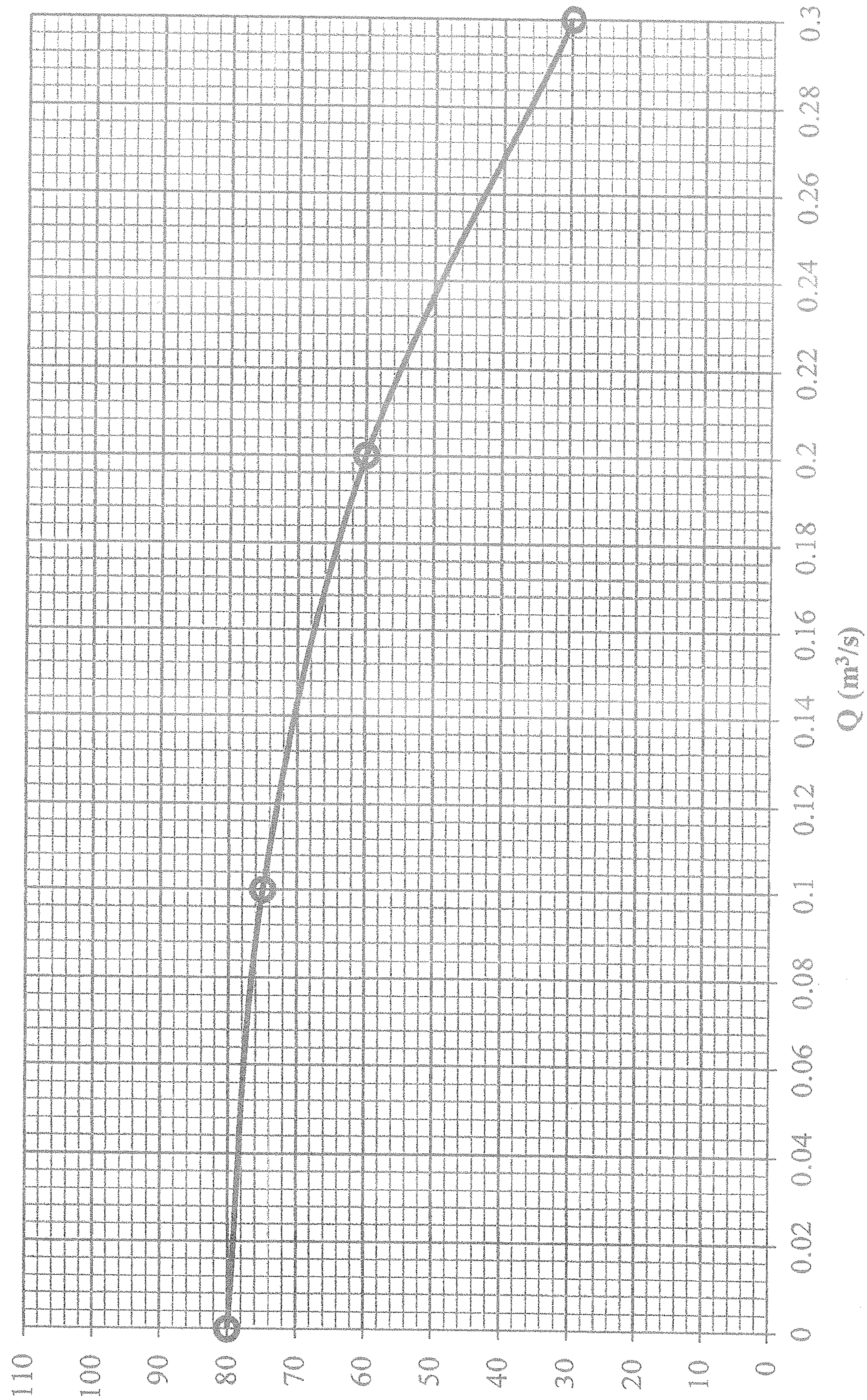

H (m)
110
100
90
80
70
60
50
40
30
20
10
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
Q (m³/s)

Figure Q2