UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: August 2018

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; If it is not specified, symbols have usual meaning; most relevant equations are provided at the end of the paper

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Q1 a) What is meant by 'Velocity Potential Function' of a two-dimensional ideal fluid flow?

[1.0 Mark]

b) If velocity potential exists, what properties that must be satisfied by the ideal fluid flow?

[2.0 Marks]

c) Determine whether the continuity equation is satisfied by the following velocity components of an incompressible fluid flow.

$$u = x^3 - y^3 - z^2x,\ v = y^3 - z^3,\ w = -3x^2z - 3y^2z + \frac{z^3}{3}$$

[1.0 Mark]

d) The velocity potential function (ϕ) of a two-dimensional ideal fluid flow is given by an expression of,

$$\phi = -\frac{xy^3}{3} - x^2 + \frac{x^3y}{3} + y^2$$

i. Find the velocity components in x and y direction.
ii. Show that ϕ represents a possible case of flow.

[4.0 Marks]

e) During the recent flood caused in Baddegama - Galle, surface velocity in a stream is measured with the help of a floating object. A float in the form of an empty sealed tin container travels a distance of 52.50m in 30s on the surface of a stream. If the velocity field on the surface of a stream is identified as $V_S = (3x+2y)i + (2z+3x^2)j + (2t-3z)k$. Determine,

i. The velocity components u, v, w at any point in the flow field,
ii. The speed at the point (1, 1, 1),
iii. The speed at time t = 2s at point (0, 0, 2).

[4.0 Marks]

Q2 a) Briefly describe how boundary layer forms when a real flow of fluid with having free stream velocity (U) flowing over a smooth thin plate which is flat and placed parallel to the direction of free stream flow.

[2.0 Marks]

b) What is meant by "Displacement Thickness" given with the usual notation of (δ^*) for a boundary layer.

[2.0 Marks]

c) If the displacement thickness for a real fluid flowing over a thin flat plate placed parallel to the fluid flow is given by $\delta^* = \int_o^\delta \left(1 - \frac{u}{U}\right) dy$, find the displacement thickness for the velocity distribution in the boundary layer given by $2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$.

NOTE: u is the velocity at distance y from the plate and, $u = U$ at $y = \delta$, where δ = boundary layer thickness. Velocity distribution is given in the usual format of u / U.

[2.0 Marks]

d) Thin flat plate with having dimensions of 1m length and 0.8m wide is immersed in a water flow in which the surface of plate is parallel to the flow field. If the mainstream velocity of water flow is 150 mm/s, and the velocity distribution (profile) over the plate is identified similar to given in Q2 c), calculate the following ;

i. Thickness of boundary layer at the end of the plate,
ii. Drag force on one side of a plate,
iii. Drag Coefficient .

[6.0 Marks]

Q3 a) With the aid of suitable diagram, explain the "Entrance Region" of a fluid entering a circular pipe at a uniform velocity.

[2.0 Marks]

b) Applying Bernoulli's equation for a uniform horizontal pipe, derive an expression for loss of head due to friction in pipes. You may use relevant and usual notations for your derivation.

[2.0 Marks]

c) A smooth pipe of diameter 400mm and length 800m carries water at the rate of 0.04 m^3/s. If the roughness of the pipe is 0.056mm, Determine;

i. The head lost due to friction.
ii. The wall shear stress.
iii. The maximum velocity of water flow.

[8.0 Marks]

Q4. a) What are the types of energy losses associated in a pipe when a fluid flowing through it ? Give examples for each type of losses.

[2.0 Marks]

b) With using relevant sketches, prove that loss of head due to sudden contraction is actually due to sudden enlargement from Vena-contracta to smaller Pipe.

[4.0 Marks]

c) A horizontal pipe of diameter 500mm is suddenly contracted to a diameter of 250 mm. The pressure intensities in the large and smaller pipe is given as 13.734 N/cm^2 and 11.772 N/cm^2 respectively. Find the loss of head due to contraction if $C_c = 0.62$. Also determine the rate of flow of water.

