Problem 240B

Air enters a long horizontal ventilation duct of circular cross-section (radius 0.25 m) with a velocity of 1.0 m/s. At the entrance it is assumed that this velocity is uniform over the entire cross-section. However as the flow proceeds down the duct a thin laminar boundary develops on the inside wall of the duct. If we first assume that this is like the boundary layer on a flat plate and that the velocity away from the boundary layer remains at $1.0 m/s$ find the displacement thickness, δ_D (in m), at a distance x (in m) from the entrance. Assume the kinematic viscosity of the air is 2.5×10^{-6} m^2/s and the density is 1.2 kg/m^3.

Having calculated this displacement thickness we recognize that the velocity outside the boundary layer cannot remain precisely constant at 1 m/s. Using the above calculated displacement thickness find the uniform velocity outside the boundary layer at a point 200 m from the entrance. What is the pressure difference between the entrance and this point 200 m from the entrance? Describe in words how you might now proceed to a more accurate boundary layer calculation which takes this pressure gradient into account.