Problem 240C

When flow initially enters a pipe, the velocity profile of the flow inside the pipe consists of an almost uniform velocity. Gradually as the boundary layers grow on the interior surface of the pipe, the velocity profile exhibits greater variation in the velocity over the cross-sectional area. Eventually the velocity profile approaches the "fully developed" form; in the case of laminar flow this would be the parabolic Poiseuille form. The distance from the entrance required before this fully developed form occurs is know as the "entrance length". Using expressions for the laminar boundary layer on a flat plate, *estimate* this entrance length, L, for a laminar flow in a pipe of radius, R. The answer, L/R, will be a function of the Reynolds number, $Re = UR/\nu$, where U is the volume-averaged velocity of flow in the pipe and ν is the kinematic viscosity of the fluid.

What is the entrance length, L, for the steady laminar flow of blood (viscosity $\mu = 0.01$ *poise* $= 0.001\ kg/m\ s$, density $\rho = 1000\ kg/m^3$) in a 4 mm diameter artery carrying a volume flow of 10 cm^3/s?