Practice problems:

Find the hydrodynamic boundary layer thickness (δ), thermal boundary layer thickness (δ_T), wall share stress (τ) and heat transfer coefficient for the following cases. Use any solution technique (Order of magnitude, Integral approach, Similarity solutions or any other technique that you think appropriate)

1. When the flat plate is heated at different sections with uniform temperature difference as presented in the figure 1.

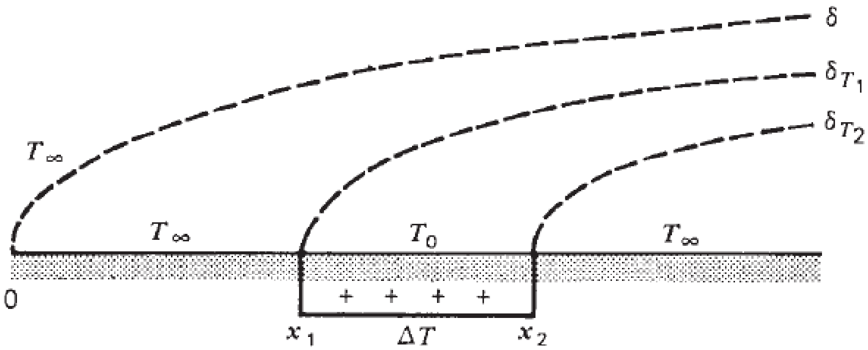


Figure 1. Arbitrary wall temperature

2. The flat plate is heated with a uniform heat flux as presented in figure 2.

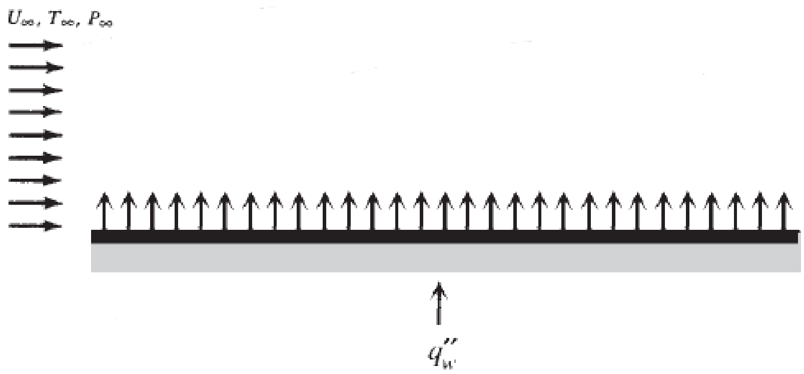


Figure 2. Uniform heat flux

3. A hot flat plate with uniform temperature T_0 $(> T_\infty)$ is placed in a stream of uniform pressure gradient.

Hint: Assume $U_\infty(\mathrm{x}) = \mathrm{Cx}^m$

4. Fluid is flowing into or out of the wall surface.

Hint: The wall surface will have normal velocity $v_0(x)$. That can be positive or negative depending on the situation.

Positive v_0 values indicate blowing, that is, the injection of fluid (the same fluid type as in the free stream) from the wall into the boundary layer. Negative v_0 values represent suction, the removal of some of the boundary layer fluid by forcing it to flow through the porous surface of the wall.

5. The flat plate in is an isothermal wall (with T0 temperature) and coated with a layer of solid material of thermal conductivity kw. The layer thickness may be nonuniform, t(x); however, it is sufficiently smaller than the wall length L so that the effect of longitudinal conduction through this layer can be neglected.

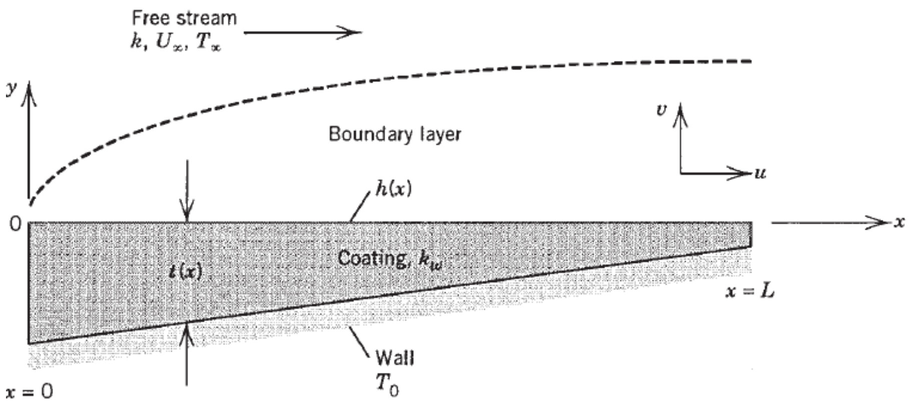
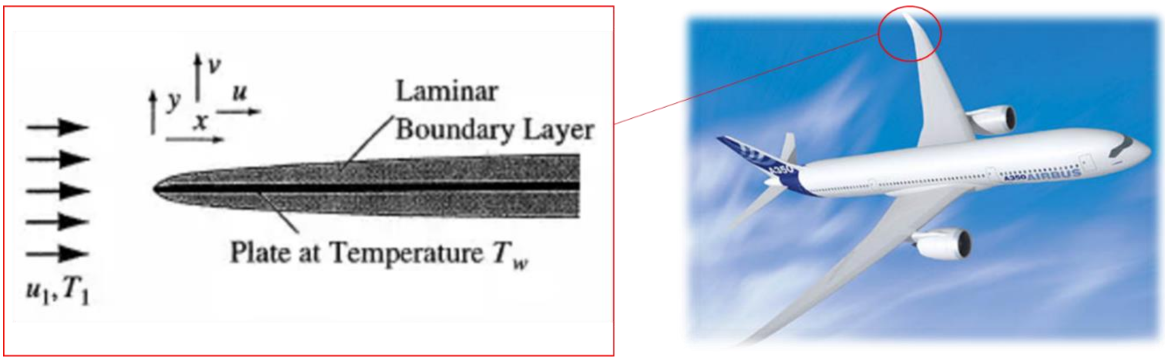


Figure 3. Laminar boundary layer flow over an isothermal wall coated with a solid of variable thickness.

6. Consider the flow of air which has a free stream temperature of O°C over the Airplane wing as that is kept at a temperature (T_w) of 30°C shown in Figure. If the flow in the boundary layer can be assumed to be laminar, determine how the temperature of the wing surface varies with Mach number. If the Mach number is 0.9, find whether heat is being transferred to or from the plate. Assume $Pr=0.7$, $\gamma=1.4$ for air.



Hint: Do not neglect dissipation effect.

The solution over a flat plate kept at a uniform temperature [Let, $\theta_T(\eta)$] when dissipation is accounted for will be a linear combination of the solution of $\theta(\eta)$ and $\theta_a(\eta)$, where $\theta(\eta)$ is the solution of temperature distribution in flow over a plate kept at a uniform temperature when there is no dissipation effect and $\theta_a(\eta)$ is the solution of temperature distribution in flow over an adiabatic plate accounting for dissipation effect.

Follow similar strategy that is used to solve $\theta_a(\eta)$, *where*

$$\theta_T(\eta)=\frac{T-T_1}{u_1^2/2c_p} \; and \;\; \eta=\frac{y}{\sqrt{\nu x/u_1}}$$