UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2017

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

[Three Hours]

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

Q1. a) State the conditions under which the following equations are applicable to steady flow in pipes.

i) $\tau_0 = \frac{d}{4}\frac{\rho g h_f}{l}$

ii) $\frac{u}{u_*} = 5.75 \log \frac{y}{y_0}$

iii) $V = u_{max} - 3.75\, u_*$

[1.0 Mark]

b) A liquid of density $800\, kg/m^3$ and kinematic viscosity $1.25 \times 10^{-6}\, m^2/s$ flows in a horizontal pipe of uniform diameter $320\, mm$ and surface roughness $0.48\, mm$. The pressure drop measured over a $8\, m$ length of pipe is $3.2\, kPa$.

i) Verify that the above equations with $y_0 = \frac{e}{30}$ are applicable to this flow.

[3.0 Marks]

ii) Find the Reynolds number and friction coefficient for the flow and draw the velocity profile giving the velocity at a distance of $16\, mm$ from the pipe wall.

[6.0 Marks]

Q2. A large closed tank contains air under a pressure of $10.3\, kPa$ and a liquid of density $700\, kg/m^3$ and kinematic viscosity $4 \times 10^{-6}\, m^2/s$. The liquid is discharged into atmosphere through a $150\, m$ long pipe APKN fitted with a pump P, a valve K, and a short nozzle N of exit diameter $100\, mm$ as shown in Figure Q2. AP = PK = KN =$50\, m$. The pipe has a uniform diameter of $200\, mm$ and a surface roughness $0.2\, mm$. The pump P has an efficiency of 0.75 and the valve K has a loss coefficient of 3.0. The liquid surface in the tank is $4.5\, m$ above the nozzle level N. The loss coefficient at pipe entry is 0.5 and the loss coefficient in the nozzle is 0.25.

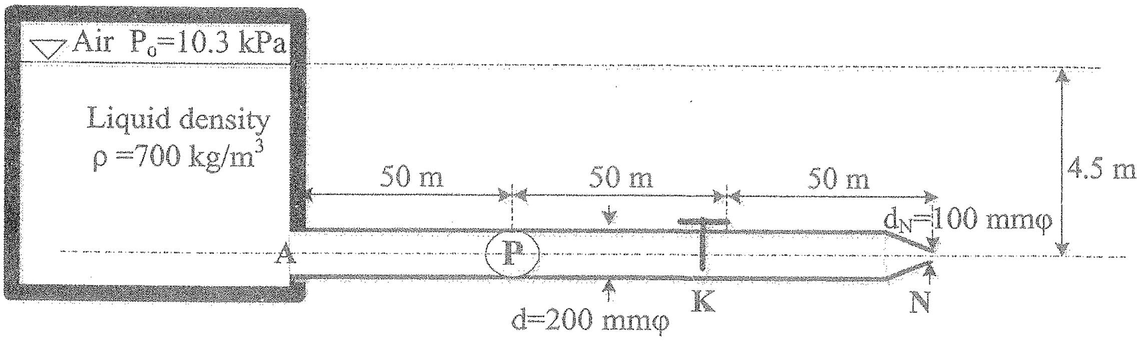

Figure Q2

a) Using the Moody diagram given (Page 5), find the power required by the pump to discharge 88 ℓ/s to atmosphere through the nozzle at N.

[7.0 Marks]

b) Draw the total head line indicating all changes in head along the pipe.

[1.0 Mark]

c) What is the power required by the pump to discharge 88 ℓ/s to atmosphere at N without the nozzle?

[2.0 Marks]

Q3. a) The piezometric pressure drop ΔP^* in a venturi meter varies only with the fluid density (ρ), approach velocity (V_1), and diameter ratio of the meter $\left(\frac{d_1}{d_2}\right)$.

