UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: August 2015

Module Number: CE3304 **Module Name: Fluid Mechanics**

[Three Hours]

[Answer **all** questions]

Note: Moody diagram is given at the end of the paper

Q1. a) Define the symbols in the equations given below and state the condition under which they are applicable to pipe flow.

(i) $\tau_o = \frac{r_o}{2}\rho g \frac{h_f}{l} = \rho U_*^2 = \frac{f}{8}\rho V^2 = \tau \frac{r_o}{r}$

(ii) $U_{max} = 2V = \frac{U}{\left(1-\frac{r^2}{r_o^2}\right)}$

(iii) $U_{max} = V + 3.75U_* = U + 5.75U_* log\frac{r_o}{y}$

[3.0 Marks]

b) A liquid of density 625 kg/m^3 and kinematic viscosity $2 \times 10^{-6}\ m^2/s$ flows in a uniform pipe of diameter 150 mm at 70.7 l/s. The frictional head loss over a 8.3 m length pipe is 1.3 m. Using an appropriate equation from Q1. a) draw the velocity and shear stress distribution giving the maximum values and values at a distance of 7. 5 mm from the pipe wall.

[7.0 Marks]

Q2. A liquid of density 750 kg/m^3 and kinematic viscosity $6 \times 10^{-6}\ m^2/s$ is pumped from a large open tank A of surface elevation 100 m to a large open tank B of surface elevation 105 m at a volume flow rate of 140 l/s through the pipe APJKB fitted with a pump P, and a valve K as shown in figure Q2. Pipe AJ is of length 24 m, diameter 200 mm and surface roughness 0.12 mm. Pipe JB is of length 60 m, diameter 300 mm, and surface roughness 0.12 mm. The local loss coefficients are $C_{L1} = 0.5$ at pipe entry, $C_{L2} = 0.3$ at enlargement J, $C_{L3} = 4.0$ at valve K, and $C_{L4} = 1.0$ at pipe exit. Using the Moody diagram (Figure A, Page 4), find the power added by the pump. Draw the total headline indicating clearly all changes in head.

[10.0 Marks]

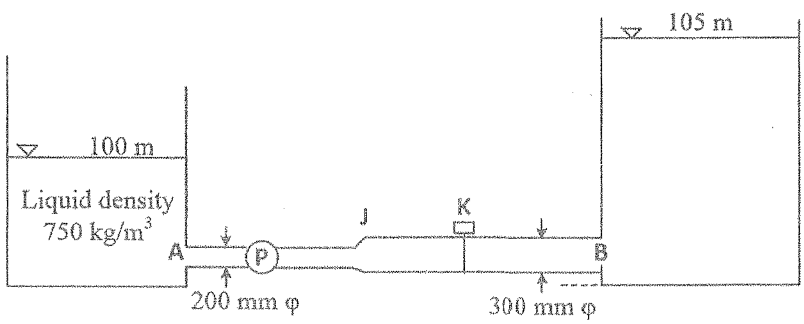

Figure Q2

Q3. a) Show by dimensional analysis that the force F on a body of length l moving with velocity V on a liquid of density ρ, viscosity μ under gravity g can be expressed as

$$F = \rho V^2 l^2 \, \phi\left(\frac{\rho V l}{\mu}, \frac{V}{(gl)^{1/2}}\right)$$

[4.0 Marks]

b) A ship 32 m long moves in sea water ($\rho = 1024\, kg/m^3, \nu = 1.28 \times 10^{-6} m^2/s$) at 36 km/h. A model of the ship 2 m long is to be tested in a towing tank containing a liquid of density 768 kg/m^3 under completely dynamically similar conditions.

(i) Find the velocity and kinematic viscosity of the liquid in the towing tank.

(ii) Give the values of Reynolds number and Froude number duplicated in the test

(iii) If the towing force on the model is 15 N what is the force required to drive the ship.

[6.0 Marks]

Q4 a) Briefly explain the statement. Ideal fluid theory may be used to describe the behaviour of real fluids away from the boundaries.

