UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2021

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

[Three Hours]

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

Q1. a) Briefly explain, what is meant by a fully developed flow.

[2 Marks]

b) The velocity u at any radius r in a fully developed laminar flow through a straight horizontal pipe of internal radius r_0 is given by

$$u = (1/4\mu)({r_0}^2 - r^2)\frac{dp}{dx}$$

where $\frac{dp}{dx}$ is the pressure gradient in the direction of the flow. Show that

(i) the pressure drop over a length L is given by $\Delta P = \frac{32\mu VL}{D^2}$, where v is the mean velocity.

[3 Marks]

(ii) wall shear stress τ_0 is given by $\frac{r_0}{2}\Delta P$

[3 Marks]

c) A liquid with density 900 kg/m^3 and kinematic viscosity $2 \times 10^{-4} m^2/s$ flows in a horizontal pipe of 50 mm diameter at a mean velocity of 5 m/s. If the length of the pipe is 10 m, determine

(i) the friction coefficient
(ii) wall shear stress

[4 Marks]

Q2. a) Assuming that a pipe run in full with a steady flow, derive an expression to estimate head lost due to dissipation of energy as heat at an abrupt enlargement of the cross section.

[3 Marks]

b) The flow rate in the pipe system in Figure Q2 is 0.05 m^3/s. The pressure at point 1 is measured to be 260 kPa. All the pipes have a roughness value of 0.15 mm. Determine the pressure at point 2. Take the loss coefficient for the sudden contraction as 0.05 and kinematic viscosity as $\nu = 10^{-6} m^2/s$. Moody diagram is given in Page 4.

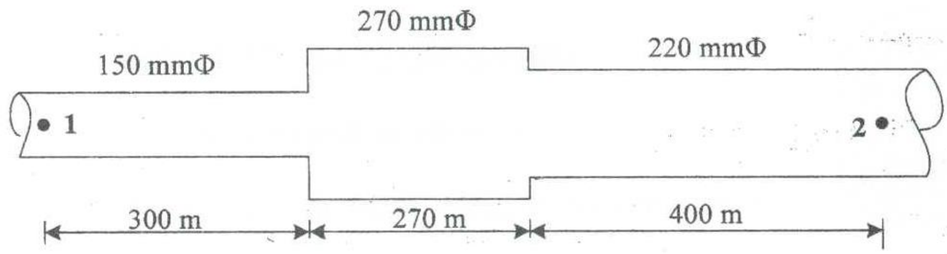


Figure Q2

[9 Marks]

Q3. a) Consider a boundary layer developed over a smooth thin flat plate. State the boundary conditions that should be statisfied by the velocity distribution of a laminar boundary layer under the conditions of zero-pressure gradient.

[2 Marks]

b) Which of the following expressions describes better velocity distribution for a laminar boundary layer on a flat plate in the absence of a streamwise pressure gradient? Provide reasons.

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

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

[2 Marks]

c) Air of density 1.2 kg/m^3 and kinemetic viscosity 14.5 mm^2/s passes over a thin flat plate of dimensions $1\ m \times 1\ m$, parallel to the plate. If transition takes place at the trailing edge of the plate at $Re = 5 \times 10^5$,

(i) determine the velocity of the airstream.

(ii) calculate the frictional drag of the plate by applying Momentum Integral equation. Use the most suitable velocity profile in part (b).

[8 Marks]

Q4. The velocity profile of a very thick liquid flowing along a rectangular channel of constant width is approximated as $u = 3y^2$ mm/s, where y is in millimeters.

a) Determine the volumetric discharge through the channel per meter width.

[2 Marks]

b) Is it possible to determine the potential function for the flow? If so, what is it?

[4 Marks]

c) (i) Determine the stream function for the flow.
(ii) Estimate the flow rate of the liquid through the channel. You may consider the liquid height as 8 mm.