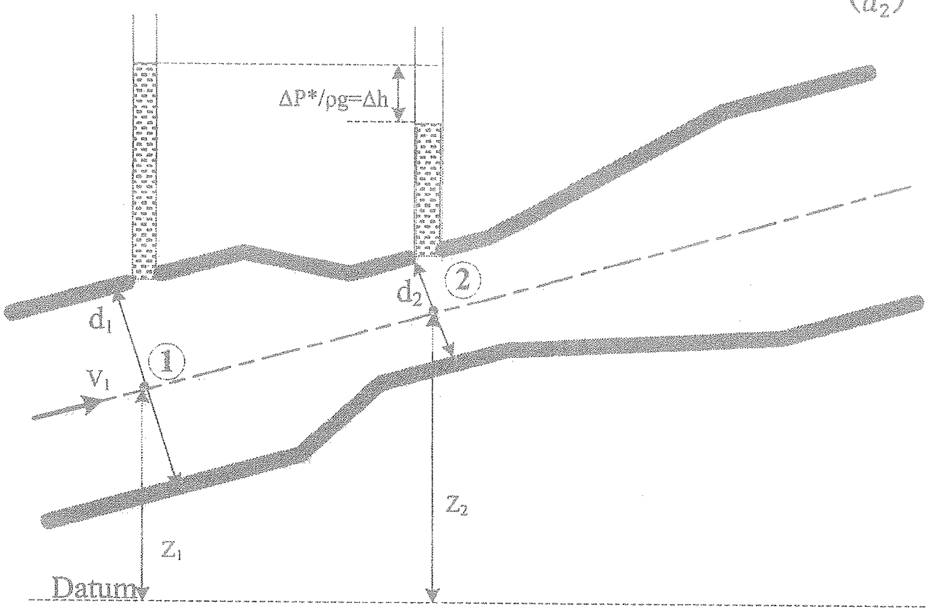

Figure Q3

Obtain by dimensional analysis that

$$\frac{\Delta P^*}{\rho {V_1}^2} = \Phi\left(\frac{d_1}{d_2}\right)$$

[4.0 Marks]

b) A model venturi meter tested in water shows a piezometric pressure drop of 5 kPa when the approach velocity is 2 m/s. A geometrically similar venturi meter having an upstream diameter of 140 mm and a throat diameter of 100 mm is used to measure gasoline ($\rho = 750\ kg/m^3$) flow rate and the piezometric pressure drop is 15 kPa. Calculate the gasoline flow rate through the pipe.

[3.0 Marks]

c) Apply the Bernoulli's equation and show that

$$\frac{\Delta P^*}{\rho V_1^2} = 0.5\left\{\left(\frac{d_1}{d_2}\right)^4 - 1\right\}$$

Calculate the gasoline flow rate through the pipe using the above equation and compare it with the answer in part (b). Provide reasons for the difference, if any.

[3.0 Marks]

Q4. The leading edge of a wing is approximated by the half body formed by placing a source of $2\,m^2/s$ in an uniform flow of $8\,m/s$. Stream function and potential function for a source are $\psi = \frac{q\theta}{2\pi}$ and $\phi = \left(\frac{q}{2\pi}\right) log_e r$, respectively.

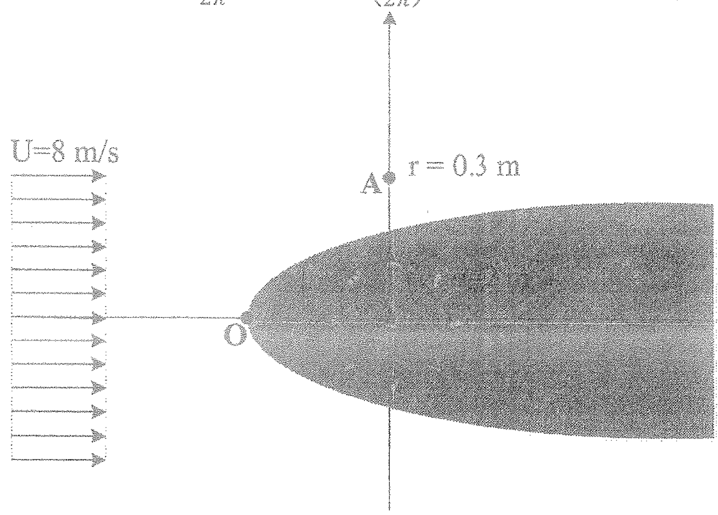

Figure Q4

(i) Determine the location of the stagnation point.

[2.0 Marks]

(ii) Determine the equation of the boundary of the half body.

[4.0 Marks]

(iii) Calculate the width of the half body and the difference in pressure between the stagnation point and point A, where $r = 0.3\,m$, $\theta = 90°$, and $\rho = 1.25\,kg/m^3$.

[4.0 Marks]

Q5. a) Describe briefly the Prandtl's boundary layer concept related to the viscous flow over a flat plate. Write the boundary conditions applicable to the fluid flow in the boundary layer.

[4.0 Marks]

b) A fluid having a kinematic viscosity of $1 \times 10^{-6}\,m^2/s$ and density of $1000\,kg/m^3$ flows with a constant free-stream velocity of $12\,m/s$ over a horizontal thin flat plate having $4\,m$ streamwise length. Assume that the boundary layer is entirely laminar with an approximate velocity profile given by $\frac{u}{U_\infty} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$, in usual notation.

(i) Calculate the ratio of momentum thickness to the boundary layer thickness.

