UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: Aug 2018

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

[Three Hours]

[Answer all questions. Each question carries TWELVE marks]

All standard notations denote their usual meanings.

Q1. a) A liquid of density 1260 kg/m^3 and kinematic viscosity 7×10^{-4} m^2/s is pumped at 0.02 m^3/s through a straight, 50 m long 200 mm diameter pipe, inclined at 15° to the horizontal. The gauge pressure at the lower, inlet end of the pipe is 590 kPa.

i) Verify that the flow is laminar,
ii) Calculate the pressure at the outlet end of the pipe, and
iii) The average shear stress at the wall

[6.0 Marks]

b) Water from a reservoir is discharged into the atmosphere through two cast iron pipes connected in series as shown in Figure Q1. The valve is located at 100 m below the water surface elevation. Resistance coefficients of the head losses at the pipe entry, sudden contraction, and at the valve are 0.5, 0.35, and 10, respectively. Roughness coefficient of the pipes is 0.26 mm and the kinematic viscosity of water is 10^{-6} m^2/s. Using the Moody diagram given in Page 5, determine the discharge through the pipes.

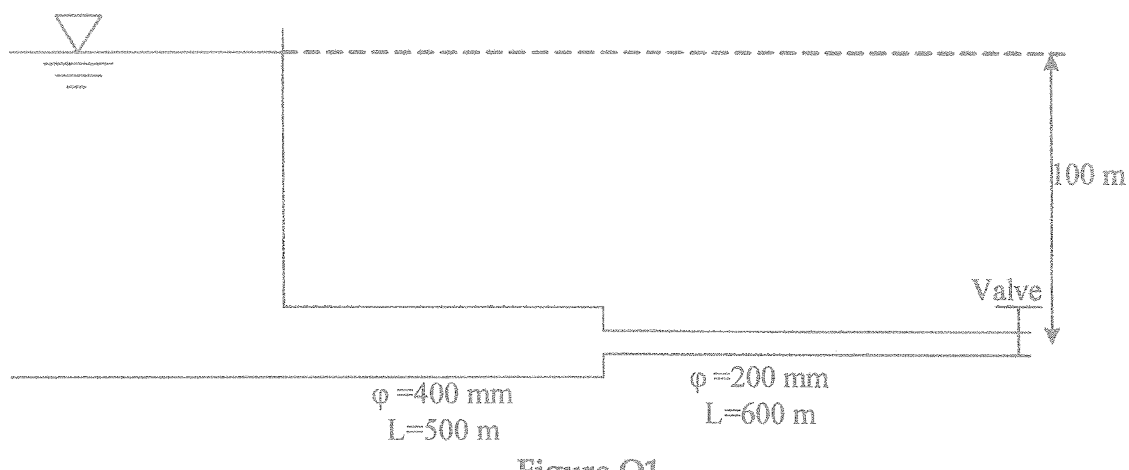


Figure Q1

[6.0 Marks]

Q2. a) A tiny particle of density ρ_s and characteristic diameter d falls in a liquid of density ρ and viscosity μ. If the particle is small enough and the creeping flow approximation is valid, the terminal settling speed of the particle V depends on $d, \mu, g,$ and the $(\rho_s - \rho)$. Use dimensional analysis to derive a functional relationship for V.

[3.0 Marks]

b) i) The drag force (F_D) acting on a spherical particle that falls very slowly through a viscous fluid depends on the particle diamater (d), particle velocity (V), and the fluid viscosity (μ). Using dimensional analysis show that $F_D = constant\ \mu V d$.

[2.0 Marks]

ii) The buoyant force (F_B), acting on a submerged body in a fluid depends on the specific weight (ρg) of the fluid and volume ($\forall$) of the body. Using dimensional analysis show that the buoyant force is directly proportional to the specific weight.

[2.0 Marks]

iii) Combine the results of (i) and (ii) to generate an equation for the settling speed V of a particle falling in a liquid. Verify that your result is consistent with the functional relationship obtained in part (a).

