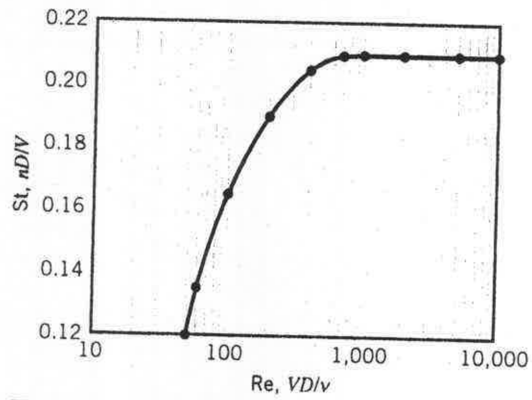
7.84

7.84 (See "**Galloping Gertie**," Section 7.8.2.) The Tacoma Narrows bridge failure is a dramatic example of the possible, serious effects of wind-induced vibrations. As a fluid flows around a body, vortices may be created which are shed periodically creating an oscillating force on the body. If the frequency of the shedding vortices coincides with the natural frequency of the body, large displacements of the body can be induced as was the case with the Tacoma Narrows bridge. To illustrate this type of phenomenon, consider fluid flow past a circular cylinder. Assume the frequency, n, of the shedding vortices behind the cylinder is a function of the cylinder diameter, D, the fluid velocity, V, and the fluid kinematic viscosity, ν. **(a)** Determine a suitable set of dimensionless variables for this problem. One of the dimensionless variables should be the Strouhal number, nD/V. **(b)** Some results of experiments in which the shedding frequency of the vortices (in Hz) was measured, using a particular cylinder and Newtonian, incompressible fluid, are shown in Fig. P7.84. Is this a "universal curve" that can be used to predict the shedding frequency for any cylinder placed in any fluid? Explain. **(c)** A certain structural component in the form of a 1-in.-diameter, 12-ft-long rod acts as a cantilever beam with a natural frequency of 19 Hz. Based on the data in Fig. P7.7 , estimate the wind speed that may cause the rod to oscillate at its natural frequency. *Hint:* Use a trial and error solution.



■ **FIGURE P7.84**

(a) $$n = f(D, V, \nu)$$

$$n \doteq T^{-1} \quad D \doteq L \quad V \doteq LT^{-1} \quad \nu \doteq L^2T^{-1}$$

From the pi theorem, $4-2=2$ pi terms required, and a dimensional analysis yields

$$\frac{nD}{V} = \phi\left(\frac{VD}{\nu}\right)$$

(b) Yes. If the variables of part (a) are correct then this is a "universal" or general relationship between the Strouhal number and the Reynolds number. It is valid over the range of Reynolds numbers covered in the experiment.

(con't)

7.84 (con't)

(c) For $n = 19\ Hz$ and $D = \frac{1\ in.}{12\ \frac{in.}{ft}} = \frac{1}{12}\ ft$

$$S_t = \frac{nD}{V} = \frac{(19\ Hz)(\frac{1}{12}\ ft)}{V} \qquad (1)$$

From Fig. P7.72, assume $S_t = 0.21$ and from Eq.(1)

$$0.21 = \frac{(19\ Hz)(\frac{1}{12}\ ft)}{V}$$

so that $\underline{\underline{V = 7.54\ \frac{ft}{s}}}$ (5.14 mph)

Check Re: $Re = \frac{VD}{\nu} = \frac{(7.54\ \frac{ft}{s})(\frac{1}{12}\ ft)}{1.57 \times 10^{-4}\ \frac{ft^2}{s}} = 4000$

From Fig. P7.72 at $Re = 4000$, $St = 0.21$ and therefore assumed value of S_t OK.