UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2022

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) Water flows at a steady mean velocity of 1.5 m/s through a 50 mm diameter pipe sloping upward at 45° to the horizontal. At some section, the pressure is 700 kPa and at a section further along the pipe, the pressure is 462 kPa. Determine the average shear stress at the wall of the pipe and at a radius of 10 mm.

[7 Marks]

b) Velocity in a laminar boundary layer is approximated by the two straight-line segments indicated in Figure Q1. Apply the momentum integral equation to determine the boundary layer thickness and wall shear stress.

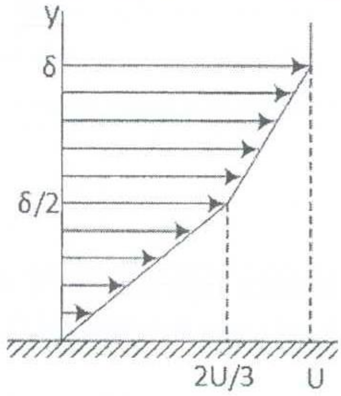


Figure Q1

[8 Marks]

Q2. The flowrate between tank A and tank B ,shown in Figure Q2 ,is to be increased by 30% by the addition of a second pipe, indicated in dotted line, running from node C to tank B. If the elevation of the free surface in tank A is 7.5 m, determine the diameter of the new pipe. You may refer to the Moody diagram given in Page 4.

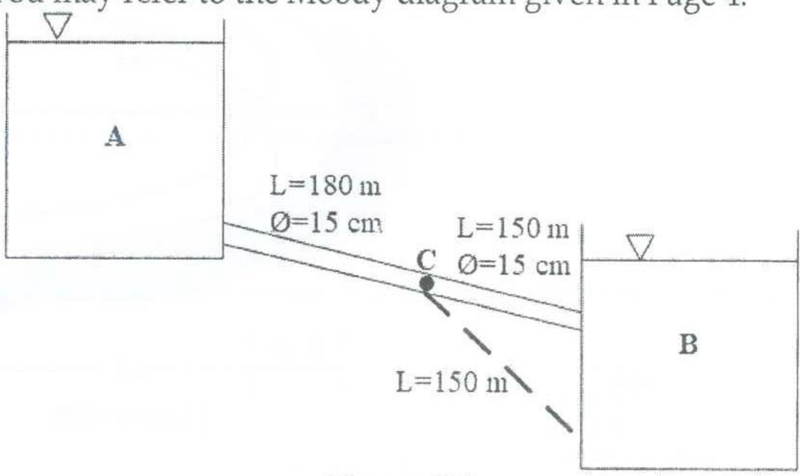


Figure Q2

[15 Marks]

Q3. a) A two-dimensional flow field for a non-viscous, incompressible fluid is described by the velocity components

$$u = 3x^2 - 3y^2$$
$$v = -6xy$$

where x and y are in meters.

(i) Determine the stream function of the flow field.

[3 Marks]

(ii) Determine the rate of flow across the straight path AB shown in Figure Q3a.

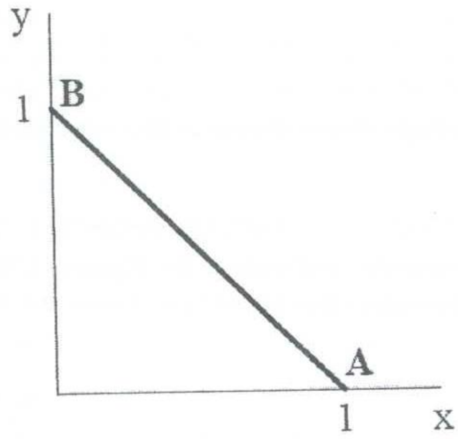


Figure Q3a

[3 Marks]

b) (i) The stream function for a source is given by $^{q\theta}/_{2\pi}$. Derive an expression for the stream function of flow around a half-body.

[1 Mark]

(ii) One end of a pond has a shoreline that resembles a half-body as shown in Figure Q3b. A vertical porous pipe is located near the end of the pond so that water can be pumped out. When water is pumped at the rate of 0.04 m^3/s through a 3 m long pipe, what will be the velocity at point A?