[1.0 Marks]

b) A circular cylinder of radius R is kept stationary in a uniform inviscid fluid flow and axis of the cylinder is normal to the fluid flow direction. Obtain an expression for the stream function, velocity distribution, and for the pressure on the surface of the cylinder. The relation between the velocity components and the stream function may be written in polar form, with usual notations as $U_r = \frac{1}{r}\frac{\partial \psi}{\partial \theta}; U_\theta = -\frac{\partial \psi}{\partial r}$. Stream function for a source and a doublet can be represented with usual notations as $= \frac{q\theta}{2\pi}, \psi = -\frac{\mu}{2\pi}\left(\frac{\sin\theta}{r}\right)$ respectively.

[5.0 Marks]

c) Sketch the pressure distribution derived in (b). Show that the net resultant force on the cylinder is zero. Also sketch the pressure distribution that you would expect in the flow of a real fluid past a circular cylinder. Explain briefly reasons for the differences in the distributions.

[4.0 Marks]

Q5 a) Pelton wheel is most suitable for operation, when water is stored at high altitude. Explain the reason.

[2.0 Marks]

b) Power (per jet) generates by the Pelton wheel is given by $P = \rho Q(v - u)u(1 - k\cos\theta)$ with usual notations. Show that the hydraulic efficiency of a Pelton wheel is maximum when the bucket velocity (u) is half of the jet velocity (v). Assume that the velocity of water relative to the bucket at the outlet is k (k<1) times that at the inlet and is deflected by θ.

[2.0 Marks]

c) A Pelton wheel nozzle, for which the coefficient of velocity is 0.97, is 400 m below the water surface of a reservoir and head loss in the pipeline will not exceed 20 m. The buckets deflect the jet through 165° and bucket friction reduces relative velocity at outlet by 15% of the relative velocity at inlet. The output power required from the hydroelectric scheme is 60 MW. The turbine is operating at 400 rpm and the specific speed ($N_s = \frac{NP^{1/2}}{H^{5/4}}$ in usual notations) is 50. Assuming operation at maximum efficiency, calculate the diameter of the Pelton wheel and the hydraulic efficiency.

[6.0 Marks]

Q6 a) What is meant by "*rapid*" and "*slow*" valve closure in connection with pressure transients in pipe lines?

[2.0 Marks]

b) A 750 m long steel pipe with 0.4 m diameter and 5 cm wall thickness carries 350 l/s average flow rate of water (density 1000 kg/m^3, bulk modulus 2.17 GPa) to a downstream location at 24 m below the reservoir free water surface. A valve is installed at the downstream end of the pipe to control the flow rate (Figure Q6). Kinematic viscosity of water (ν) = $1.31 \times 10^{-6}\ m^2/s$ and Young's modulus of steel (E) = 190 GPa.

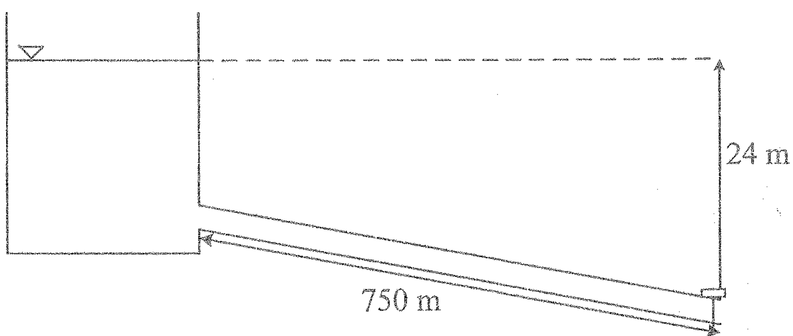

Figure Q6

(i) If the surface roughness of the pipe is 0.3 mm, calculate the pressure at the downstream end when the valve is fully opened.

(ii) If the valve is completely closed in 0.5 s, calculate the total pressure at the downstream end.

Pressure wave speed in a rigid pipe and in a non-rigid pipe is given by $C = \sqrt{\frac{K}{\rho}}$ and $C = \sqrt{\frac{K}{\rho}\left(\frac{1}{1+\frac{DK}{tE}}\right)}$,respectively.

