UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2017

Module Number: ME3301 **Module Name: Fluid Mechanics**

[Three Hours]

[Answer **all questions**; each question carries **twelve marks**; provide neat sketches where necessary; state any reasonable assumptions made; most relevant equations are provided at the end of the paper]

Q1 a) What is meant by 'Source Flow' and write down an equation for radial velocity (u_r) for the strength of the source is q?

[1.0 Mark]

b) The velocity potential of a two dimensional fluid flow is given by $\phi = x(2y-1)$. Determine,

i. Velocity of a point P located at (4, 5).

ii. Value of stream function ψ at the point P.

[2.0 Marks]

c) Write down two properties of a free vortex flow.

[1.0 Mark]

d) The flow generated by a helicopter rotor can be approximated to a free vortex of strength Γ. Wind flows at a relative velocity of U towards the helicopter as shown in Figure Q1. Determine the followings,

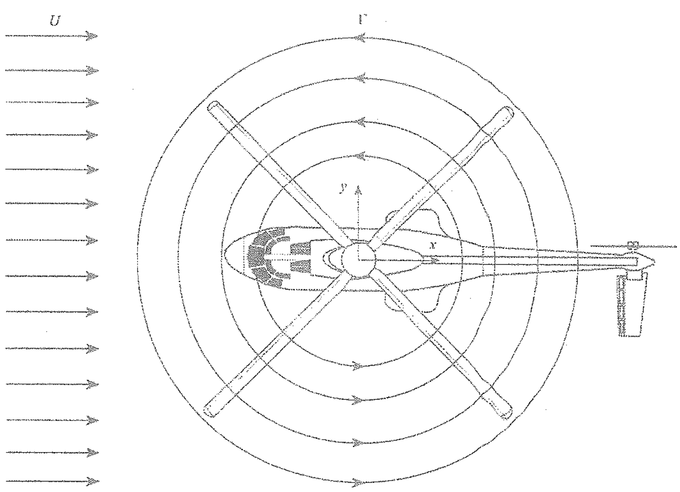


Figure Q1

i. Velocity potential ϕ for the air flow around the helicopter.

Q1 is continued to page 2

ii. If the origin of the free vortex lies on the rotating axis of the helicopter, obtain an expression for the components v_r and v_θ of the flow field.

iii. The location of the stagnation point.

iv. If the atmospheric pressure in the flow far away from the helicopter is p_o, what is the pressure at a point (r,θ) near the helicopter? Verify that the pressure is p_o at the stagnation point.

[8.0 Marks]

Q2 a) Compare the difference between Laminar and Turbulent Flow.

[2.0 Marks]

b) Air is flowing over a horizontal flat plate which is 500 mm long and 600 mm wide, with a velocity of 4 m/s. The kinematic viscosity of air is 1.5×10^{-5} m²/s.

i. Find the boundary layer thickness at the end of the plate.

ii. Calculate the shear stress at 200 mm from the leading edge of the plate.

iii. Find the drag force on top surface of the plate.

Take the velocity profile over the plate as $\frac{u}{U}=\sin\left(\frac{\pi}{2}.\frac{y}{\delta}\right)$, and density of air is 1.24 kg/m³. For the given velocity profile,

$$\delta=\frac{4.795x}{\sqrt{R_{e_x}}}\ ,\ \tau_0=0.327\frac{\mu U}{x}\sqrt{R_{e_x}}\ ,\ F_D=0.655\times\mu U\times b\times\sqrt{\frac{\rho UL}{\mu}}\ .$$

[5.0 Marks]

c) Briefly describe the effect of pressure gradient on boundary layer separation with the aid of suitable diagram.

[3.0 Marks]

d) Clearly state five methods that can be used to minimize the separation of boundary layer in an aero-foil.

[2.0 Marks]

Q3 a) With the aid of a diagram, explain the difference between 'Hydro-dynamically smooth' and 'Hydro-dynamically rough' boundaries.

[2.0 Marks]

b) Derive an expression for co-efficient of the friction of a fluid in terms of shear stress. Hint: head loss due to friction of a flowing fluid is given by the Darcy-Weisbach equation.

[2.0 Marks]

c) A smooth pipe (diameter 80 mm and 800 m length) carries water at a rate of 0.480 m³/min. Calculate the followings,

i. The loss of head.

ii. Wall shear stress.

iii. Center line velocity.

iv. Velocity and shear stress at 30 mm from pipe wall.

v. Calculate the thickness of the laminar sub-layer.

Q3 is continued to page 3

Assume the kinematic viscosity of water is 0.015 stokes. Take the value of co-efficient of friction 'f' from the relation given by $f = \frac{0.0791}{(R_e)^{1/4}}$, where R_e = Reynolds number.

