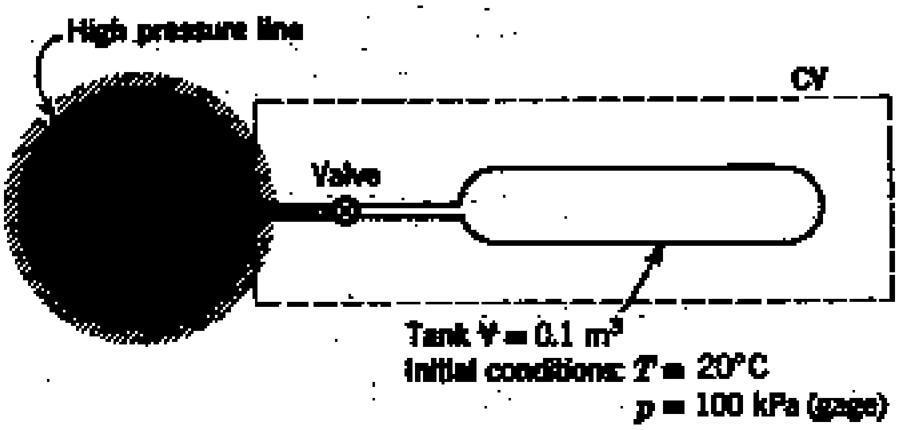
prob.1
25 points

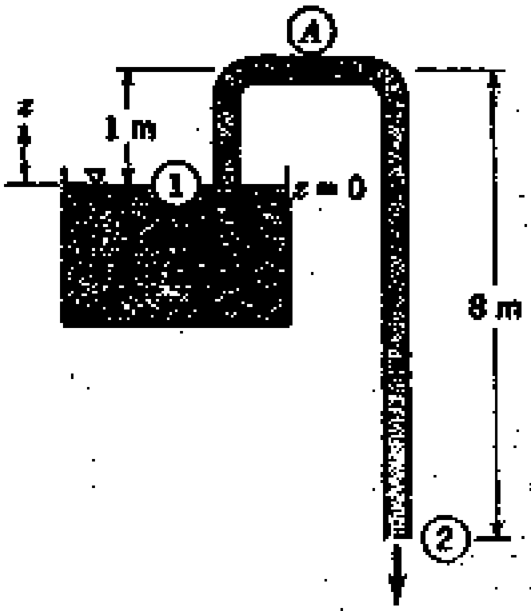
A tank of 0.1 m^3 volume is connected to a high-pressure air line; both line and tank are initially at a uniform temperature of 20°C. The initial tank gage pressure is 100 kPa. The absolute line pressure is 2.0 MPa; the line is large enough so that its temperature and pressure may be assumed constant. The tank temperature is monitored by a fast-response thermocouple. At the instant after the valve is opened, the tank temperature rises at the rate of 0.05°C/s. Determine the instantaneous flow rate of air into the tank if heat transfer is neglected.



< energy equation : $\dot{Q} - \dot{W}_s - \dot{W}_{shear} - \dot{W}_{others} = \frac{\partial}{\partial t}\int_{CV} e\rho\, dV + \int_{CS} (e + pv)\rho \hat{V}\cdot d\hat{A}$,
$e = u + \frac{V^2}{2} + gz$;
Ideal gas Law, $p = \rho RT$, $du = C_v dT$, $R = 287 \frac{N\cdot m}{kg\cdot K}$ for air,
continuity equation : $0 = \frac{\partial}{\partial t}\int_{CV} \rho\, dV + \int_{CS} \rho \hat{V}\cdot d\hat{A}$, $C_v = 717 \frac{N\cdot m}{kg\cdot K}$ for air >

prob.2
25 points

A U-tube acts as a water siphon. The bend in the tube is 1 m above the water surface; the tube outlet is 7 m below the water surface. The fluid issues from the bottom of the siphon as a free jet at atmospheric pressure. If the flow is frictionless as a first approximation, determine (after listing the necessary assumptions) the speed of the free jet and the absolute pressure of the fluid in the bend.



< $P_{atm} = 1.01\times10^5 \frac{N}{m^2}$; $\rho_{H_2O} = 999 \frac{kg}{m^3}$; $g = 9.81 \frac{m}{s^2}$ >
Bernoulli equation : $\frac{P}{\rho} + \frac{V^2}{2} + gz = \text{constant}$

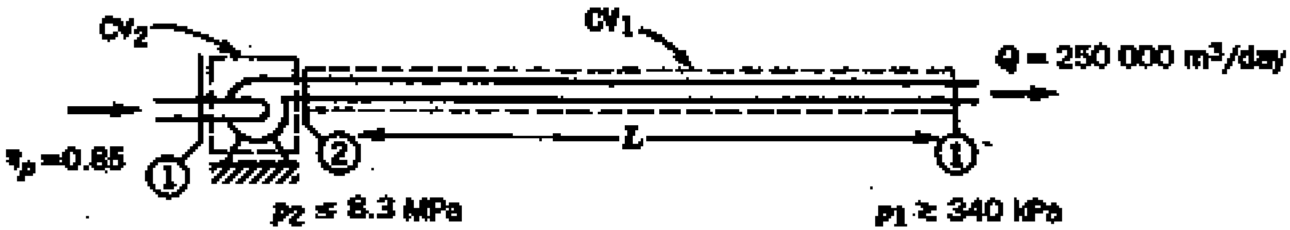
prob. 3
25 points

Consider the flow field given by $\psi = ax^2 - ay^2$, where $a = 3\ \mathrm{s}^{-1}$. Show that the flow is irrotational. Determine the velocity potential for this flow.