(ii) Show that the boundary layer grows proportionately to the square root of the distance from the leading edge of the plate.

(iii) Calculate the drag force per unit width of the plate due to viscous shear.

The momentum integral equation is $\frac{d}{dx}(U_\infty^2\theta) + U_\infty\delta^*\frac{dU_\infty}{dx} = \frac{\tau_0}{\rho}$ where

$\theta = \int_0^\delta \frac{u}{U_\infty}\left(1 - {}^{u}/_{U_\infty}\right)dy$ and $\delta^* = \int_0^\delta \left(1 - {}^{u}/_{U_\infty}\right)dy$

[6.0 Marks]

Q6. a) The pump characteristics of a centrifugal pump are given in Figure Q6 for a speed of 1000 rpm. Find the operating speed of the pump, if it is required to deliver 40 l/s of water against a 32 m head.

[4.0 Marks]

b) The pump impeller has an outer diameter of 400 mm, inner diameter of 200 mm, and effective area of 10000 mm^2. The blades are backward-facing, with a blade angle of 20°. The flow approaches the impeller radially. Calculate the radial component of the absolute velocity and whirl velocity at the outlet. Find also the head imparted by the impeller to water and the hydraulic efficiency of the pump.

[6.0 Marks]

Flow number and head number are $\frac{Q}{ND^3}$ and $\frac{gH}{N^2D^2}$, respectively.

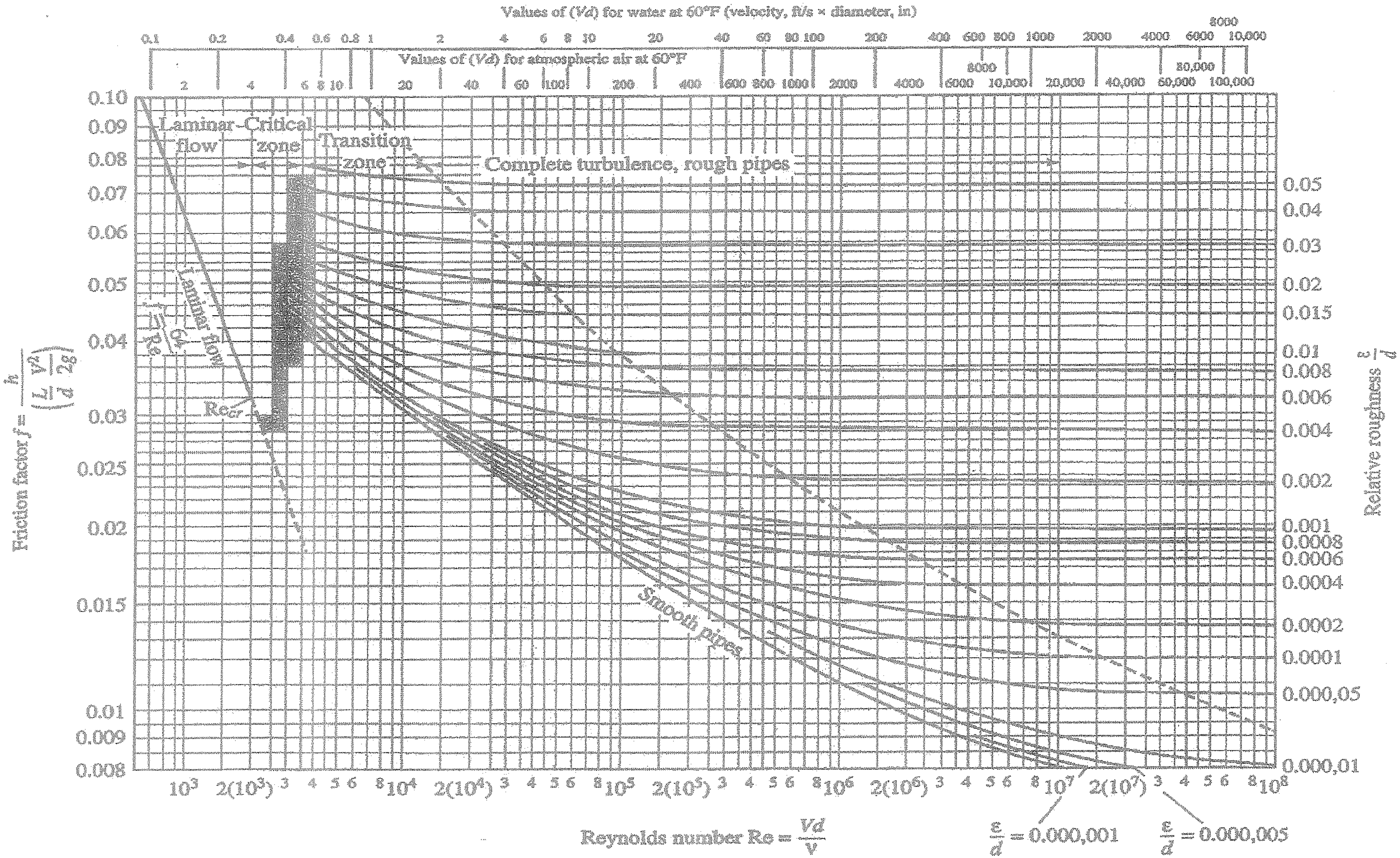

Figure Q2b: Moody diagram

*Note: Detach this page and attach to the answer script.

