UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2016

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 pipe flow.

(i) $\frac{u}{U_{max}} = \frac{y}{r_o}\left(2 - \frac{y}{r_o}\right)$

(ii) $\frac{U_{max} - u}{u_*} = -5.75 \log \frac{y}{r_0}$

[2.0 Marks]

b) A liquid of density 750 kg/m^3 and kinematic viscosity $2 \times 10^{-5}\ m^2/s$ flows in a pipe of diameter 200 mm. The velocity measured at distances of 30 mm and 100 mm from the pipe wall are 4.15 m/s and 4.75 m/s, respectively.

(i) Select the appropriate equation from part (a) and draw the velocity distribution giving the velocity at 10 mm from the pipe wall.

[5.0 Marks]

(ii) Making suitable assumptions, find the shear stress at the pipe wall, Reynolds number, and the friction coefficient.

[3.0 Marks]

Q2. A large closed tank A contains air under a pressure of 17 kPa and an oil of density 825 kg/m^3 and kinematic viscosity $4 \times 10^{-6}\ m^2/s$. The oil is pumped from closed tank A to an open tank B through a horizontal pipe AB of diameter 150 mm, surface roughness 0.3 mm and length 72 m. A pump 'P' of efficiency 65% is located at $AP = 24\ m$ and a valve 'K' of loss coefficient 3.5 is fitted at $AK = 48\ m$. The pipe entry and pipe exit are sharp and the oil surface elevation in tanks A and B are equal (Figure Q2a).

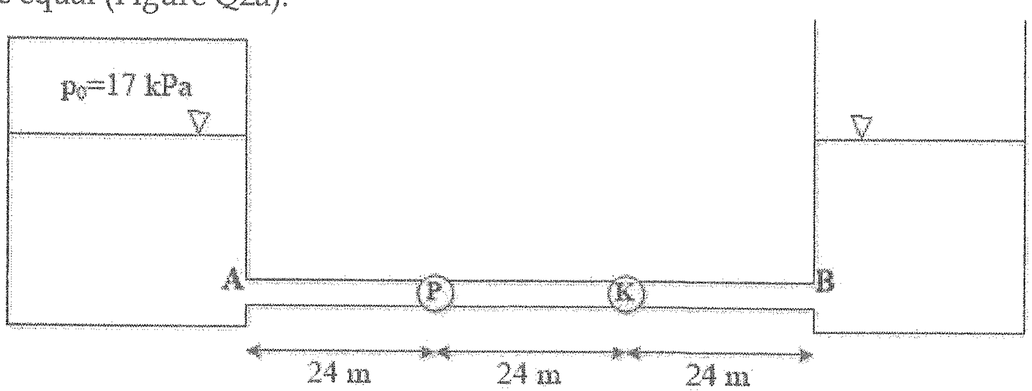

Figure Q2a

(i) Using the Moody diagram (Figure Q2b in Page 4) find the power required to deliver 70 l/s from A to B.

[8.0 Marks]

(ii) Draw the total headline indicating all changes in head.

[2.0 Marks]

Q3. The pressure drop ΔP across a gate valve controlling an oil flow in a pipe depends on the gate opening h, pipe diameter d, fluid density ρ, viscosity μ, and velocity v.

a) Obtain by dimensional analysis that

$$\frac{\Delta P}{\rho v^2} = \Phi\left(\frac{h}{d}, \frac{\rho v d}{\mu}\right)$$

[4.0 Marks]

b) A ¼ scale model of a gate valve is built to test the pressure drop across a gate valve in a pipe conveying oil of density 800 kg/m^3 and viscosity 0.002 $Pa\,s$ at 100 l/s.

(i) What should be the volume flow rate of water ($\mu = 0.001\ Pa\,s$) in the model corresponding to the same gate opening ratio (h/d) for dynamic similarity.

[3.0 Marks]

(ii) Find the pressure drop across the prototype valve when the pressure drop in the model is 48 kPa.

[3.0 Marks]

Q4. A 2D water flow is defined by the stream function $\Psi = 2(x^2 - y^2) m^2/s$.

a) Determine the flow per unit depth in m²/s that occurs though AB, CB, and AC as shown in Figure Q4.

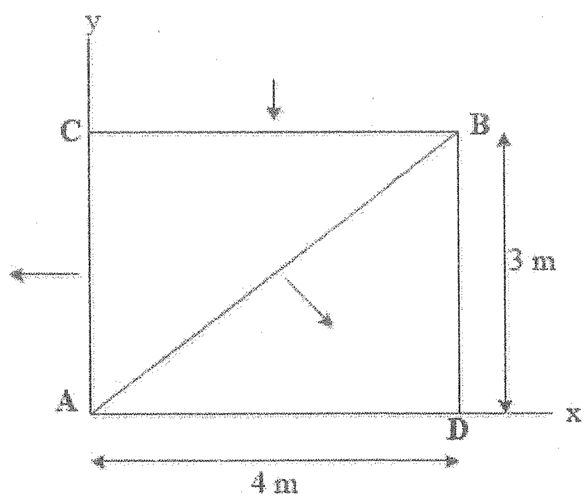

Figure Q4

[3.0 Marks]

b) Show that it is a potential flow and find the potential function.

