UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2026

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) A sudden expansion in a pipeline is shown in Figure Q1-A.

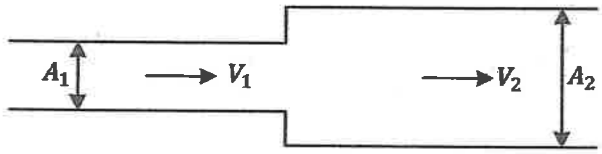


Figure Q1-A

Where A_1 and V_1 are the area and velocity of fluid in the smaller pipe, and A_2 and V_2 are the area and velocity of the fluid in the larger pipe. Show that head loss due to sudden expansion in the pipe is given by

$$h_m = \frac{V_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$$

[3 Marks]

b) Two reservoirs are connected by two 6 m long wrought iron pipes in series as in Figure Q1-B. The entrance and exit are sharp-edged. Including minor losses, calculate the flow rate if the Reservoir 1 is 18 m above the Reservoir 2, and the average temperature of the system is 20 °C. You may consider absolute roughness in pipes as 0.00015 mm. Moody diagram is given in Page 4.

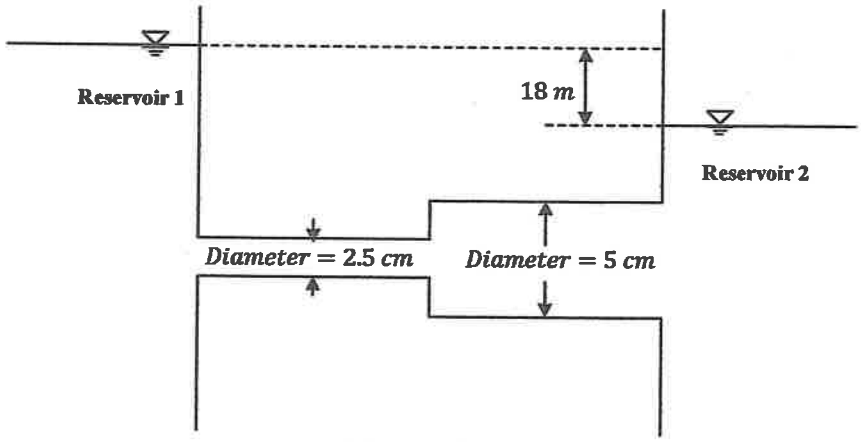


Figure Q1-B

[12 Marks]

Q2. a) Explain the boundary layer theory proposed by Ludwig Prandtl including the followings.

i) Formation of the boundary layer over a flat plate.

[3 Marks]

ii) Transition from laminar to turbulent flow.

[3 Marks]

iii) Boundary layer separation and the effect of adverse pressure gradient.

[3 Marks]

b) Oil with a free stream velocity of 2 m/s flows over a thin plate of 2 m wide and 3 m long. Calculate the boundary layer thickness and the shear stress at the mid length point. Consider density and kinematic viscosity of fluid as 860 kg/m^3 and 10^{-5} m^2/s, respectively.

[6 Marks]

Q3. a) Under what circumstances does potential flow analysis give an accurate prediction of the flow of real fluids?

[1 Mark]

b) Define a doublet and derive its streamflow function.

[3 Marks]

c) Explain how flow around a cylinder is obtained using superposition. Define stagnation points and locate them for cylinder flow.

[5 Marks]

d) A cylinder of radius 4 cm is held with its centre at the point (0,0) in a fluid stream. At large distances from the cylinder, the fluid velocity is constant at 30 m/s parallel to the x axis and in the direction of increasing x. Calculate the components of the fluid velocity at the point $x = -4$ cm, $y = 1$ cm.

[2 Marks]

e) Derive pressure coefficient expression and calculate the minimum and maximum pressure around the cylinder. Consider fluid density as 800 kg/m^3.

Draw the pressure distribution around the cylinder and state the reason for zero drag in cylinder for potential flow.

Sketch and explain real fluid flow around the cylinder.

[4 Marks]

Streamflow function for a source $\psi = \frac{q\theta}{2\pi}$

$U_r = \frac{1}{r}\frac{\partial\psi}{\partial\theta}$; $U_\theta = -\frac{\partial\psi}{\partial r}$

Q4. a) The pressure rise ΔP generated by a centrifugal pump of given geometry depends on the impeller diameter D, its rotational speed n, the fluid density ρ and viscosity of the fluid μ, and volume flow rate through the pump Q. Derive the dimensionless relationship between variables using the pi theorem.

$$\left[\frac{\Delta P}{\rho n^2 D^2} = f\left(\frac{Q}{nD^3}, \frac{\rho n D^2}{\mu}\right)\right]$$

[6 Marks]

b) A given pump rotates at a speed of 1000 rev/min and at its duty point it generates a head of 12.2 m when pumping water at a rate of 0.0151 m^3/s. Assume that the effects of viscosity are negligible.

