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On a difficulty in eigenfunction expansion solutions for the start-up of fluid flow[1] IVAN C. CHRISTOV, Theoretical Division & Center for Nonlinear Studies, Los Alamos National Laboratory — Most mathematics and engineering textbooks describe the process of "subtracting off" the steady state of a linear parabolic partial differential equation as a technique for obtaining a boundary-value problem with homogeneous boundary conditions that can be solved by separation of variables (i.e., eigenfunction expansions). While this method produces the correct solution for the start-up of the flow of, e.g., a Newtonian fluid between parallel plates, it can lead to erroneous solutions to the corresponding problem for a class of non-Newtonian fluids. We show that the reason for this is the non-rigorous enforcement of the start-up condition in the textbook approach, which leads to a violation of the principle of causality. Nevertheless, these boundary-value problems can be solved correctly using eigenfunction expansions, and we present the formulation that makes this possible (in essence, an application of Duhamel's principle). The solutions obtained by this new approach are shown to agree identically with those obtained by using the Laplace transform in time only, a technique that enforces the proper start-up condition implicitly (hence, the same error cannot be committed).

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