UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION - December 2001

Second Year - Programs 1 and 2

MIE270F - FLUID MECHANICS I

Examiner: Professor H.J. Leutheusser

Note: - *No aids permitted; no restrictions on calculators.*
- *Values of the various questions (out of a total of 100) are as indicated.*
- *A complete paper (100%) contributes 60 points to the final mark in the subject.*

Question 1 (17)

The fluid drive shown schematically in Fig. 1 transmits a constant torque for steady-state conditions, i.e., angular velocities ϖ_1 and ϖ_2 constant. Derive an expression for the slip (ϖ_1 - ϖ_2) in terms of torque T, disk diameter d, disk spacing h (assumed to be very small), and dynamic viscosity μ.

Question 2 (16)

Fig. 2 depicts the plan view of the gates at the entrance to an empty canal lock. The two vertical gates are plane rectangles with a height of 4.5 m. Calculate magnitude, direction (relative to canal axis), and location (relative to canal bottom) of the reaction at the two hinges when the water surface is 0.9 m below the top of the gates.

Question 3 (17)

A water-filled U-tube has two 1.50-m long, straight, vertical legs, 1.00 m apart, and a semi-circular bottom section. The tube can be rotated about its central axis. When at rest, the elevation of the two menisci (open to the atmosphere, p_{amb} = 101.33 kPa) is +1.90 m while the lowermost point of the tube (point A) is at elevation zero.

(a) Calculate the speed of rotation of the tube, in rpm, for the first appearance of water vapour at point A. Assume p_v = 1.70 kPa, and remember that radial acceleration equals $\varpi^2 r$.

(b) What is the corresponding gauge pressure, in kPa, at points B, with elevation +1.60 m, in the legs of the tube?

Question 4 (16)

A free circular jet of diameter d issues into the atmosphere from the "Borda orifice" (diameter D) shown in Fig. 3. Significant velocities occur only in the immediate vicinity of the orifice, while hydrostatic pressure conditions prevail elsewhere. With the aid of the momentum equation and Torricelli's efflux theorem determine the diameter ratio d/D.

Question 5 (17)

Consider Fig. 4. The average velocity of the fluid (S = 0.90) in the 75-mm line is 6 m/s and the corresponding Reynolds number **R** = 10^5. Determine the unknown pressure reading at the gauge in the 150-mm pipe (elevation +30 m) when the gauge in the 75-mm line (elevation +27 m) reads 140 kPa. Both reaches of pipe are hydrodynamically smooth, and the minor loss coefficient for the abrupt enlargement of the pipe line is 0.56.

Question 6 (17)

A ship 120 m long moves through fresh water (μ = 1.139x10^{-3} Pa.s). A 1:100 model of this ship is to be tested in a towing tank containing a liquid of specific gravity 0.92.

(a) What dynamic viscosity must the model liquid have for both the Froude and the Reynolds laws of similitude to be satisfied?

(b) At what velocity must the model be towed to match a prototype speed of 32 km/h?

(c) What propulsive force on the prototype ship corresponds to a towing force of 9 N in the model?