[6.0 Marks]

Q5 a) Figure Q5 (a) is a schematic view of a Hydro-electric power plant. Based on the diagram,

i. Name the particulars denoted by A, B, C, D and E.
ii. Give brief descriptions for A and B.
iii. Explain why the value of "A" always higher than the value of "B".

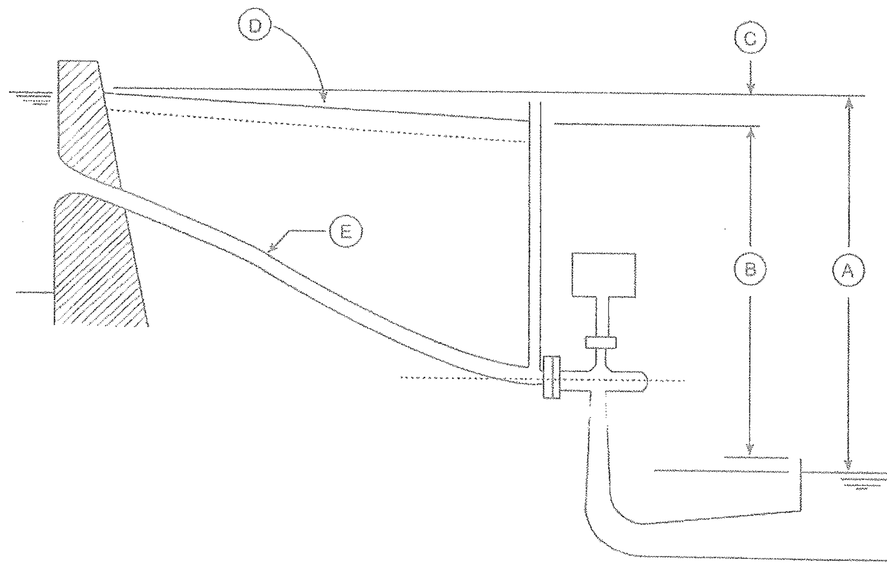


Figure Q5 (a)

[3.0 Marks]

b) Velocity triangles relevant to jet of water from the nozzle strikes the bucket at the splitter and the Pelton wheel is shown in Figure Q5 (b). By taking all the notations given in the Figure Q5 (b) as usual terminologies associated to Pelton wheel, derive an mathematical expression for Hydraulic efficiency η_h of a Pelton turbine.

Q5 is continued to page 4

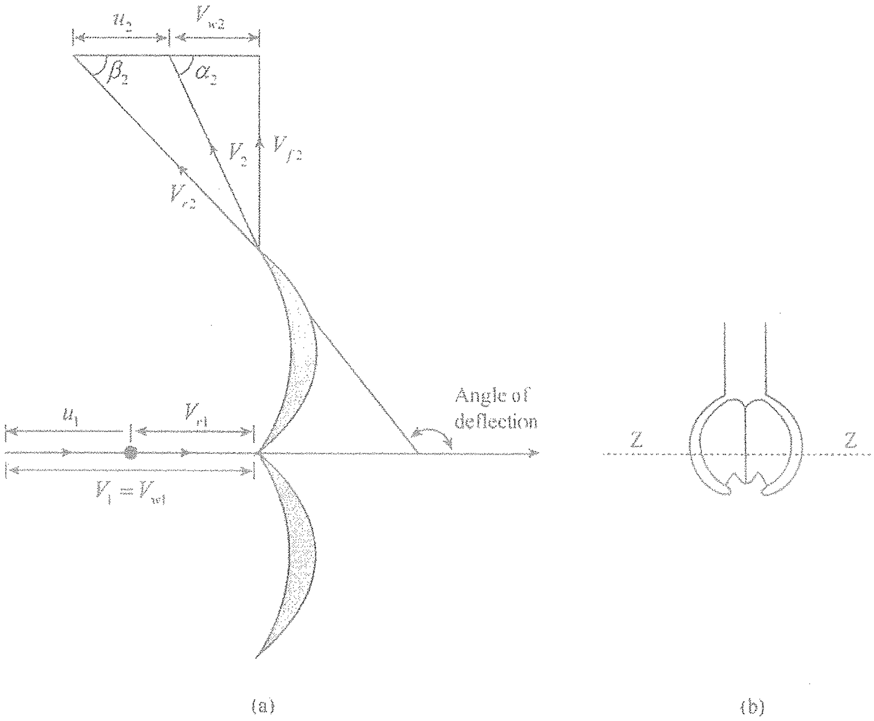


Figure Q5 (b)

