一、An effectively two-dimensional jet of water impinges on a wedge as shown in Figure 1. The wedge is supported at its apex such that the lower surface remains horizontal. If the thicknesses t_2 and t_3 are equal and $U_2 = U_3 = 2U_1$, find the angle for which the magnitude of the x- and y-components of the reaction at the apex are equal. Neglect gravitational effects. The pressure is atmospheric everywhere. (20%)

二、A continuous belt, passing upward through a chemical bath at speed U (as shown in Figure 2), picks up a liquid film of thickness h, density ρ, and viscosity μ. Gravity tends to make the liquid drain down, but the movement of the belt keeps the liquid from running off completely. Assume that the flow is fully developed and laminar with zero pressure gradient, and that the atmosphere produces no shear stress at the outer surface of the film.

(a) State clearly the boundary conditions to be satisfied by the velocity at y = 0 and y = h. (10%)

(b) Obtain an expression for the velocity profile. (20%)

三、Consider two-dimensional laminar boundary layer flow along a flat plate.

Assume the velocity profile in the boundary layer is parabolic:

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

where u is the velocity at a distance y from the plate surface, δ is the boundary layer thickness, and U is the freestream velocity.

Find expressions for:

(a) The rate of growth of δ as a function of x. (15%)

(b) The displacement thickness, δ^*, as a function of x. (10%)

(c)The total friction force on a plate of length L and width b. (10%)

四、Pylons supporting a bridge over a fast-flowing river often have footings (the part of the pylon below and just above the water level) shaped like a wedge, both in the upstream and downstream direction. Why do you think this is done？ (15%)

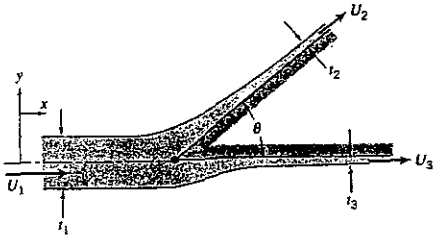

Figure 1

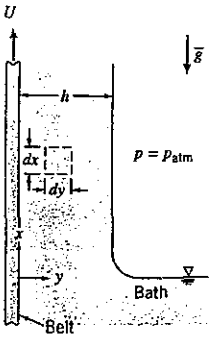

Figure 2

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