**Lecture F3 Mud: Aerodynamic Forces and Moments**
(36 respondents)

1. **What exactly is the angle of attack?** (1 student)
It's the angle between the freestream direction and the body's reference line. The freestream direction is defined to be parallel to $\vec{V}_\infty$. The body reference line is arbitrary, but on an airfoil it's traditionally chosen to be the chord line, which connects the leading edge and trailing edge points.

2. **How do you generate a pressure distribution?** (1 student)
There are a number of analytical and numerical methods for computing the pressures on a given airfoil shape. We will cover a few of these in Unified.

3. **In the integral for the lift: $L' = \int (p_l - p_u) dx$ don't you need to consider the shape of the airfoil?** (1 student)
If we neglect $\tau$, the exact formula for the normal force is $N' = \int (p_l - p_u) dx$, which doesn't depend on the shape $y(x)$ at all. The key substitution is $ds \cos\theta = dx$ (see notes and Anderson for more details). A physical explanation is that pressure acts only on the "projected" area $dx$, and the vertical height of the airfoil doesn't matter. All this applies to $N'$. Assuming $L' \simeq N'$ requires further assuming that $\alpha \ll 1$.

4. **How can $\tau$ be "very small", but still not negligible?** (1 student)
It depends on which force component we are after. If we're computing $L'$ and $M'$, then $\tau$ can be neglected, since $p$ contributes vastly more by comparison. But if we're computing $D'$ on a streamlined shape like an airfoil, then $\tau$ cannot be neglected. This is because on such shapes the integration of $p$ mostly cancels (the $p$ integrand is positive on some parts of the airfoil, and negative on other parts). So the remaining $\tau$ contribution is quite significant.

5. **Confused about moment subscripts and sign convention?** (7 students)
The subscript on the moment in the lecture indicated where the reference point of that moment was. So $M'_{\text{LE}}$ is about the leading edge ($x = 0$), $M'_x$ is about some arbitrary $x$ location, $M_{\text{cp}}$ is about the center of pressure (where $M_{\text{cp}} = 0$ by definition), etc.

   Positive $M'$ is defined to be nose-up. On a large majority of airfoils, the moment about the quarter-chord $x = c/4$ happens to be negative, or nose-down.

6. **Are $L'$, $D'$, $M'$, more useful than $L$, $D$, $M$ ?** (1 student)
In 2-D situations, yes. A quantity like $L$ requires knowing the out-of-plane span of the airfoil, which is undefined or irrelevant in 2-D. When we are computing $L'$, the span never comes up, so it's the more natural measure of lift in 2-D. Ditto for $D'$, $M'$, etc.

7. **What are the limits of the $M'$ integral?** (1 student)
We can integrate in $x$, like in the examples in class, in which case the limits are $0 \ldots c$. Or we can integrate along the arc length, in which case the limits are $0 \ldots s_{\text{max}}$, done separately for the upper and lower sides. Same result either way.

8. **How do you know which moment reference point to use?** (1 student)
The choice is arbitrary, and you will get correct results from aero analyses regardless

of the choice. But some locations make the analysis job easier than other locations. The best (simplest) choice for an airfoil is the quarter-chord location $x = c/4$. We'll see why later.

9. **Did the Wright Brothers know and use all the stuff we're learning?** (1 student)
   Yes and no. The had only a high school education, and no calculus. They understood forces and moments intuitively. They also understood that aerodynamic lift and drag depend on angle of attack, and are proportional to area $\times V_\infty^2$. So they could scale data from their wind tunnel tests and apply it to their airplanes. They didn't understand the effect of Reynolds number – slow small wings don't work quite as well as fast big wings – but this wasn't a big liability for their designs.

10. **How is all this stuff used in practice?** (1 student)
    Aerodynamic forces and moments directly affect airplane performance (speed, range, payload, etc.). They also affect flight behavior (stability, maneuverability, etc.). Being able to predict forces and moments, and to analyze force and moment data is an absolutely key part of designing aircraft. It also enters into spaceflight, such as the rocket launch phase, and vehicle re-entry. We're starting with the simplest 2-D geometry (an airfoil), and will work towards more complicated 3-D shapes, like wings.

11. **No mud** (16 students)