[8.0 Marks]

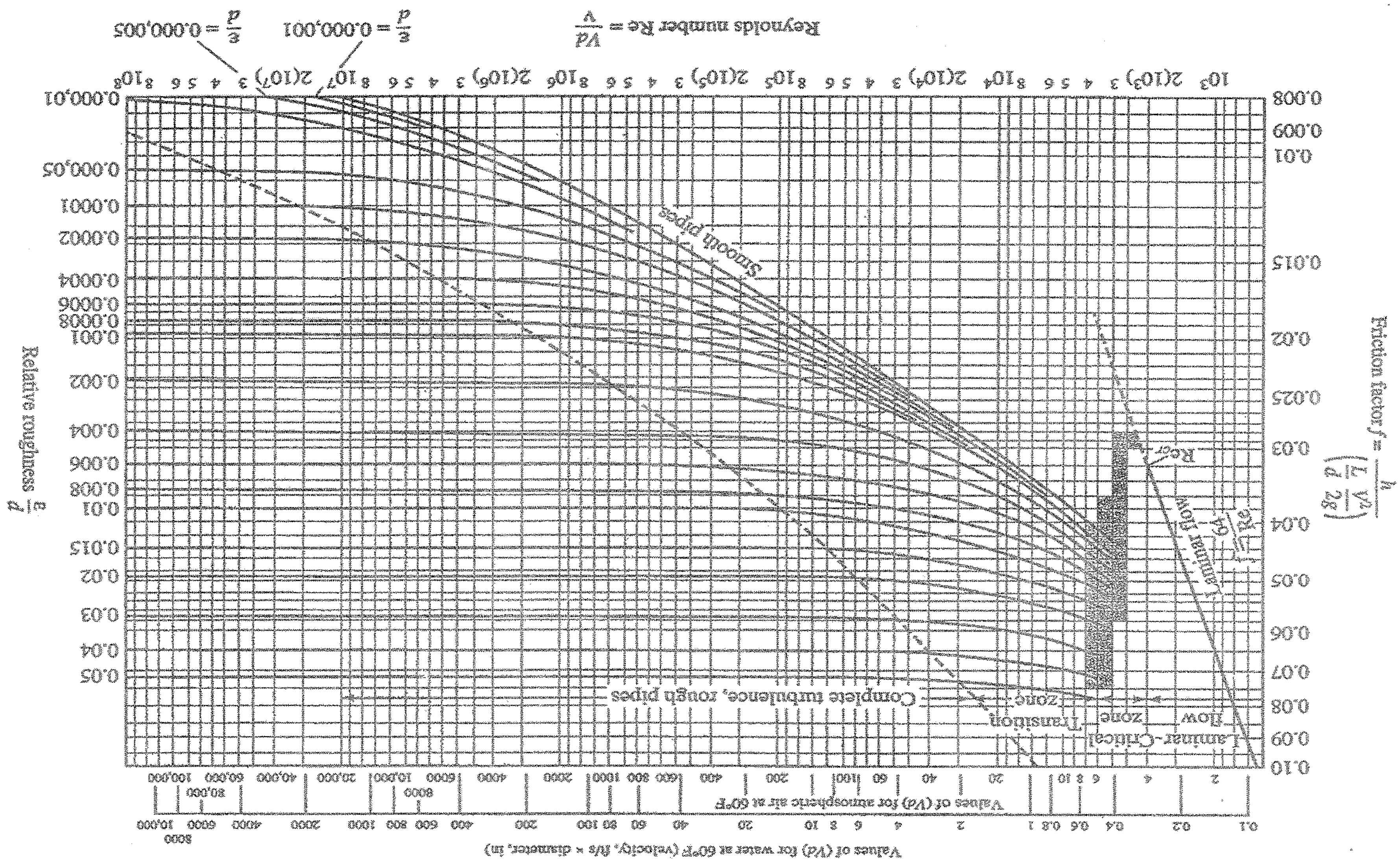

Figure A: Moody Diagram