[4.0 Marks]

c) If the pressure at B is atmospheric, determine the pressure at point A.

[3.0 Marks]

Q5. An incompressible viscous fluid of kinematic viscosity $\nu = 1.02 \times 10^{-6}\ m^2/s$ and density $\rho = 1000\ kg/m^3$ flows over a smooth rectangular plate of span $2\ m$ and streamwise length $1\ m$ with a constant free-stream velocity. Assume that the boundary layer is entirely laminar with an approximate velocity profile given by $\frac{u}{U_\infty} = \frac{3}{2}\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^3$.

a) Calculate the ratio of momentum thickness (θ) to the boundary layer thickness (δ).

[2.0 Marks]

b) Show that the boundary layer grows proportionally to the square root of the distance from the leading edge of the plate.

[4.0 Marks]

c) If the viscous shear stress on the plate at a location of $1\ m$ downstream of the leading edge, measured by a sensor is $0.01\ N/m^2$, calculate the free-stream velocity.

[2.0 Marks]

d) Calculate the drag force on the plate due to viscous shear.

[2.0 Marks]

Q6. A pump is required to raise water from a sump to a channel which is located at a vertical height of $10\ m$ from the sump level. The combined length of suction and delivery pipe is $30\ m$ and $0.1\ m$ in diameter and has a friction factor 0.018. Minor losses in the system can be accommodated by a loss coefficient $K = 12$. Pump characteristics at a rotation speed of $1200\ rpm$ are given in Figure Q6 (Page 5). Flow number, head number, and power number are $\frac{Q}{ND^3}, \frac{gh}{N^2D^2}, \frac{P}{\rho N^3 D^5}$, respectively with usual notations.

a) Find the system characteristic giving numerical values.

[3.0 Marks]

b) Find the discharge and power consumption of the pump at the duty point

[3.0 Marks]

c) Due to a rearrangement, the delivery point is changed by a vertical height of 10 m and the delivery pipe is lengthened by the same amount. If the same discharge is to be maintained, find the new rotation rate of the pump.

[4.0 Marks]