[6 Marks]

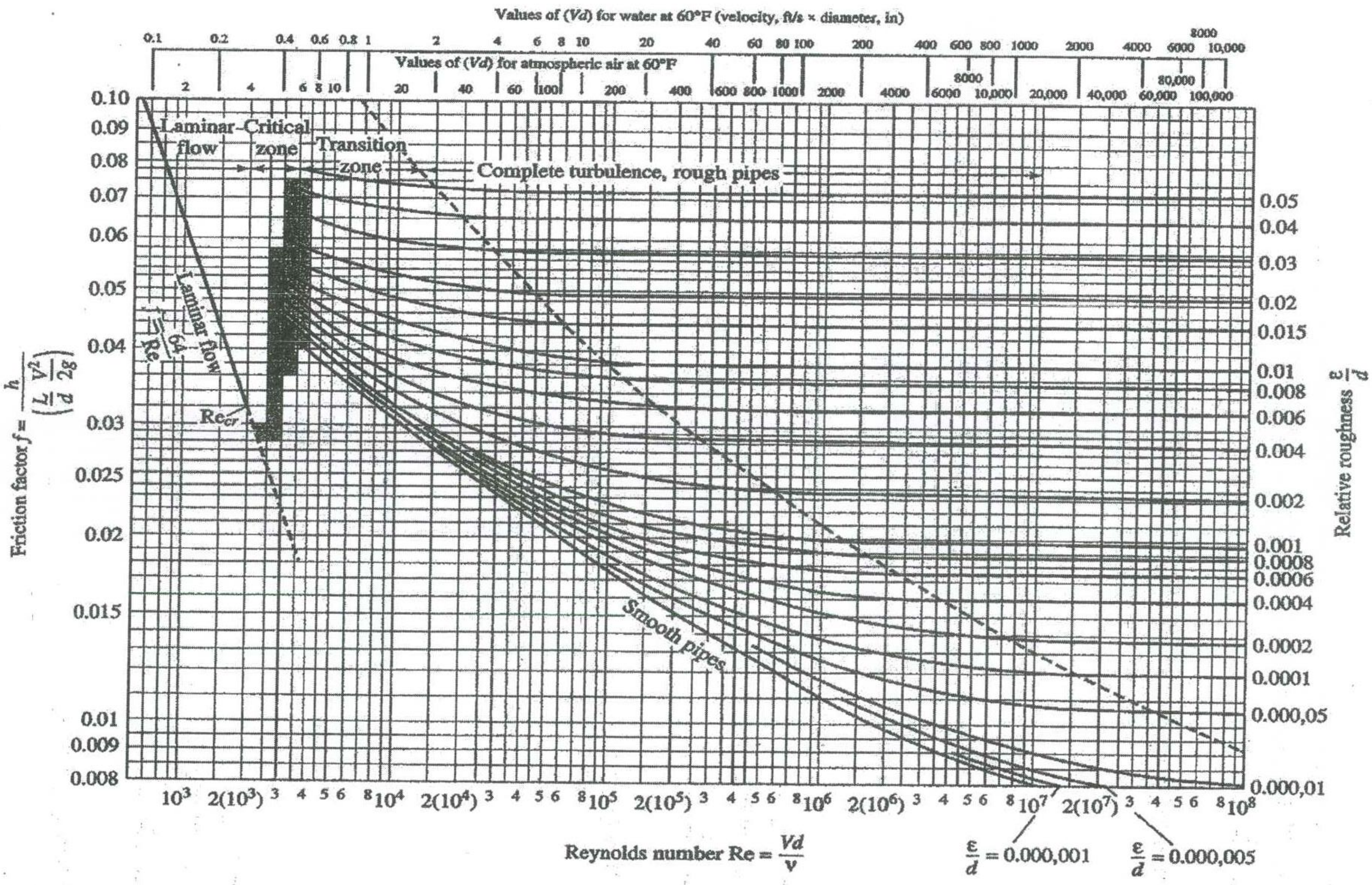
Q5. The power generated by a wind turbine (P) depends on the physical quantities rotor diameter(D), rotational speed(N), upstream wind velocity(V), air density(ρ), and dynamic viscosity of air(μ).

a) Develop the appropriate dimensionless groups in determining wind turbine power generation. Show that $\frac{P}{\rho D^5 N^3} = \emptyset\left(\frac{V}{ND}, \frac{\rho V D}{\mu}\right)$

[6 Marks]

b) Determine how power of a dynamically similar machine can be increased by three times.

[6 Marks]



Moody diagram