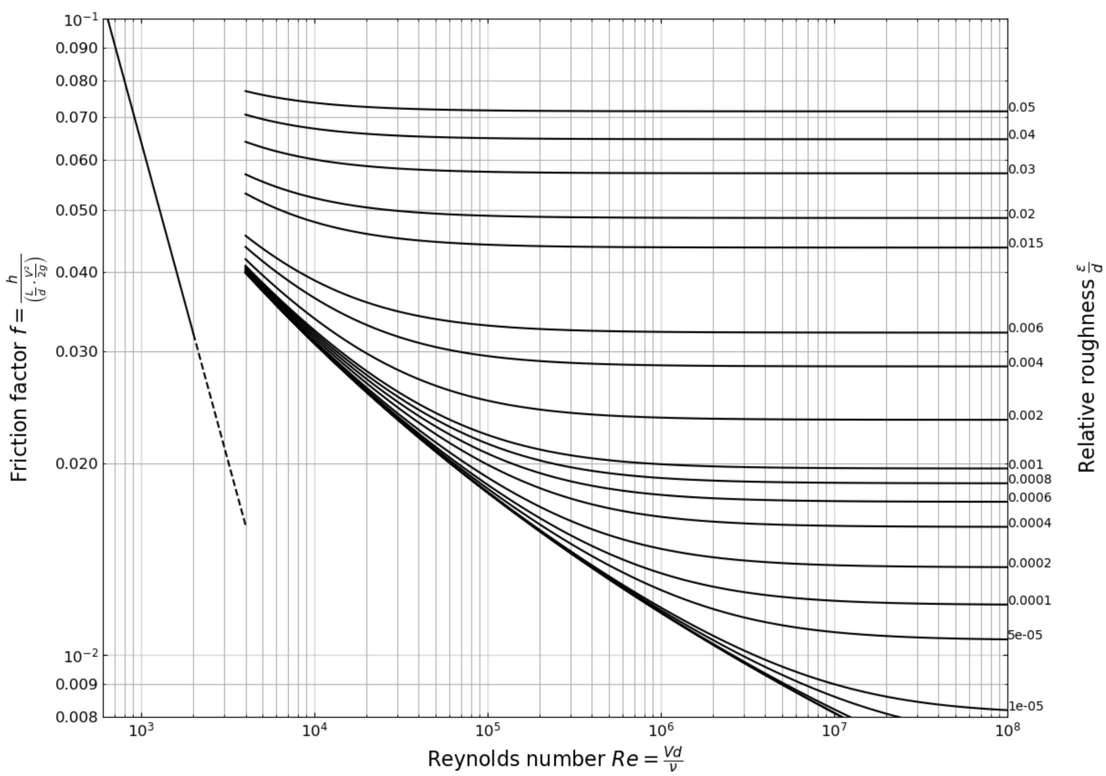
You will be writing three different Python programs in three different files named hw5a.py, hw5b.py and hw5c.py. You will place your files in a folder named HW5 and then zip the folder and upload it to Canvas.

a. BYOMD (Build Your Own Moody Diagram). The Moody diagram is used in fluid mechanics to relate the friction factor (f) to Reynolds number (Re) for pipes with various Relative roughness (ϵ/d) in the laminar and turbulent flow ranges with some ambiguity in transitional flow ($2\times10^3<Re<4\times10^3$). In the laminar range, the relative roughness seems to be irrelevant and $f = \frac{64}{Re}$ whereas in the turbulent range, f is calculated with the Colebrook equation:

$$\frac{1}{f^{\frac{1}{2}}} = -2.0log\left(\frac{\frac{\epsilon}{d}}{3.7} + \frac{2.51}{Re \cdot f^{\frac{1}{2}}}\right)$$

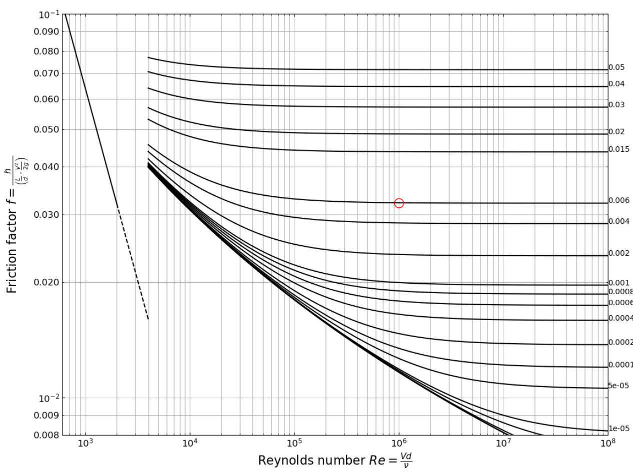
Write a program that produces a Moody diagram like the one below.