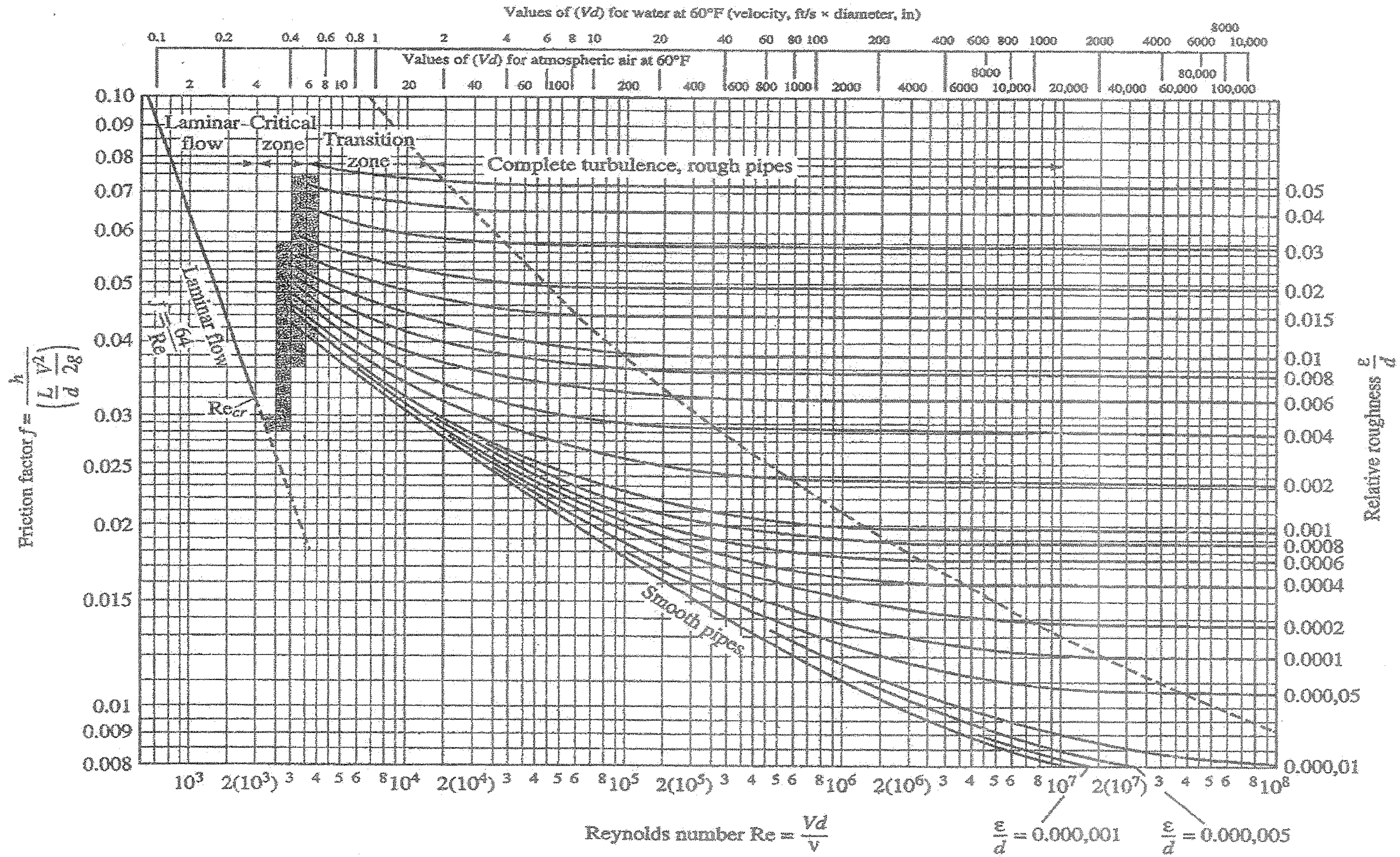

Figure Q2b: Moody diagram

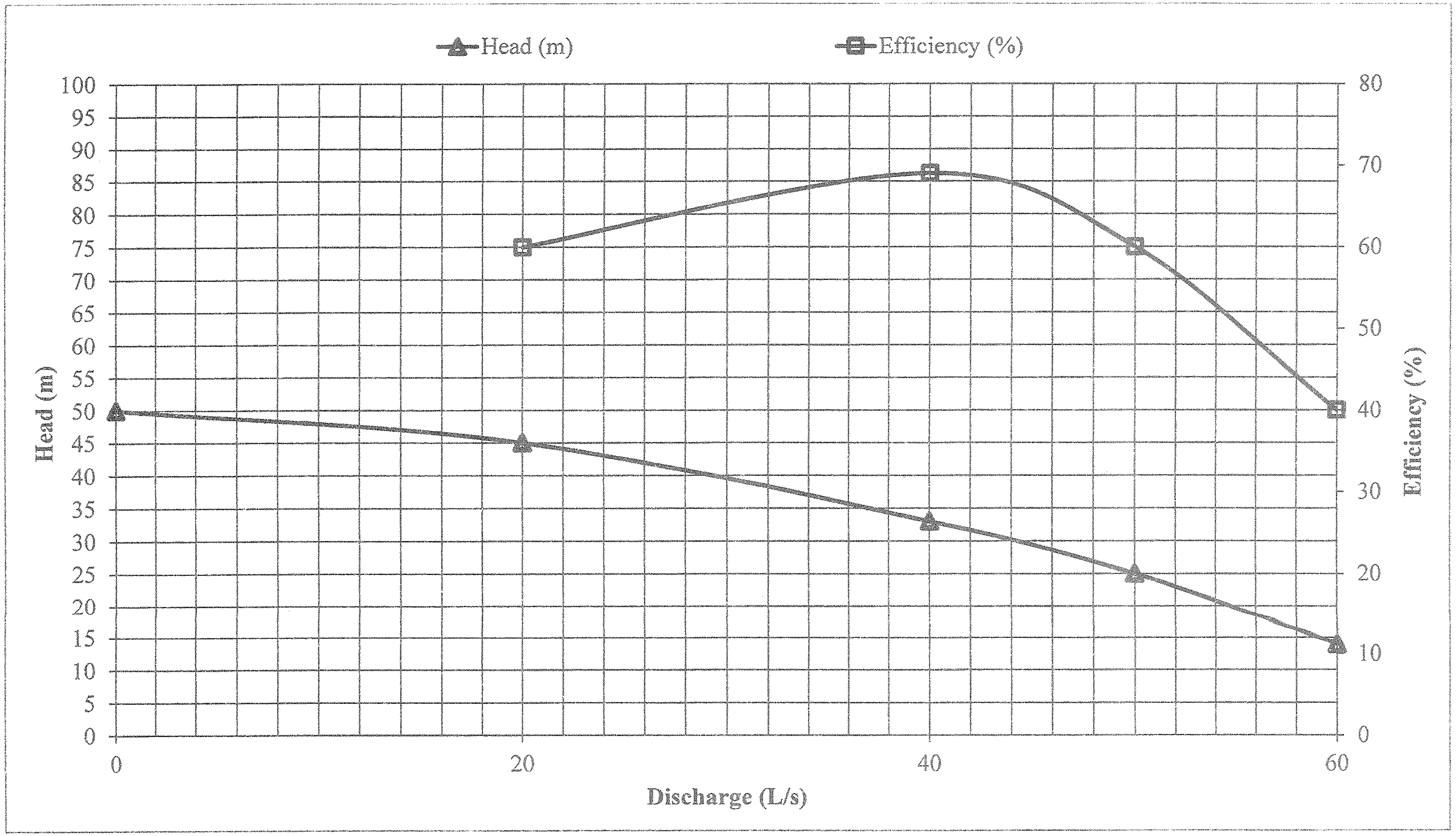
Head (m)
Efficiency (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
80
70
60
50
40
30
20
10
0
0
20
40
60
Discharge (L/s)

Figure Q6