AML2020/APL107/APL106 (2026-2027-I): Quiz-5

Department of Applied Mechanics, IIT Delhi

November 13, 2026

Maximum score is 40. There are 2 questions in total. Time limit is 60 minutes. Clearly write all your assumptions and steps. No marks will be given for correct answers without any steps.

1. We may simulate potential flow of speed U_∞ past a two-dimensional ridge or bump of height $a/2$ by using a streamline that passes above the potential flow over a cylinder as shown below.

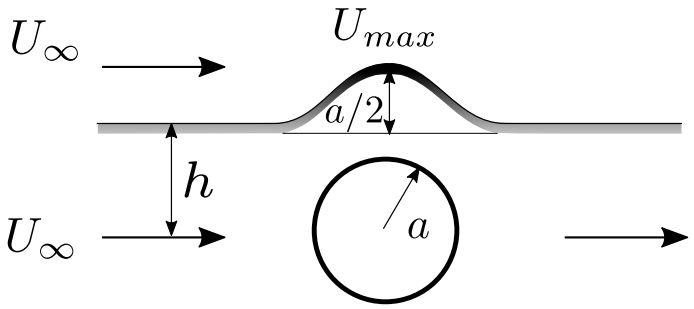


Figure 1: Potential flow past a bump

   (a) Write the streamfunction ψ and velocity potential ϕ for potential flow past a cylinder of radius a in polar coordinates. **(2)**

   (b) Using ψ, calculate the height h corresponding to the streamline which has a deflection of $a/2$ due to the cylinder. **(8)**

   (c) Assuming the streamline of the above part (b) as a solid surface with the desired bump, calculate the maximum velocity U_{max} at the top of the bump. **(5)**

   (d) Calculate the pressure distribution and the pressure coefficient $c_p = \dfrac{(p - p_\infty)}{\frac{1}{2}\rho U_\infty^2}$ over the bump. **(5)**

2. For a flat plate laminar boundary layer, assuming $\dfrac{u}{U_\infty} = a + b\eta + c\eta^2$ for $\eta = \dfrac{y}{\delta(x)}$.

   (a) Write three boundary conditions for u with $\delta(x)$ being the boundary layer thickness. **(3)**

   (b) Compute the momentum thickness Θ and the displacement thickness δ^*. **(3)**

   (c) Using the boundary layer equation, derive the Von-Karmann momentum integral equation. **(5)**

   (d) Substitute the quadratic relation in the momentum integral and compute $\dfrac{\delta}{x}$. **(5)**

   (e) Derive the skin-friction relation $c_f(x)$ and the drag coefficient assuming a plate of length L and width b. **(4)**