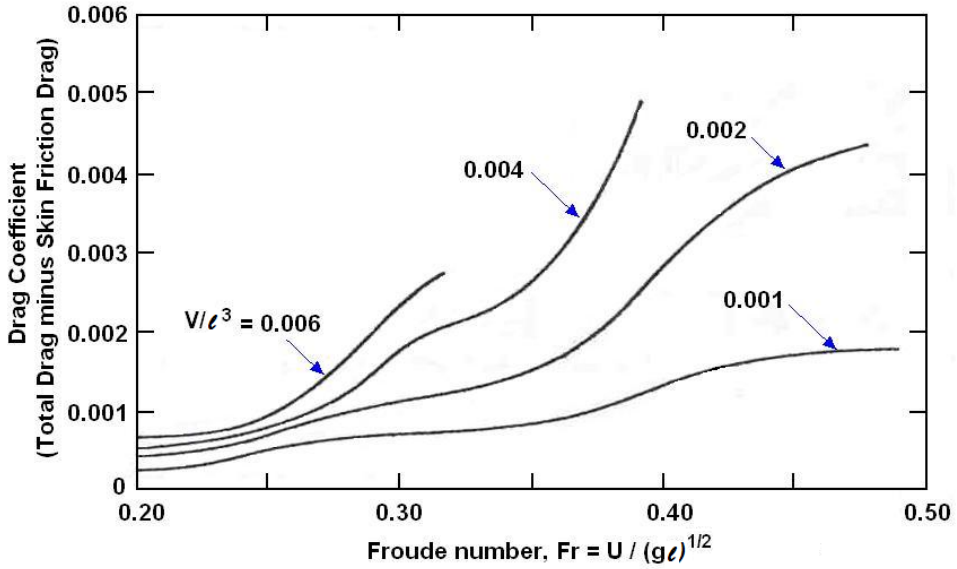
Problem 280D

A long, streamlined boat or ship will have a drag that is primarily comprised of skin friction drag (C_{DS}) and wave drag (or residual drag, $C_D - C_{DS}$) comprised of wave drag plus a little form drag) where the drag coefficients are all based on the velocity of the ship, U, the kinematic viscosity of the water ($\nu = 10^{-6} m^2/s$) and the wetted hull surface area, S, of the ship (surface area in contact with the water). The skin friction drag can be estimated using the turbulent drag coefficient for a flat plate based on the length of the ship, ℓ. The residual drag (wave drag) is typically given by a graph like the following:



where the Froude number, $Fr = U/(g\ell)^{1/2}$. However, for simplicity, we shall assume the following crude approximation to these curves:

$$C_D - C_{DS} \;=\; \frac{V}{\ell^3}\left(\frac{Fr}{0.35}\right)^3 \tag{1}$$

where V is the immersed volume of the hull.

The residual drag increses more rapidly with U than the skin friction drag. Therefore at some critical speed the two components of the drag are equal. Find that critical speed for "ships" of length, $1.0m$, $10.0m$, $100.0m$, and $1000.0m$ if the value of V/ℓ^3 for the shape is 0.004.