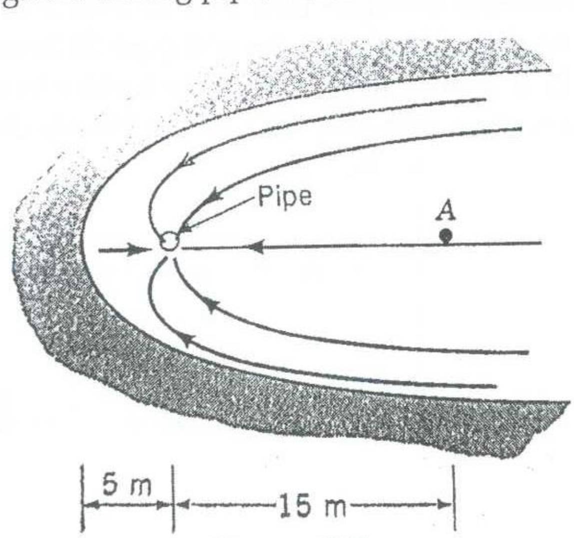


Figure Q3b

[8 Marks]

Q4. The pressure rise ΔP generated by a pump of given geometry depends on the impeller diameter D, its rotational speed N, the fluid density ρ, the viscosity μ, and the discharge Q.

a) Show that the relationship between these variables can be expressed as;

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

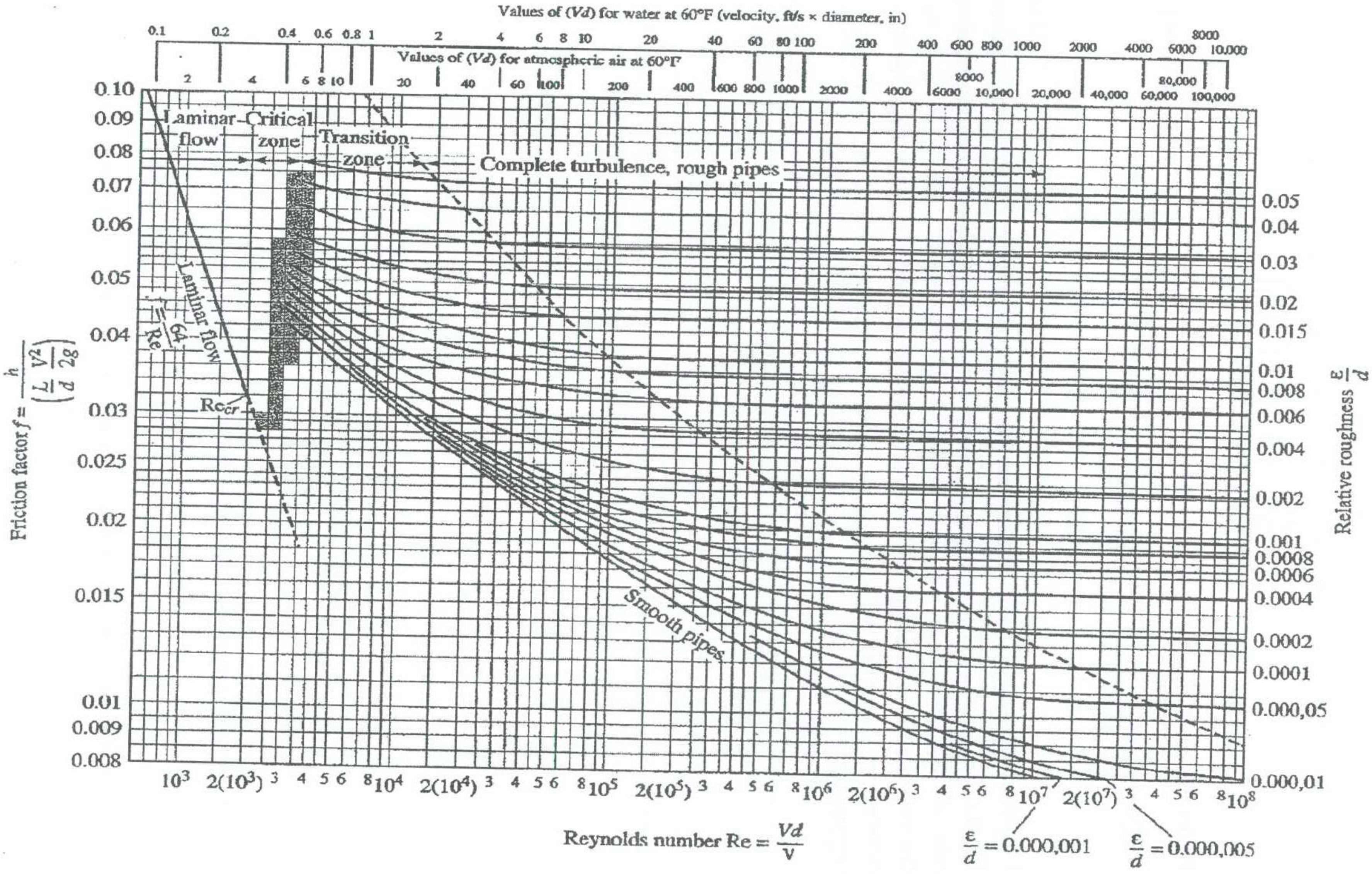
[6 Marks]

b) From the relationship obtained in part (a), show that hydraulic scaling laws for a single pump are (1) $\frac{Q_2}{Q_1} = \frac{N_2}{N_1}$ and (2) $\frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2$.

