prob.1 (25 points) A section of pipe carrying water contains an expansion chamber with a free surface whose area is 2 m^2. The inlet and outlet pipes are both 1 m^2 in area. At a given instant, the velocity at section ① is 3 m/s into the chamber. Water flows out at section ② at 4 m^3/s. Both flows are uniform. Find the rate of change of free surface level at the given instant. Indicate whether the level rises or falls.

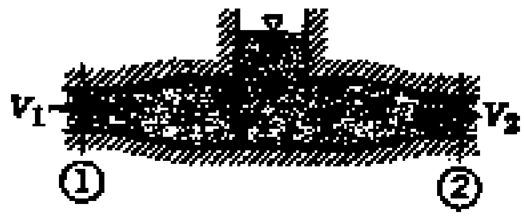


FIGURE I.

hint: Governing eq. $0 = \frac{\partial}{\partial t}\int_{CV} \rho\, d\forall + \int_{CS} \rho \hat{V} \cdot d\hat{A}$.

prob.2 (25 points) The sketch shows a vane with a turning angle of 60°. The vane moves at constant speed, U = 10 m/s, and receives a jet of water that leaves a stationary nozzle with speed V = 30 m/s. The nozzle has an exit area of 0.003 m^2. Determine the force that must be applied to maintain the vane speed constant.

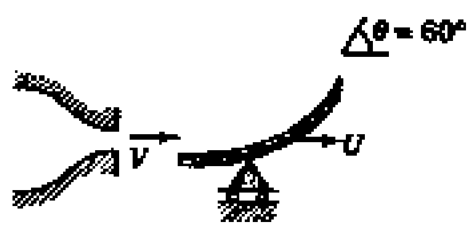


FIGURE II.

hint: Governing eq.,

- $\vec{F} = \vec{F}_S + \vec{F}_B = \frac{\partial}{\partial t}\int_{CV} \vec{V}_{xyz}\rho\, d\forall + \int_{CS} \vec{V}_{xyz}\rho \vec{V}_{xyz} \cdot d\vec{A}$
- ρ_{H_2O} = 999 kg/m^3.

prob. 3 (25 points)

Water flows from the pipe shown in Fig. III. as a free jet and strikes a circular flat plate. The flow geometry shown is axisymmetrical. Determine the flowrate and the manometer reading, H.

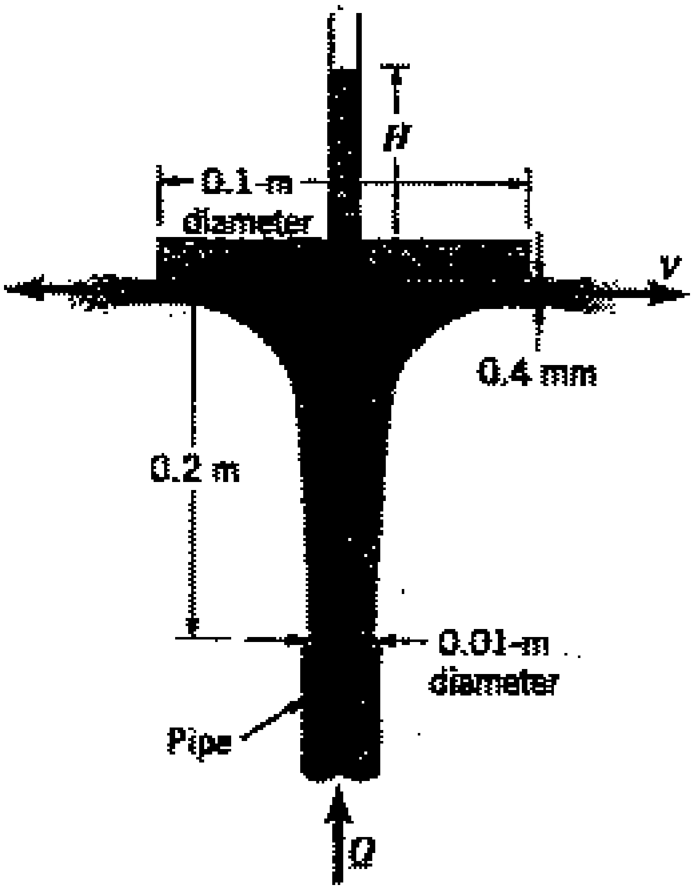


FIGURE III.

prob. 4 (25 points)

A 100 m length of smooth horizontal pipe is attached to a large reservoir. What depth, d, must be maintained in the reservoir to produce a volume flow rate of 0.0084 m^3/s of water? The inside diameter of the smooth pipe is 75 mm. The inlet is square-edged and water discharges to the atmosphere.

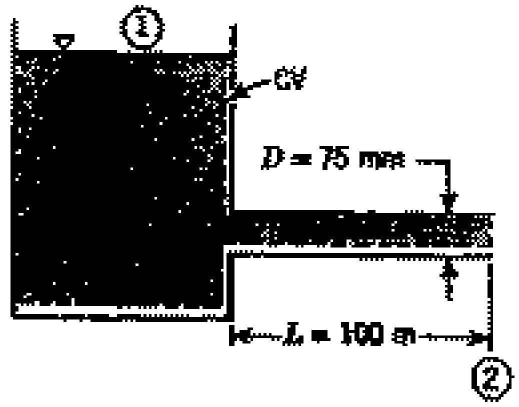


FIGURE IV.

