Tutorial 10 : External and internal flows

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November 11, 2026

1. A hydrofoil 36.58 cm long and 183 cm wide is placed in seawater flow of 12 m/s with $\rho = 1025.6\ \mathrm{kg/m^3}$ and $\nu = 1.022 \times 10^{-6}\ \mathrm{m^2/s}$.
   (a) Estimate the boundray layer thickness at the end of the hydrofoil.
   (b) Estimate the friction drag for turbulent smooth-wall flow from the leading edge.
   (c) Laminar turbulent flow with $\mathrm{Re_{cr}} = 5 \times 10^5$
   (d) Turbulent rough wall flow with $\epsilon = 0.000122$ m.
2. Perform Reynolds averaging over the boundary layer equations to derive x momentum equation for a turbulent boundary layer. In practice, it is better to apply Reynolds averaging to Navier-Stokes, and then substitute assumptions for a turbulent boundary layer.
3. Using Thwaite's method, compute the separation point for a linearly decelerating flow $U_\infty(x) = U_0\left(1 - \frac{x}{L}\right)$. Also compute the value of c_f at $x/L = 0.1$. Perform the same analysis for $U_\infty = \frac{U_0}{\left(1+\frac{x}{L}\right)}$
4. Consider the flat walled diffuser with constant width b into the page. Assuming very thin wall boundary layers, derive the inviscide core velocity $U_\infty(x)$ in the diffuser. Use this velocity distribution with Thwaite's method to comptue the wall angle θ for which laminar separation will occur in the exit plane if $L = 2W$.

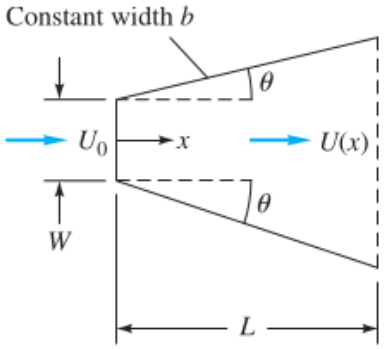


Figure 1: *Flat wall diffuser.*

5. A sphere of density ρ_s and diameter D is dropped from rest in a fluid of density ρ and viscosity μ. Assuming a constant drag coefficient, derive a expression for fall velocity.
6. Two reservoirs contain water at 20° and are connected via a smooth ($\epsilon = 0$) pipe of length $L = 4500$ m and diameter $D = 4$ cm. Calculate the flow rate in $\mathrm{m^3}/s$ for $\Delta z = 100$ m. Use $\nu = 10^{-5}\ \mathrm{m^2/s}$.
7. For straightening and smoothing airflow in a duct of diameter $D = 50$ cm, the duct is packed with a honeycomb of thin straws of length $L = 30$ cm and diameter 4 mm. The inlet flow is of air at 110 kPa

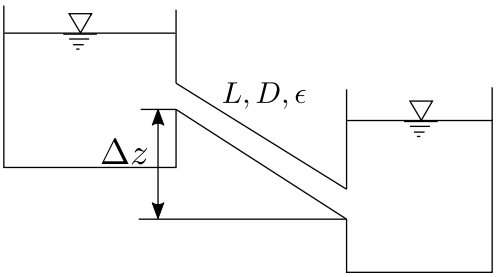


Figure 2: *Pipe connecting reservoirs.*

and $20°$, moving at an average velocity of $U_0 = 6$ m/s. Estimate the pressure drop across the honeycomb. Use kinematic viscosity of air as $\nu = 10^{-4}$ m^2/s.