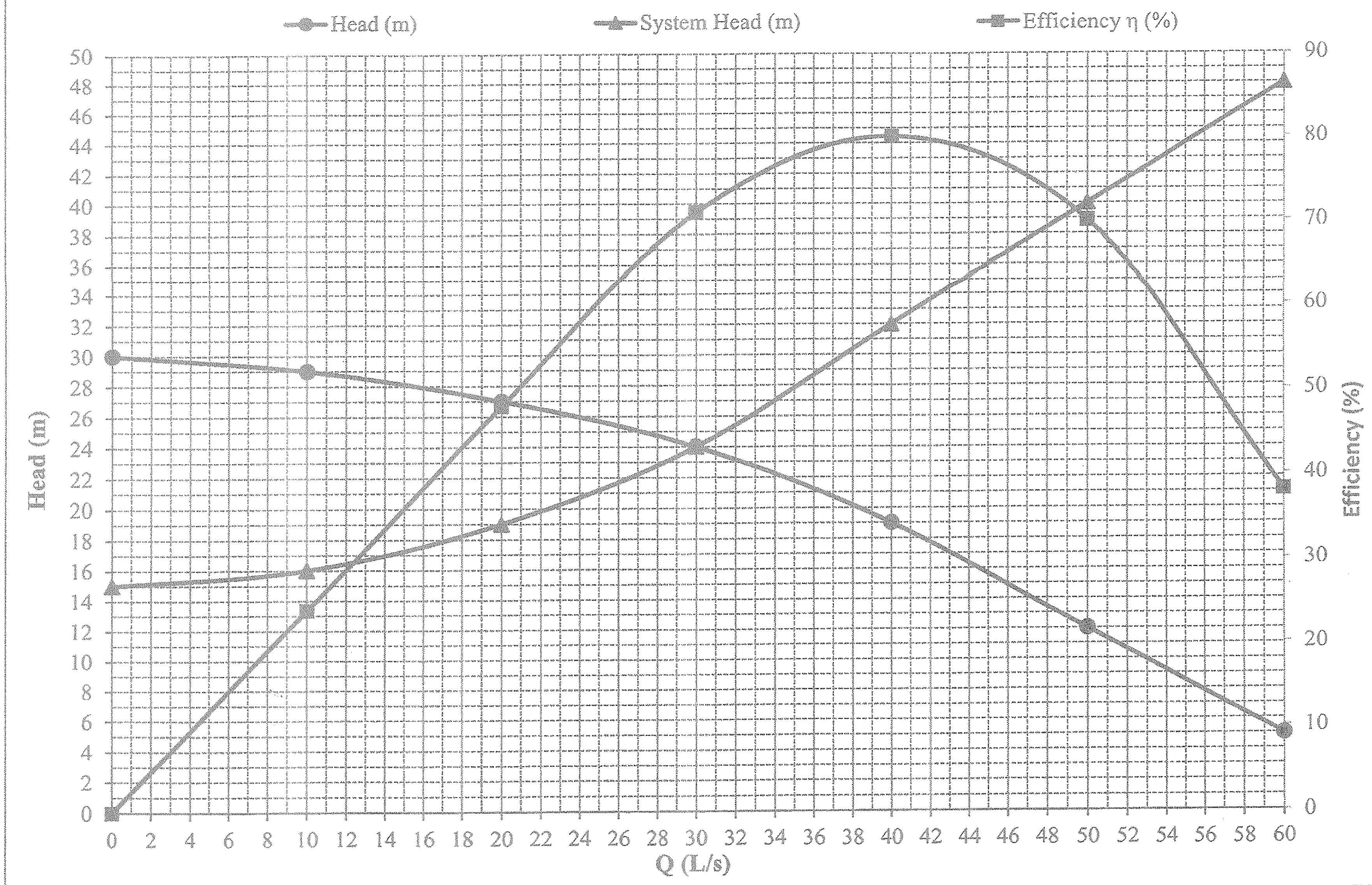

Figure Q6