Hint:

Computing equation:

$$\left(\frac{p_1}{\rho}+\alpha_1\frac{\bar{V}_1^2}{2}+gz_1\right)-\left(\frac{p_2}{\rho}+\alpha_2\frac{\bar{V}_2^2}{2}+gz_2\right)=h_{l_T}$$

$$=h_l+h_{l_m},$$

where

$$h_l=f\frac{L}{D}\frac{\bar{V}^2}{2} \quad \text{and} \quad h_{l_m}=K\frac{\bar{V}^2}{2}.$$

- $\mu = 1.0\times10^{-3}$ kg/(m·s) for liquid water.

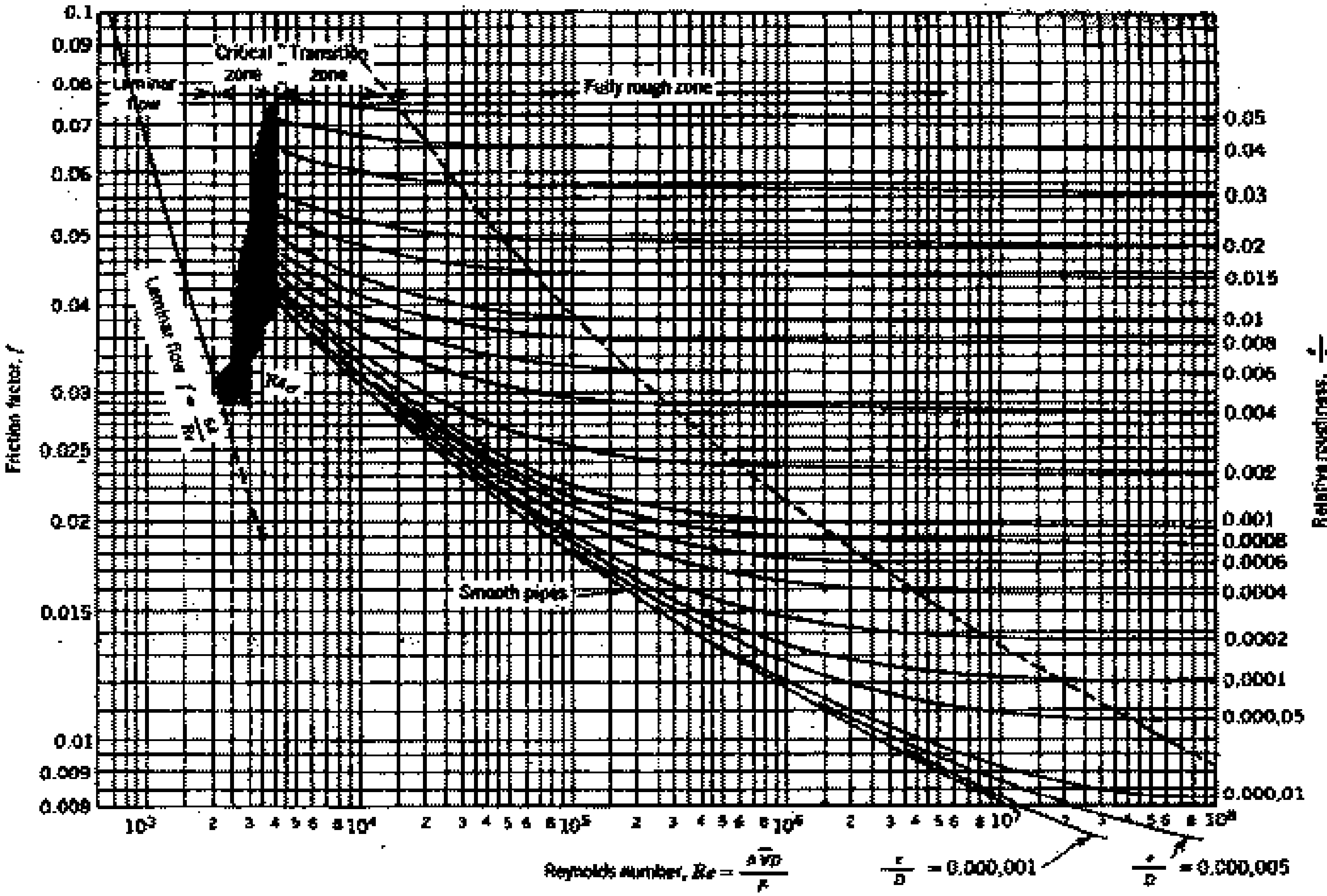
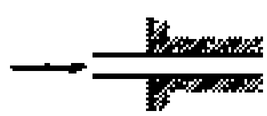
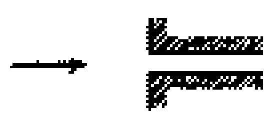


Fig. A1. Friction factor for fully developed flow in circular pipes. (Data from [6], used by permission.)

