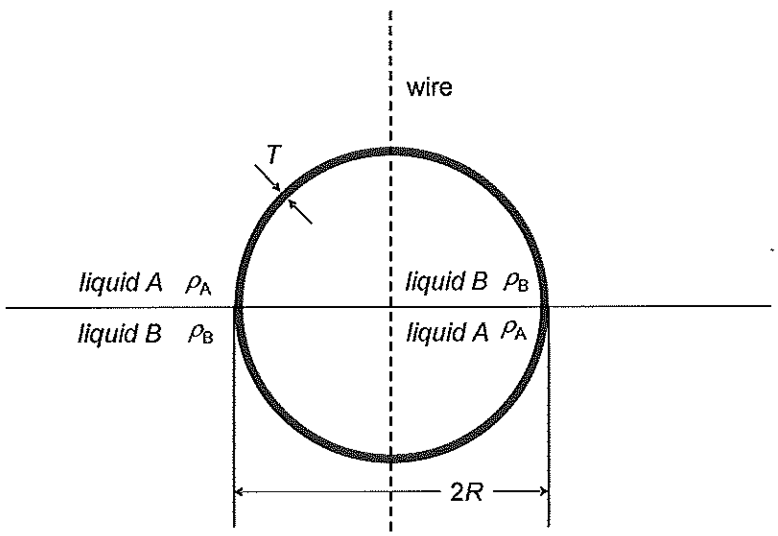
1) Consider a spherical shell/container of radius R and shell thickness T that is symmetrically submerged between two layers of immiscible liquids "A" and "B" (having densities ρ_A and ρ_B) as shown below. The spherical shell contains equal hemispherical volumes of each liquid, but ***within the container liquid "B" is above liquid "A"***. The container is guided by a thin wire passing through clearance holes through the "north" and "south" poles such that there is no friction between the container and the wire but no liquid can leak either inward or outward. It can be assumed that all interfaces between the liquids "A" and "B" remain horizontal (i.e., heavy and light liquids do not move down or up, respectively).

   Determine what should be the density of the container material ρ_c, such that its elevation remains unchanged when:

   a) $\rho_A > \rho_B$;

   and when

   b) $\rho_A < \rho_B$.

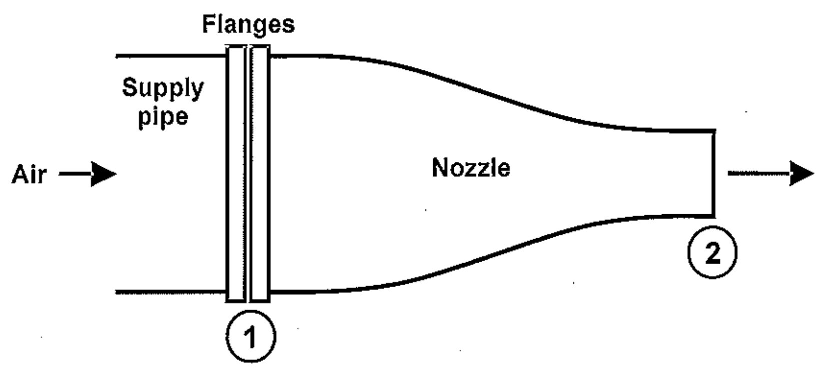


2) Consider air flowing through a horizontal nozzle as shown below. The nozzle, which is connected to a supply pipe by flanges, has an inlet diameter D_1 = 60 mm and an exit diameter D_2 = 10 mm. The inlet absolute pressure P_1=105 kPa, and the air exhausts into the atmosphere so the exit pressure $P_2 = P_{atm.}$=101.3 kPa. Assume that the air has a constant density of 1.22 kg/m^3, and neglect the weight of the nozzle.

Find:

a) The air speed V_2 at the exit of the nozzle;

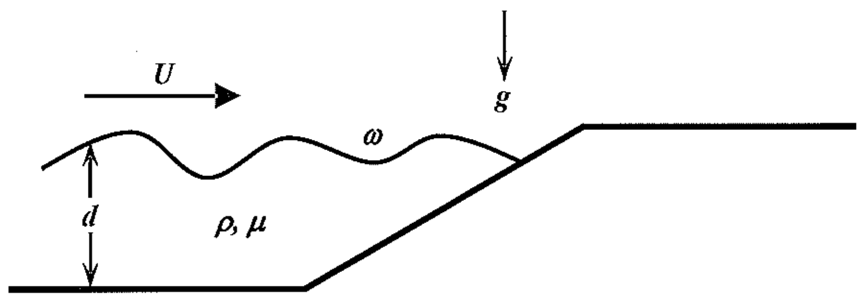
b) The force $\vec{\mathbf{F}}$ required to hold the nozzle stationary



3) A film studio is designing a model for a movie set that features wind-driven waves hitting a sloping beach, as shown below. The desire is for the waves to have the same frequency ω as actual waves hitting a beach.

a) Assuming the wind speed U, the depth d, gravitational acceleration g and fluid properties ρ, μ all contribute to the frequency ω, use the Buckingham Pi Theorem to determine the number of independent dimensionless parameters needed to describe the phenomenon. Then determine these parameters.

b) The model to be developed will be 1/25 scale. Given that the densities of most liquids are nearly equal, what is the ratio between the prototype and model wind speeds and viscosities needed to obtain the same frequency? Is this possible, maintaining full dynamic similarity?



4) Consider the steady flow of a liquid film of uniform thickness h down an inclined flat wall at angle α above the horizontal, as illustrated below. Neglect any variations normal to the page. The liquid is a Newtonian fluid of density ρ and viscosity μ. The flow is driven by gravity, where the gravitational acceleration is g. The air above the liquid film has a density $\rho_g << \rho$ and a viscosity $\mu_g << \mu$ and is at a constant pressure p_g.

a) Specify the boundary conditions at the wall and at the free surface.

b) Find the velocity distribution in the liquid film u and the volumetric flow rate per unit (z) dimension normal to the page q if the air velocity u_g is comparable to u.

A fan now sets the air in motion above the liquid film to slow down the flow of liquid. For this steady-state situation:

c) Find the minimum magnitude of shear stress (per unit dimension normal to the page) at the free surface that gives $q = 0$ in the liquid.

d) Sketch the velocity profiles in the liquid and in the air for this case. How does the magnitude of the air velocity u_g compare with u?