$$\left\langle \nabla \times \hat{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ u & v & w \end{vmatrix} \quad ; \quad \text{Cauchy–Riemann equation,} \quad u = \frac{\partial \psi}{\partial y} = -\frac{\partial \phi}{\partial x}, \quad v = -\frac{\partial \psi}{\partial x} = -\frac{\partial \phi}{\partial y} \right\rangle$$

prob. 4
25 points

Crude oil flows through a level section of the Alaskan pipeline at a rate of 250 thousand cubic meters per day. The pipe inside diameter is 1200 mm; its roughness is equivalent to that of galvanized iron. The maximum allowable pressure is 8.3 MPa; the minimum pressure required to keep dissolved gases in solution in the crude oil is 340 kPa. The crude oil has SG = 0.93; its viscosity at the pumping temperature of 60°C is $\mu = 0.017\ \mathrm{N \cdot s/m^2}$. For these conditions, determine the maximum possible spacing between pumping stations. If the pump efficiency is 85 percent, determine the power that must be supplied at each pumping station.



$$\left\langle \left(\frac{p_2}{\rho} + \alpha_2 \frac{\bar{V}_2^2}{2} + g z_2\right) - \left(\frac{p_1}{\rho} + \alpha_1 \frac{\bar{V}_1^2}{2} + g z_1\right) = h_{l_T} \ ; \ h_{l_T} = h_l + h_{l_m} = f \frac{L}{D} \frac{\bar{V}^2}{2} + K \frac{\bar{V}^2}{2} \right\rangle$$