Table A1. Minor Loss Coefficients for Pipe Entrances (Data from [10].)

Entrance Type		Minor Loss Coefficient, K^a
Reentrant		0.78
Square-edged		0.5
Rounded		r/D: 0.02 | 0.06 | ≥ 0.15; K: 0.28 | 0.15 | 0.04

[a] Based on $h_{l_m} = K(\bar{V}^2/2)$, where $\bar{V}$ is the mean velocity in the pipe.

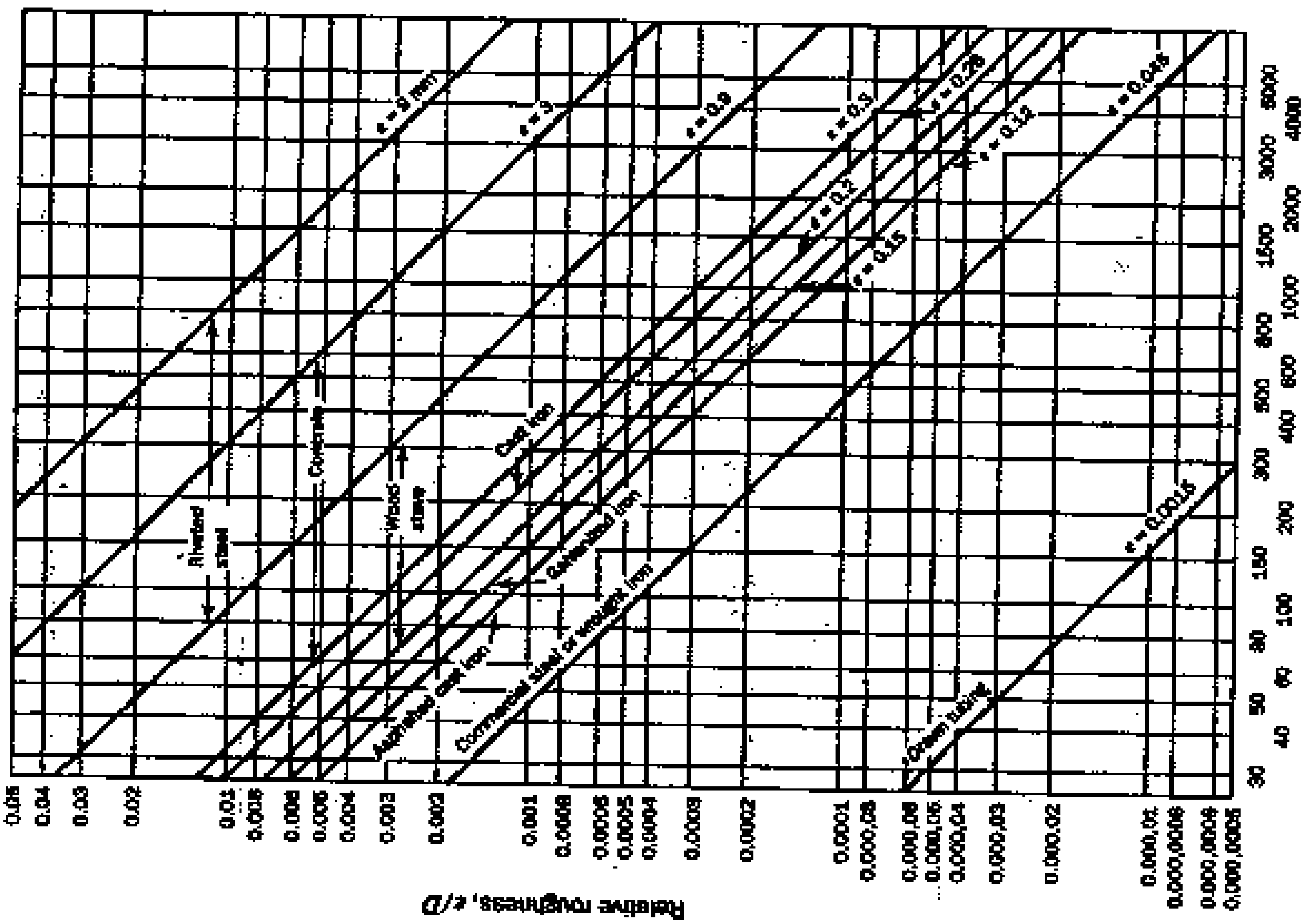


Fig. A2. Relative roughness for pipes of common engineering materials. (Data from [6], used by permission.)

Table A2 Representative Dimensionless Equivalent Lengths (L_e/D) for Valves and Fittings (Data from [10].)

Fitting Type	Equivalent Length,[a] L_e/D
Valves (fully open)	
Gate valve	8
Globe valve	340
Angle valve	150
Ball valve	3
Lift check valve: globe lift	600
: angle lift	55
Foot valve with strainer: poppet disk	420
: hinged disk	75
Standard elbow: 90°	30
: 45°	16
Return bend, close pattern	50
Standard tee: flow through run	20
: flow through branch	60

[a] Based on $h_{l_m} = f \frac{L_e}{D} \frac{\overline{V}^2}{2}$.