Cole Peters
AME 60635
27 August 2025
HW1 Part 2: Feynman Lectures Essay

In his lectures "The Flow of Dry Water" and "The Flow of Wet Water", Feynman derives the fundamentals of fluid mechanics from first principles and frames them in an intuitive manner. He describes inviscid water as *dry*, drawing on von Neumann's satire of hydrodynamics' early developers negligence of viscosity. While this critique is valid, as viscosity introduces loads of flow effects observed in reality that cannot simply be ignored, the desire to neglect it is compelling, as it brings with it loads of difficult math lacking simple solutions. Elegantly solved for and illustrated streamlines of potential flow are corrupted by turbulence, boundary layers, and shear stresses when viscosity is included.

A classic example of this discrepancy between *dry* and *wet* water solutions is flow around a long cylinder. Under the inviscid assumption, the flow moves neatly around the cylinder, trading pressure for speed as it moves around the bluff body. The case of the long cylinder is more greatly applicable than at first it may seem, because it indicates how any surface curved along the streamwise direction, whether cylindrical or elliptical, might behave when exposed to varying flow conditions. The curl of the velocity field is zero, and there is nothing present in the inviscid flow equations that allows for the induction of any curl into the flow. The streamlines converge neatly back into the freestream, and soon it as if the cylinder were never there. This solution holds true at any velocity or cylinder diameter (provided the incompressibility assumption still holds), with the only changes being the magnitude of change in pressure and velocity. When viscosity is introduced, however, the situation changes greatly. Now, the flow solutions are dependent on the Reynold's number ($\Re$) of the flow, with sudden changes in flow behavior becoming observable at different thresholds of $\Re$. Notably, vortices begin forming behind the cylinder, eventually devolving into vortex streets, then finally fully separating into a turbulent wake. Initially two-dimensional, the flow now has components in three dimensions, violently twisting and turning.

This variety of chaotic solutions stems from the introduction of shear stresses and a boundary layer in the flow. Feynman notes that, interestingly, there is nothing in the math to suggest that the velocity of a fluid should go to zero near a surface, yet it happens in every observable case. Similarly, the equations suggest that potential flow solutions should be valid as $\Re$ approaches ∞, as this should send the viscous term in the equations to zero. However, at a high $\Re$, the flow visualization shows that the solution does not look like the potential flow solutions, instead becoming more and more turbulent. These realities underscore one of Feynman's more panoramic claims in "Wet Water"; "the complexity of things can so easily and dramatically escape the simplicity of the equations which describe them". In both cases, experimental observation is needed to uncover the truth of the matter, and still there is little overarching generality to be uncovered. Dimensional analysis allows for scaling of solutions, but slight perturbations in initial conditions greatly perturb the final solution with which we are concerned.

The boundary layer and it's varying behavior in differing flow conditions provides a fantastic example of this phenomenon. This thin layer dictates drag forces and flow separation, which in turn have great impact on the heating rates, flow instabilities, and downstream behavior of the flow. Nearly all of the interesting behavior of the fluid occurs within or is caused by the relatively tiny layer near the surface in which velocity is forced to zero. What exactly occurs within that boundary layer and how it responds to changes in temperature, pressure, or surface morphology is extremely difficult to predict directly via math or computational simulation, and can be difficult to observe experimentally. Yet, these responses often dominate the utility of a given article in practical application.

Feynman understood the tension between the elegance of simple solutions and the complexity of reality, and he saw the beauty and utility in each. Indeed, the clean math and picturesque solutions of inviscid flow are pleasant, but they do not tell a complete story, or at least a realistic one. Feynman was far more excited by the complexity introduced by viscosity, however: "If such variety is possible in a simple equation with only one parameter, how much more is possible with more complex equations!". To "fully solve" the problem of *wet water* requires far greater understanding of these complexities than we have today.