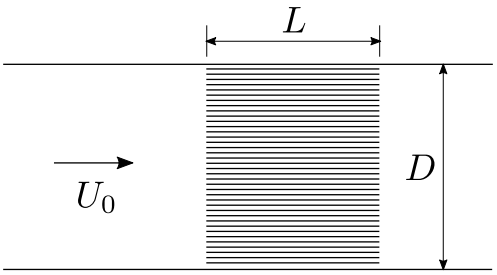


Figure 3: *Honeycomb flow straightener*

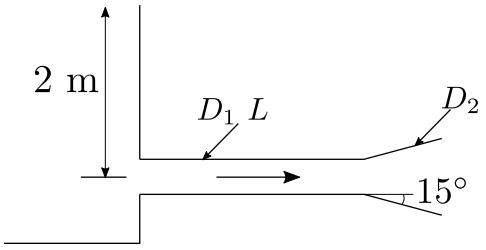


Figure 4: *Diffuser*

8. Figure 4 shows a smooth inlet pipe of diameter $D_1 = 3$ cm with a $15°$ conical diffuser expanding to a 5 cm diameter D_2. The length of the pipe is $L = 2$ m. The pipe entrance is sharp-edged. Calculate the flow rate. Compare this value with the case of no-diffuser. See chart for diffuser minor losses.

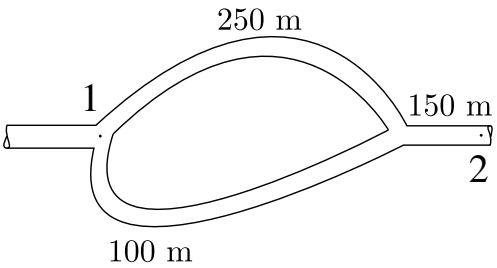


Figure 5: *Pipe network*

9. For pipe network shown in figure 5, all pipes are 8 cm diameter asphalted cast iron. If the total pressure drop $p_1 - p_2 = 750$ kPa, find the resulting flow rate for water. Use $\nu = 10^{-5}$ m^2/s.

10. A tank is connected to a flexible pipe with smooth walls as shown in the figure. The length of the pipe is $L = 25$ m and the diameter of the pipe is $D = 40$ mm. Velocity of water flow coming out of the pipe needs to be evaluated for two cases A and B. Case A : when the pipe is left as it is, Case B : when the end of the pipe is pinched at the end so that the diameter at the exit is $D_c = 20$ mm. Assume that the tank is very wide and has a constant head $H = 10$ m.

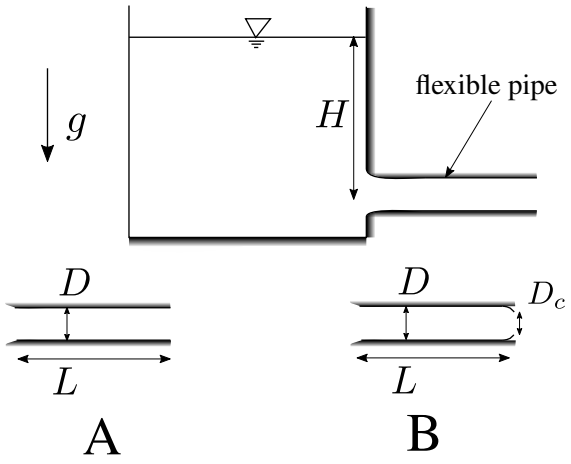


Figure 6: *Pinching of a flexible pipe*

(a) Assuming ideal flow with no losses, find the velocity of the water at the exit of the pipe for cases A and B

(b) Assume that the entry and exit losses in the pipe can be neglected but the friction losses need to be accounted for. Further, assume that the friction factor for both the cases is $f = 0.015$. Find the velocity of the water at the exit of the pipe for both cases A and B.

(c) For case A alone, use Moody's diagram to refine the estimate obtained in the above part.

11. Oil with density $\rho = 950\ \mathrm{kg/m^3}$ and $\nu = 2 \times 10^{-5}\ \mathrm{m^2/s}$ flows through a 30 cm diameter pipe 100 m long with a friction head loss of 8 m. The roughness ratio is $\epsilon/d = 0.0002$. Find the average velocity and flow rate.