[3.0 Marks]

c) A 137mm diameter jet of water issuing from a nozzle impinges on the bucket of a Pelton wheel and the jet is deflected through an angle of 165° by the buckets. The head available at the nozzle is 400m. Assuming co-efficient of velocity as 0.97, speed ratio as 0.46, and reduction in relative velocity while passing through buckets as 15%, find;

   i. The force exerted by the jet on buckets in tangential direction.
   ii. The power developed by the water on Pelton wheel.

Hint: Since the deflection angle is obtuse (of an angle more than 90° and less than 180°), -ve sign for horizontal components of absolute velocities of water need to be taken.

[6.0 Marks]

End of the paper.

Fundamentals useful for answering the questions with usual notations

$\delta = 5.48\dfrac{x}{\sqrt{R_{e,x}}}$ and $\tau_0 = 0.365\dfrac{\mu U}{x}\sqrt{R_{e,x}}$ for the velocity distribution of $2\left(\dfrac{y}{\delta}\right)-\left(\dfrac{y}{\delta}\right)^2$,

where $R_{e,x} = \dfrac{\rho U x}{\mu}$ is Reynold number correspond to x length along the considered plate.

$F_D = \int_0^L \tau_0 \times b \times dx$, where b is width of the plate.

$C_D = \dfrac{F_D}{\frac{1}{2}\rho A U^2}$, where A = Area of plate = $L \times b$.

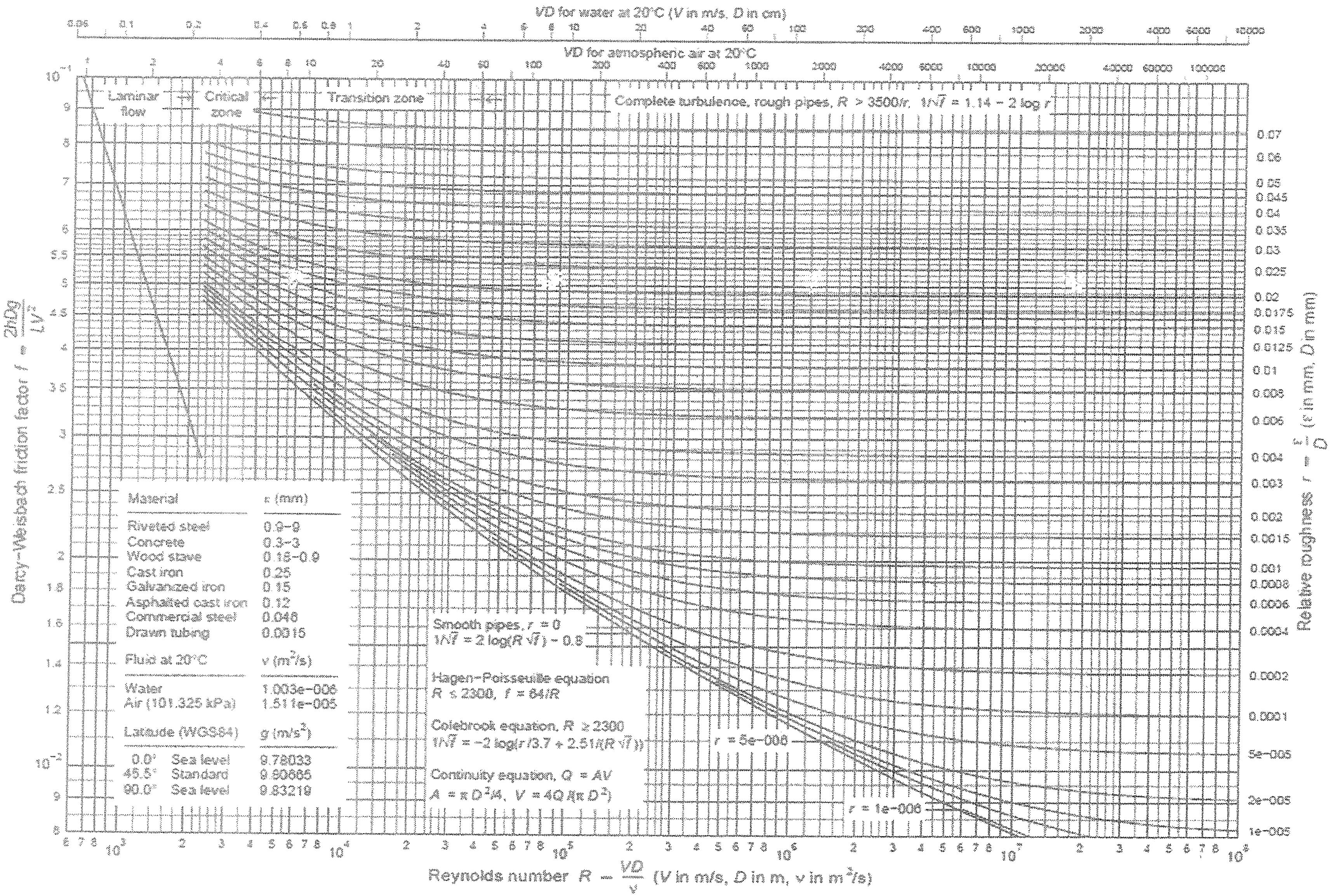
Take μ for water $= 0.001\,\text{Ns}/\text{m}^2$ and $\rho = 1{,}000\,\text{kg/m}^3$