[3 Marks]

c) The characteristics curve for a centrifugal pump operating at 1000 rpm is given in Figure Q4. At its duty point, it generates a head of 12 m when pumping water at a rate of 0.015 m^3/s. If a similar pump is to operate at a corresponding to its characteristics delivering 0.03 m^3/s of water against a total head of 30 m, determine the rotational speed at which the pump should run to meet the requirement.

[6 Marks]



Moody diagram

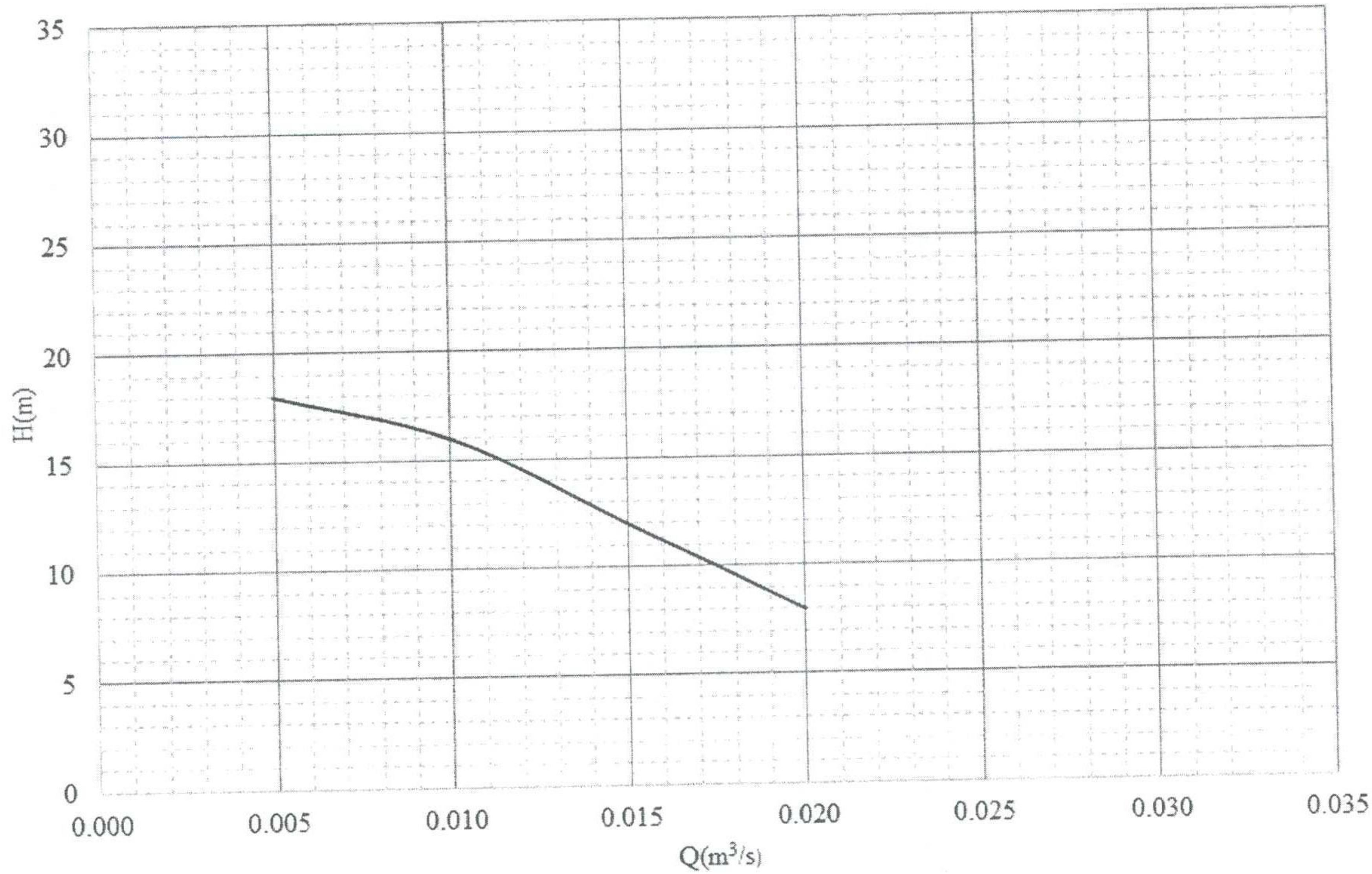

35
30
25
20
15
10
5
0
H(m)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
Q(m3/s)

Figure O4