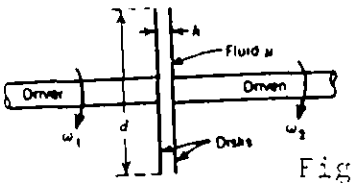


Fig. 1

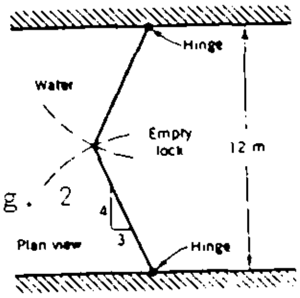


Fig. 2

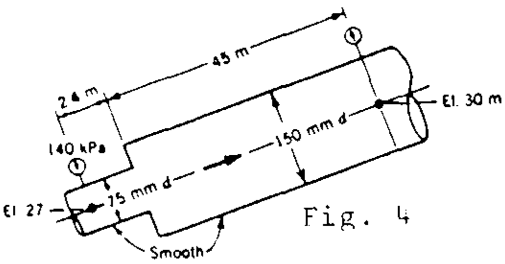


Fig. 4

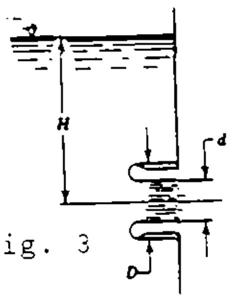
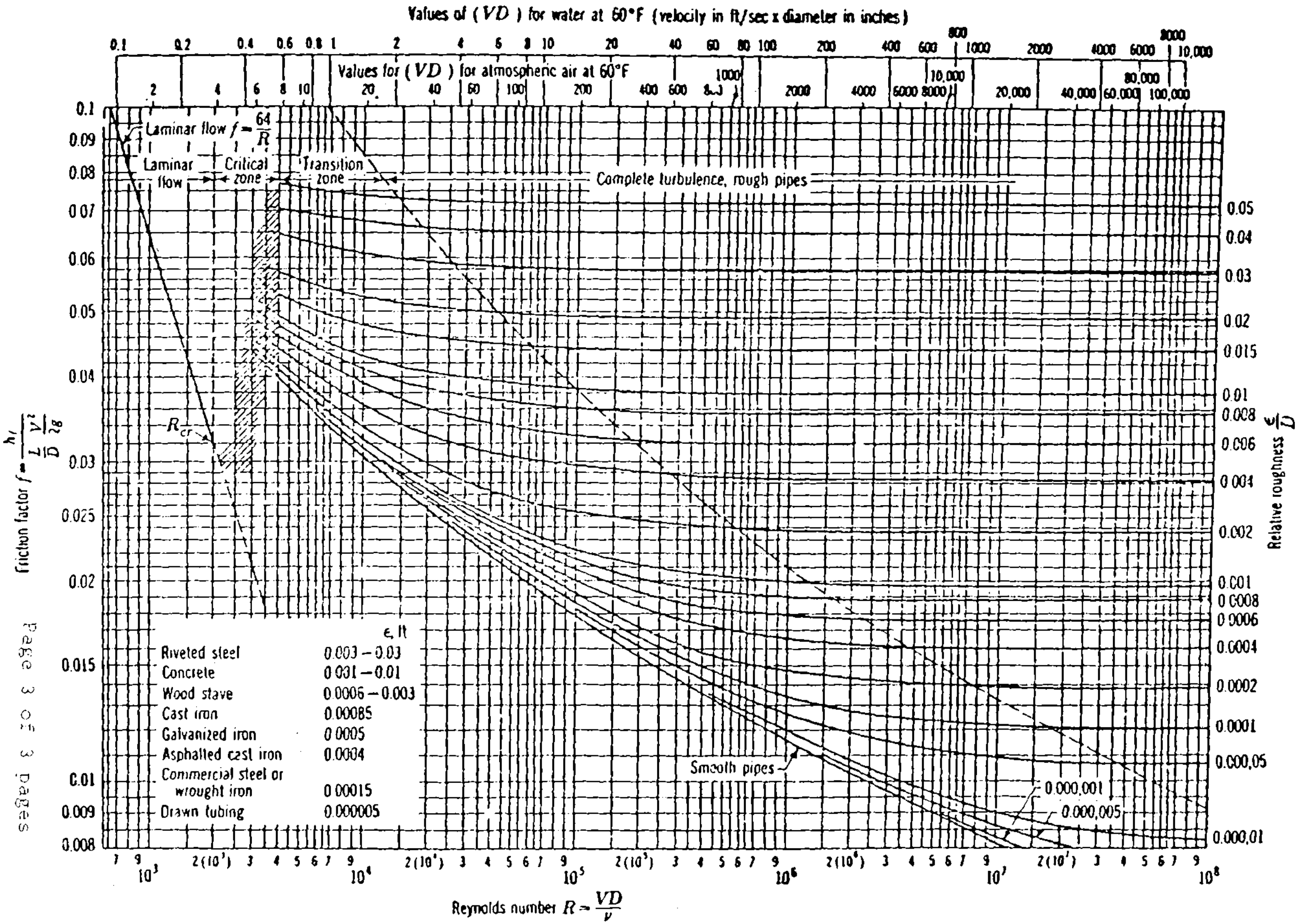


Fig. 3



MOODY DIAGRAM

MIE 270F

SOME USEFUL FORMULAS & EQUATIONS

$$Re = \frac{V D \rho}{\mu}; \quad Fr = \frac{V}{\sqrt{g y}}; \quad Ma = \frac{V}{c}; \quad We = \frac{\rho L V^2}{\sigma}$$

$$\nu = \frac{\mu}{\rho}; \quad \tau = \mu \frac{dv}{dy}; \quad S = \frac{\rho}{\rho_{ref}} = \frac{\gamma}{\gamma_{ref}}; \quad p = \gamma h$$

$$c = \sqrt{k R T}; \quad p v = R T; \quad v = \frac{1}{\rho}$$

$$V = \sqrt{2 g h}; \quad F = \gamma \bar{h} A; \quad Q = V A$$

$$\overline{\sum F} = \rho Q (\overline{V_2} - \overline{V_1})$$

$$dp = \rho (X dx + Y dy + Z dz)$$

$$z_1 + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + H_P - H_T = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_l$$

$$h_l = h_f + h_L$$

$$h_f = f \frac{L}{D} \frac{V^2}{2g}; \quad h_L = C_L \frac{V^2}{2g}$$