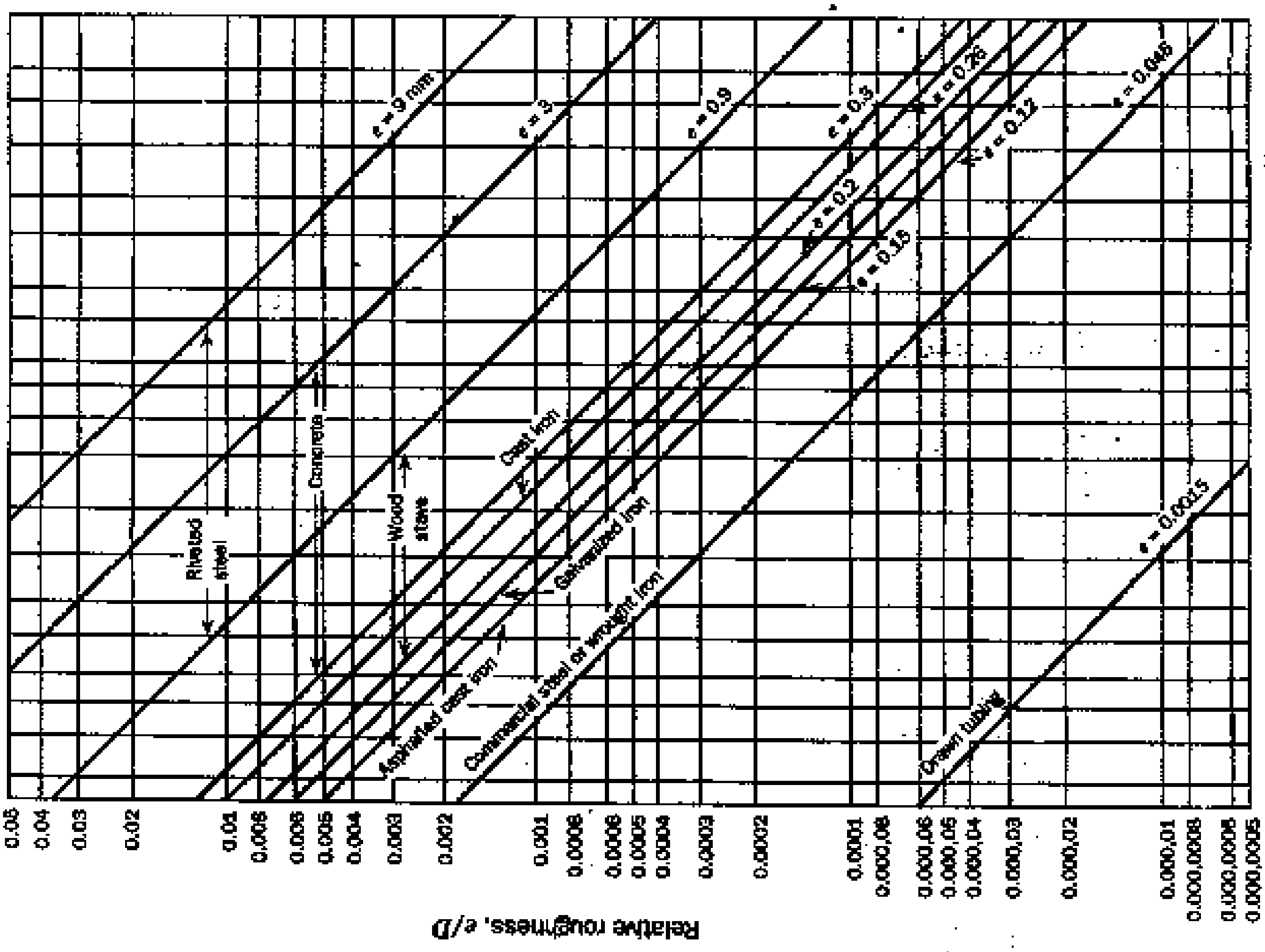


Fig. 1. Relative roughness for pipes of common engineering materials. (Data from [6], used by permission.)

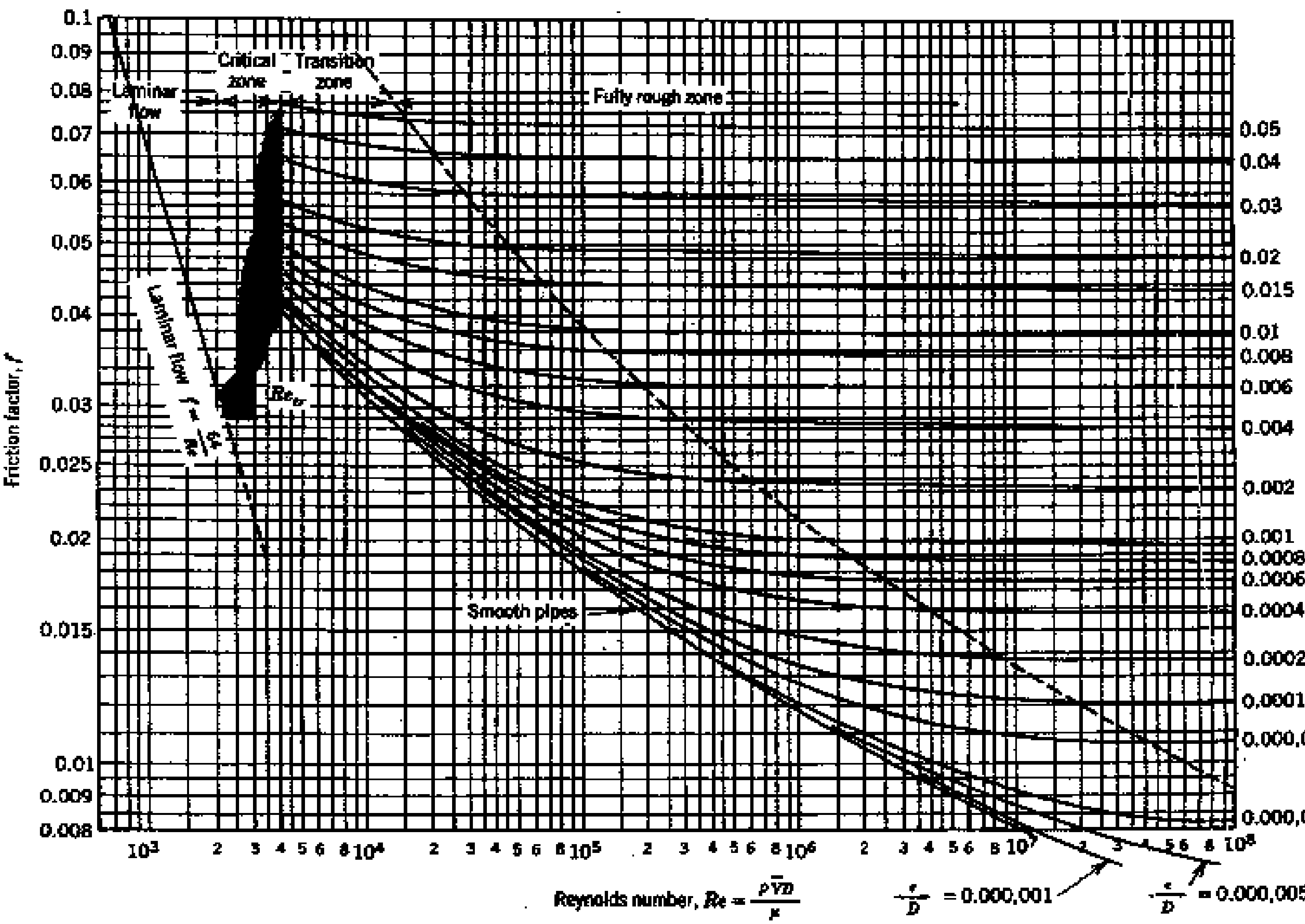


Fig. 2. Friction factor for fully developed flow in circular pipes. (Data from [6], used by permission.)