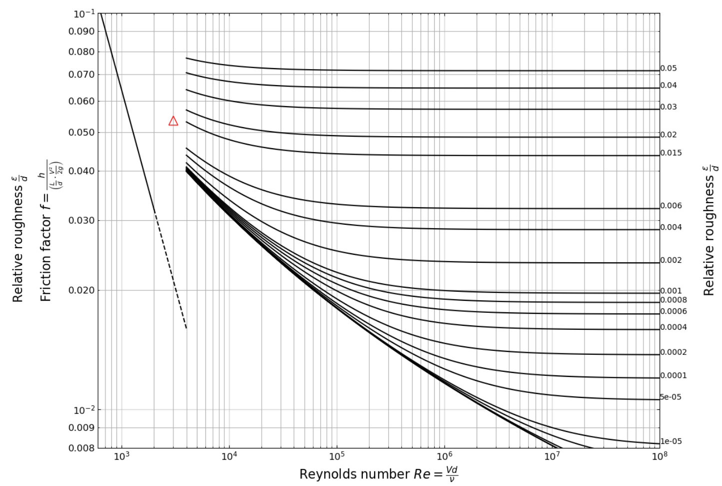


b. Beyond BYOMD: Create a function that takes as input the Reynolds number and relative roughness and outputs a red icon on the Moody diagram for the *Re*, *f* location. The icon should be an upward triangle if the flow is transition or a circle if otherwise. You should solicit input from the user through the command line (see https://www.w3schools.com/python/python_user_input.asp). You may import functions from part a) as needed. **Note:** since there are three domains on your Moody diagram (laminar, transition and turbulent) your function should use either the laminar equation, the Colebrook equation or a random number from a normal distribution with:

$$\mu_f = \frac{f_{lam} + f_{CB}}{2} \text{ and } \sigma_f = 0.2\mu_f$$

Where: f_{lam} and f_{CB} are the friction factors at the given Re predicted by the laminar and Colebrook equations, respectively. See following figures for example output:



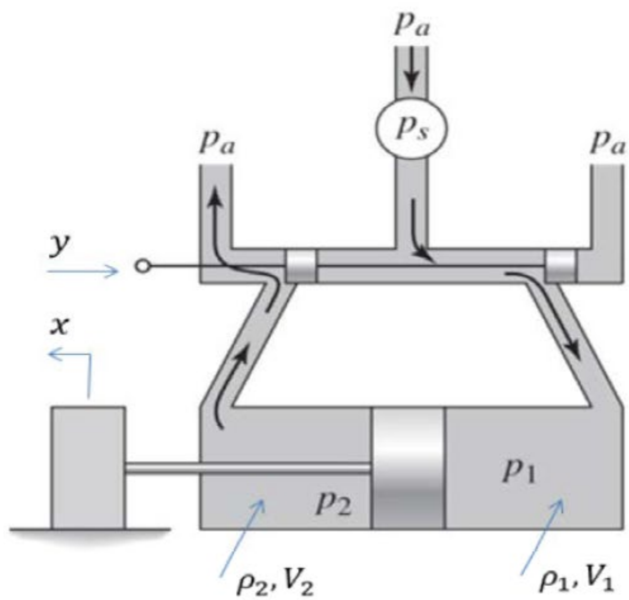


c. The following differential equations describe the behavior of a hydraulic valve system

$$(p1 - p2)\cdot A = m\cdot\frac{d^2x}{dt^2}$$

$$y\cdot K_{valve}\cdot(ps - p1) = \rho\cdot A\cdot\frac{dx}{dt} + V\cdot\frac{\rho}{\beta}\cdot\frac{dp1}{dt}$$

$$y\cdot K_{valve}\cdot(p2 - pa) = \rho\cdot A\cdot\frac{dx}{dt} - V\cdot\frac{\rho}{\beta}\cdot\frac{dp2}{dt}$$



The values for the constant parameters are:

$A = 4.909\times10^{-4}\,m^2$ $C_d = 0.6$ $ps = 1.4\times10^{7}\,Pa$ $pa = 1\times10^{5}\,Pa$

$V = 1.473\times10^{-4}\,m^3$ $\beta = 2\times10^{9}\,Pa$ $\rho = 850\,\frac{kg}{m^3}$ $K_{valve} = 2\cdot10^{-5}$

$m = 30\cdot kg$

NOTE: **All units** *for the variables and the constants are* ***consistent*** *as given, and no unit conversions of any kind are necessary.*

Required:
Use `odeint()` to solve the differential equations for the response to a constant input of `y=0.002`

The initial conditions are: $x=0$, $\dot{x}=0$, $p1=pa$, $p2=pa$

1. From that solution, plot $\dot{x}$ as a function of time, with nice title and labels.
2. From that solution, plot p1 and p2 together as functions of time, on a new graph, with nice title and labels and legend.