[8.0 Marks]

Q4. a) Starting with the Bernoulli's equation, derive an equation for the loss of head due to a sudden enlargement in a pipe as shown in Figure Q4.

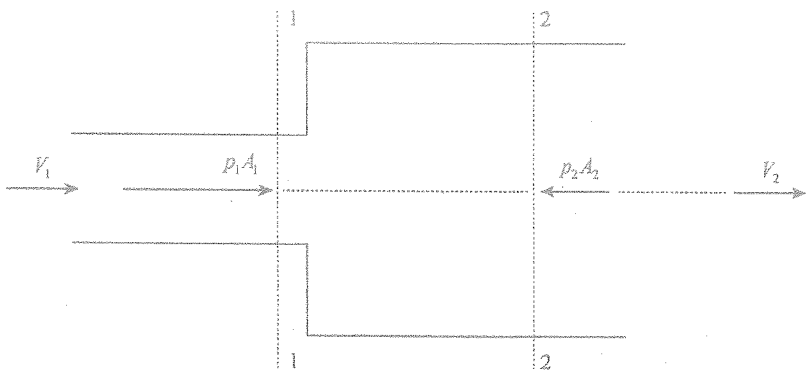


Figure Q4

[2.0 Marks]

b) Using the equation derived in Q4 (a) estimate the rate of flow through a pipe line which has 240 mm to 480 mm diameter enlargement. Assume the hydraulic gradient rises due to enlargement is 10 mm.

[4.0 Marks]

c) Calculate the steady flow rate at which oil flows through a 140 m long Galvanized iron pipe of 100 mm diameter under a head difference of 5 m. (kinematic viscosity = $1.0 \times 10^{-5}\ m^2/s$)

[6.0 Marks]

Q5 a) Figure Q5 represents a piping network consisting of five pipes. Calculate the flow rate in each pipe of the network for two iterations. For each pipe, head loss h_f is given by KQ^2. The values of K for various pipes and also the inflow or outflows at nodes are also given in the Figure Q5. For the first trial, the assumed discharges (liters/minutes) are also indicated in the diagram.

Q5 is continued to page 5

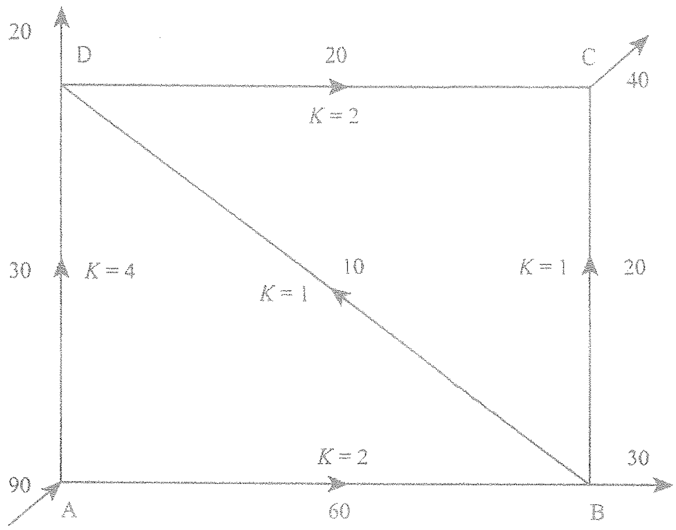


Figure Q5

[6.0 Marks]

b) In a hydropower plant penstock supplies water from a reservoir to a Pelton wheel turbine at a gross head of 500 m. One third of the gross head is lost as friction in the penstock. The flow rate of water through the nozzle fitted at the end of the penstock is 2.0 m^3/s. The angle of deflection of the water jet is 165^0. Determine the followings,

i. The power delivered by the water to the turbine runner.
ii. Hydraulic efficiency of the turbine.

Assume, Speed ratio = 0.45 and $C_v = 1.0$, respectively.