Take the kinematic viscosity (υ) of water as $0.018 \times 10^{-4}\,\text{m}^2/\text{s}$

Wall shear stress (τ_0) is given by $\tau_0 = \dfrac{f \times \rho \times V^2}{2}$, where f is co-efficient of friction.

Velocity distribution for turbulent flow in smooth circular pipes given by

$\dfrac{u}{u_*} = 5.75 \log_{10} \dfrac{u_* y}{\upsilon} + 5.55$, where u_* is shear velocity and $u_* = \sqrt{\dfrac{\tau_0}{\rho}}$.


VD for water at 20°C (V in m/s, D in cm)
VD for atmospheric air at 20°C
Darcy-Weisbach friction factor $f = \frac{2hDg}{LV^2}$
Laminar flow
Critical zone
Transition zone
Complete turbulence, rough pipes, $R > 3500/r$, $1/\sqrt{f} = 1.14 - 2 \log r$
Material | ε (mm)
Riveted steel | 0.9–9
Concrete | 0.3–3
Wood stave | 0.18–0.9
Cast iron | 0.25
Galvanized iron | 0.15
Asphalted cast iron | 0.12
Commercial steel | 0.046
Drawn tubing | 0.0015
Fluid at 20°C | ν (m²/s)
Water | 1.003e−006
Air (101.325 kPa) | 1.511e−005
Latitude (WGS84) | g (m/s²)
0.0° Sea level | 9.78033
45.5° Standard | 9.80665
90.0° Sea level | 9.83219
Smooth pipes, $r = 0$
$1/\sqrt{f} = 2 \log(R\sqrt{f}) - 0.8$
Hagen–Poiseuille equation
$R \le 2300$, $f = 64/R$
Colebrook equation, $R \ge 2300$
$1/\sqrt{f} = -2 \log(r/3.7 + 2.51/(R\sqrt{f}))$
Continuity equation, $Q = AV$
$A = \pi D^2/4$, $V = 4Q/(\pi D^2)$
r = 5e−006
r = 1e−006
Reynolds number $R = \frac{VD}{\nu}$ (V in m/s, D in m, ν in m²/s)
Relative roughness $r = \frac{\varepsilon}{D}$ (ε in mm, D in mm)