[3.0 Marks]

c) A solid ball having a diameter of 20 mm and a density of 3000 kg/m³ dropped into a liquid having a density of 2300 kg/m³ and a kinematic viscosity of 0.052 m²/s. Assuming Re<1, calculate its terminal velocity. Consider $F_D = 3\pi\ \mu V d$

[2.0 Marks]

Q3. a) Figure Q3 in Page 4 shows the characteristics of a pump operated at 1000 rpm. The pump is used to elevate water by 30 m from a reservoir. Flow rate is measured as 50 l/s while the delivery valve is fully opened and the pump is operating at 1000 rpm. If it is required to deliver 80 l/s of water, at which speed the pump should be operated?

[4.0 Marks]

b) An identically similar pump as in part (a) is used to pump water from a reservoir whose surface is 1.2 m above the centerline of the pump inlet. The piping system from the reservoir to the pump consists of 3.2 m of cast iron pipe with a diameter of 5 cm and an average roughness of 0.05 cm. Minor losses at the suction side of the pump are; a sharp edged inlet (k = 0.5), three flanged smooth 90 elbows (k = 0.3 each) and a fully open flanged globe valve (k = 6). Estimate the maximum flow rate that can be pumped without cavitation, if the pump is operating at 1000 rpm.

[8.0 Marks]

Flow number, head number, and power number are Q/ND^3, gH/N^2D^2, and $P/\rho N^3 D^5$, respectively. Vapour pressure of water at the working temperature is 31.8 mmHg.

Q4. Two sources, each having a strength of 2 m^2/s, are located at a distance of 4 m from the origin.

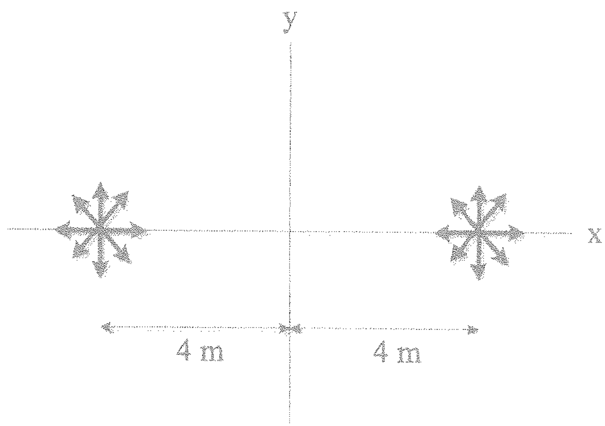


Figure Q4

a) Determine the stream function of the combined flow.

[2.0 Marks]

b) Determine the stream function for the flow that passes through the origin and that passes through point (0, 8 m).

[4.0 Marks]

c) Determine the x and y components of the velocity of fluid particles that pass through point (x, y).

[3.0 Marks]

d) Is the flow irrotational?

[3.0 Marks]

Q5. Water flows with a free stream velocity of 2 m/s over a flat plate having a length of 5 m. The transition from the laminar boundary layer to turbulent boundary layer occurs at a critical Reynolds number of 10^5.

a) Use the momentum integral equation to determine the shear stress on the surface of the plate at a distance of 0.1 m.

[6.0 Marks]

b) Determine the maximum boundary layer thickness over the plate's surface. State any assumption you made.

[6.0 Marks]

You may consider velocity profile for laminar boundary layer as $u/U = 1.5(y/\delta) - 0.5(y/\delta)^3$ and for turbulent boundary layer as $u/U = (y/\delta)^{1/6}$.