[6.0 Marks]

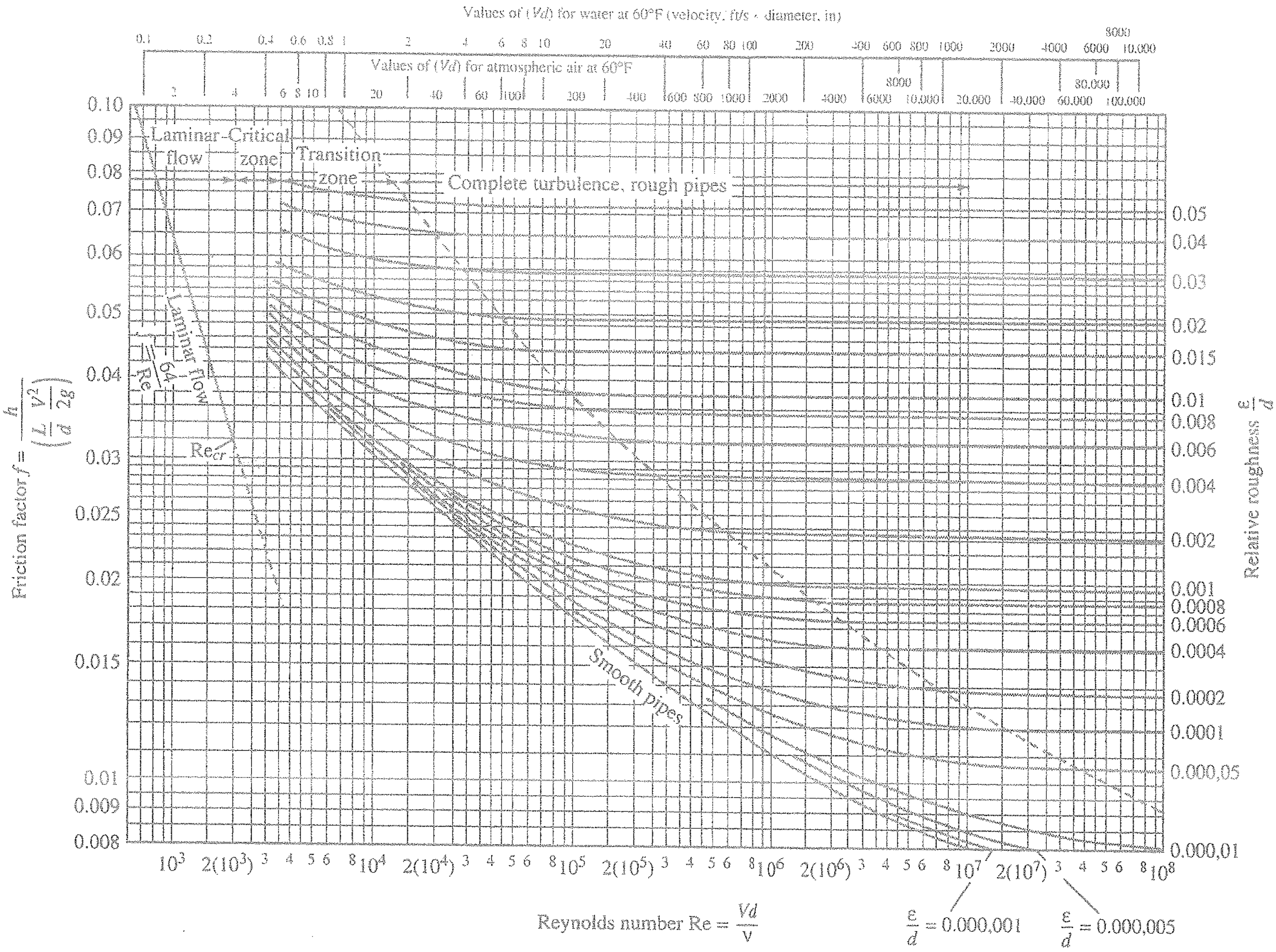
Useful equations with usual notations;

$$f = \frac{0.0791}{R_e^{1/4}}$$

$$\frac{u}{u_*} = 5.75\log_{10}\frac{u_* y}{\nu} + 5.55$$

$$u_* = \sqrt{\frac{\tau_0}{\rho}}$$

$$\delta' = \frac{11.6 \times \nu}{u_*}$$



Material	Condition	ε ft	ε mm	Uncertainty, %
Steel	Sheet metal, new	0.00016	0.05	± 60
	Stainless, new	0.000007	0.002	± 50
	Commercial, new	0.00015	0.046	± 30
	Riveted	0.01	3.0	± 70
	Rusted	0.007	2.0	± 50
Iron	Cast, new	0.00085	0.26	± 50
	Wrought, new	0.00015	0.046	± 20
	Galvanized, new	0.0005	0.15	± 40
	Asphalted cast	0.0004	0.12	± 50
Brass	Drawn, new	0.000007	0.002	± 50
Plastic	Drawn tubing	0.000005	0.0015	± 60
Glass	—	Smooth	Smooth	
Concrete	Smoothed	0.00013	0.04	± 60
	Rough	0.007	2.0	± 50
Rubber	Smoothed	0.000033	0.01	± 60
Wood	Stave	0.0016	0.5	± 40