(i) Calculate the head generated by a similar pump of twice the size when operating under dynamically similar conditions and discharging 0.0453 m^3/s.

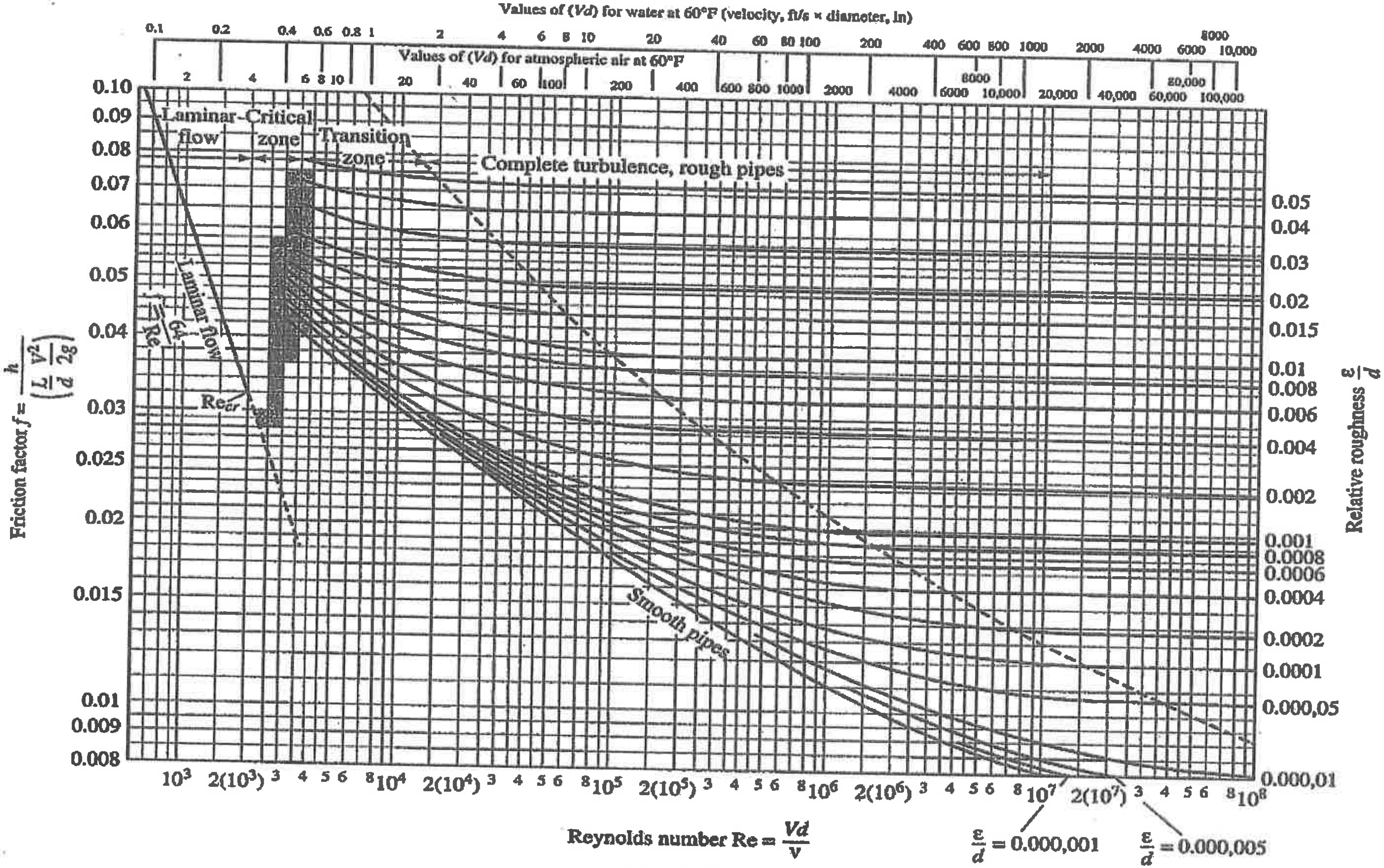
[3 Marks]

(ii) Determine the rotational speed of the larger pump.

[3 Marks]

(iii) Calculate the ratio of whirl velocities.

[3 Marks]



Moody Diagram