Shear stress for the turbulent flow is given by the emprical formular $\tau_0 = \frac{0.0225\rho U_\infty^2}{(Re_\delta)^{1/4}}$

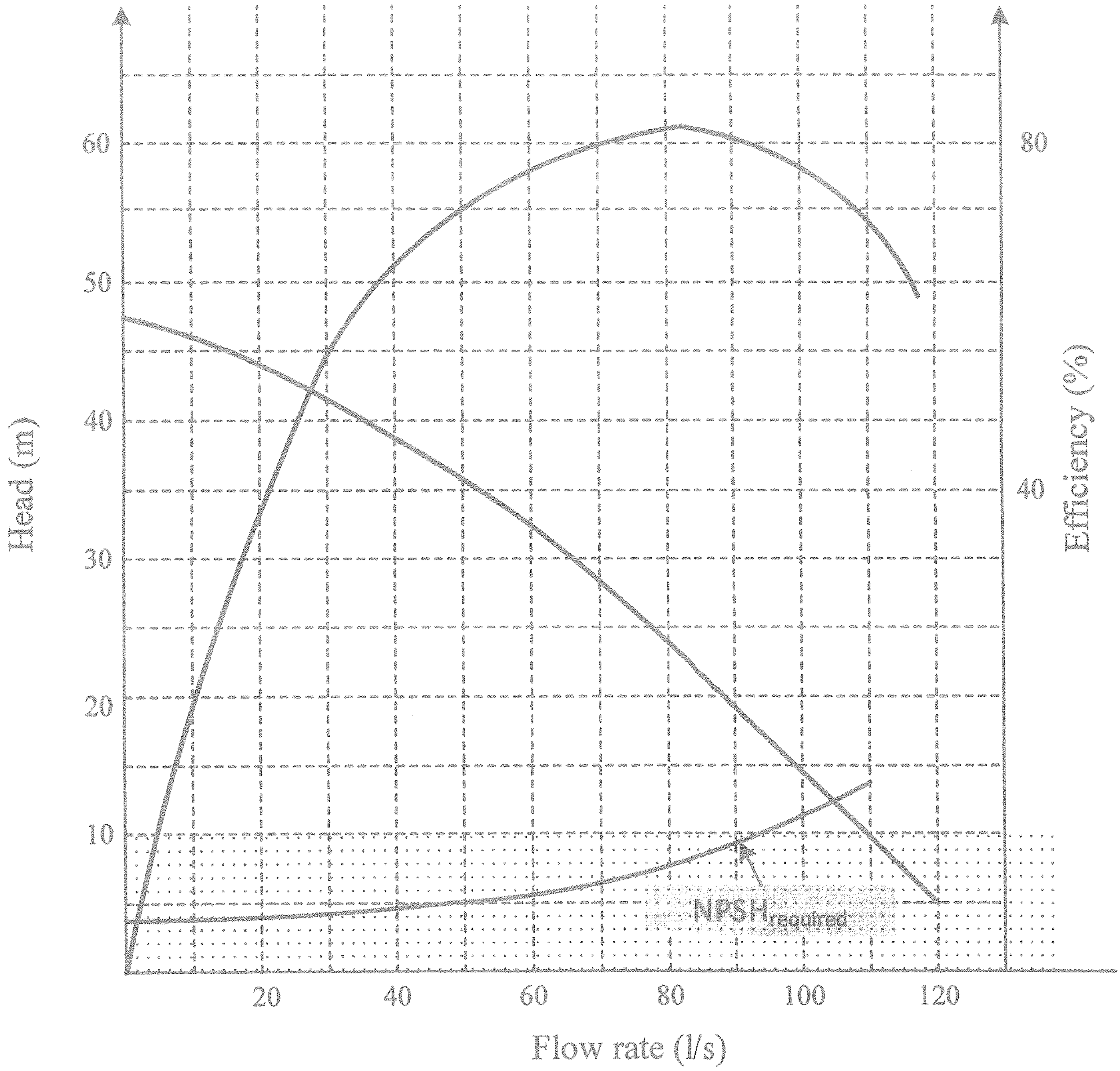
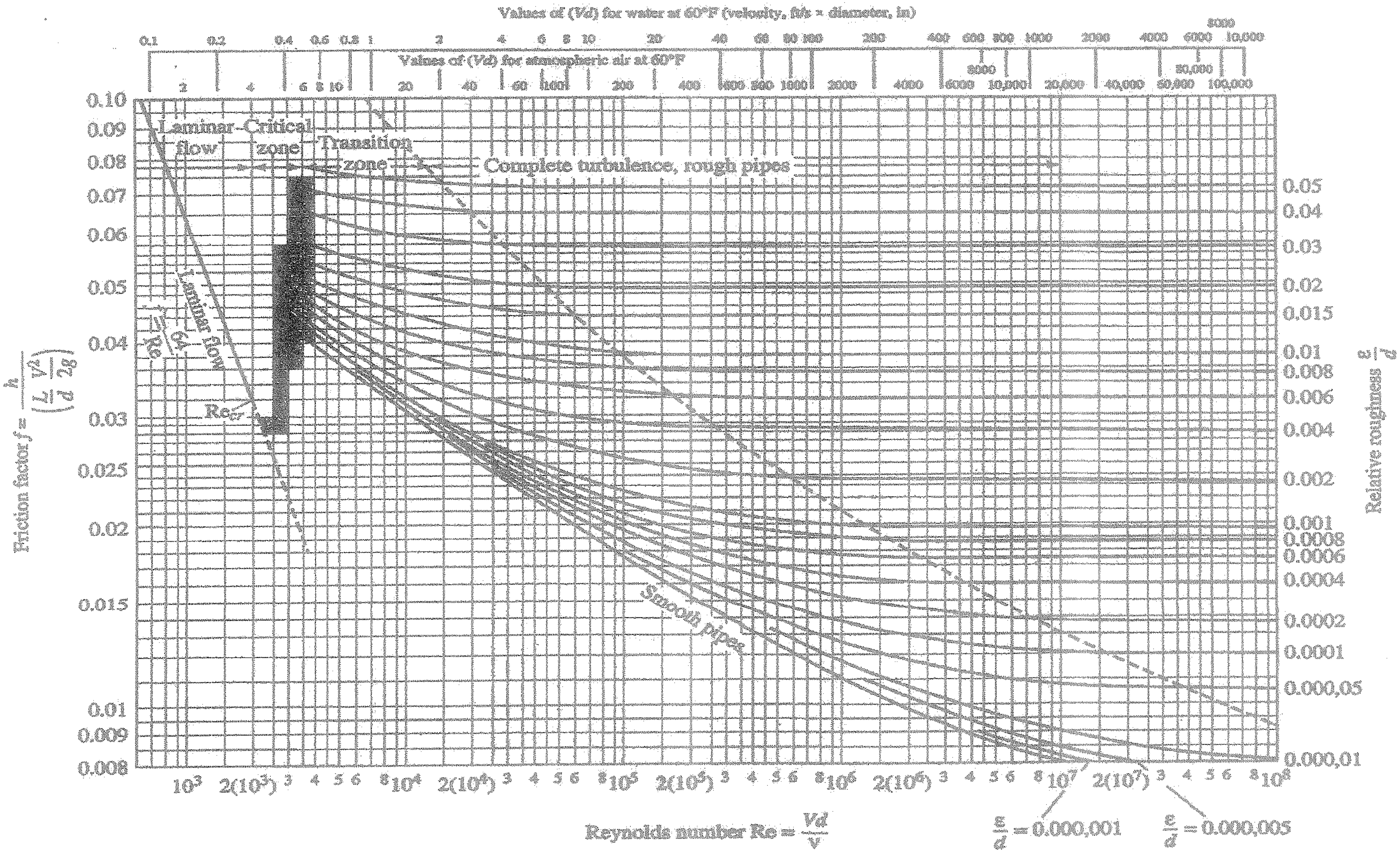


Figure Q3: Pump Characteristic Curves



Moody diagram