Unified Engineering Fall 2007
Fluids Problem F19+F20

A wall with air flowing over it has a shallow $\sin^2$ bump of length l and max height h: $Y(x) = h\,\sin^2(\pi x/l)$, with $h \ll \ell$.

a) Determine the wall curvature κ at the center of the bump, and the resulting normal pressure gradient $\partial p/\partial n$ over the center of the bump.

b) Assume that the normal pressure gradient extends some height Δn into the flow. What is the resulting overpressure $\Delta p \equiv p - p_\infty$ at the center of the bump? Specify the sign of Δp. Make a sketch of $p(n)$ showing Δp, Δn, and $\partial p/\partial n$ at the wall.

c) Experiments indicate that $\Delta p \simeq -10 q_\infty\, h/l$. How must Δn relate to the bump geometry? (i.e. what determines how far does the bump's pressure disturbance reaches into the flow?)

d) Glider wings are known to require extreme smoothness (or small waviness) for low drag. One rule of thumb is that a tolerable bump on the surface must have $\Delta C_p < 0.01$ (in magnitude). What is the maximum tolerable height of a 10 cm – long bump? Express in millimeters.