ESO204A: Fluid Mechanics and Rate Processes
TUTORIAL 10 PROBLEMS

August-November 2017

1. Review of Tutorials 8-9

2. Study the combined effect of the two viscous flows in Fig. 4.12; such a flow configuration is called Couette-Poisseulle flow. That is, find $u(y)$ when the upper plate moves at speed V and there is also a constant pressure gradient (dp/dx). Is superposition possible? If so, explain why. Plot representative velocity profiles for (*a*) zero, (*b*) positive, and (*c*) negative pressure gradients for the same upper-wall speed V.

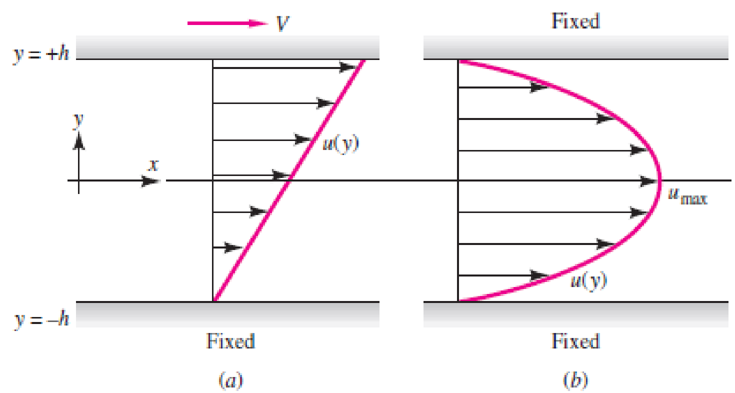
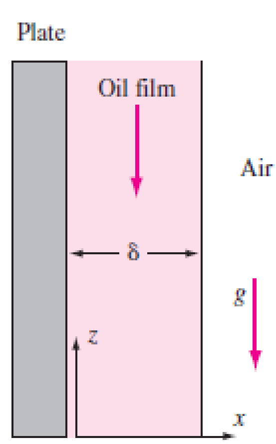


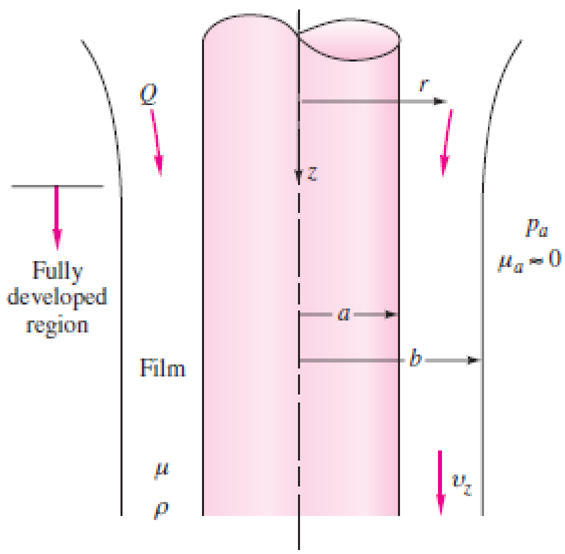
Fig. 4.12 Incompressible viscous flow between parallel plates: (*a*) no pressure gradient, upper plate moving; (*b*) pressure gradient $\partial p/\partial x$ with both plates fixed.

3. Oil, of density ρ and viscosity μ, drains steadily down the side of a vertical plate, as in Fig. P4.80. After a development region near the top of the plate, the oil film will become independent of z and of constant (small) thickness δ. Assume that $w = w(x)$ only and that the atmosphere offers no shear resistance to the surface of the film.
(*a*) Solve the Navier-Stokes equation for $w(x)$, and sketch its shape.
(*b*) Suppose that film thickness δ and the slope of the velocity profile at the wall $[\partial w/\partial x]_{wall}$ are measured with an instrument called the laser-Doppler anemometer. Find an expression for oil viscosity μ as a function of $\left(\rho,\ \delta,\ g,\ [\partial w/\partial x]_{wall}\right)$.



P4.80

4. Consider a viscous film of liquid draining uniformly down the side of a vertical rod of radius *a*, as in Fig. P4.84. At some distance down the rod the film will approach a terminal or *fully developed* draining flow of constant outer radius *b*, with $v_z = v_z(r)$, $v_\theta = v_z = 0$. Assume that the atmosphere offers no shear resistance to the film motion. Derive a differential equation for the axial velocity component as a function of the radial coordinate, i.e. $v_z(r)$. State the proper boundary conditions at *r*=*a* and *r*=*b*, and solve for the film velocity distribution. Relate film radius *b* to the total film volume flow rate *Q*?



P4.84