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A direct forcing, immersed boundary method for flows with conjugate heat transport

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Motivated by applications to fluid flows with conjugate heat transfer and/or electrokinetic effects, we propose a direct forcing, immersed boundary, method for simulating general, discontinuous, Dirichlet and Robin conditions at the interface between two materials. The method is built on the concept of a "forcing pair," defined as two grid points that are adjacent to each other, but on opposite sides of an interface. For 2D problems, we show this approach can simultaneously enforce discontinuous Dirichlet and Robin conditions using a six-point stencil at one of the forcing points, and a 12-point stencil at the other. In comparison, prior work requires up to 14-point stencils at both points. We also propose two methods of accommodating surfaces with sharp corners. The first locally reduces stencils within sharp corners, while the second globally smooths all corners on a surface, in a manner that recovers the actual corners as the grid is refined. We verify second-order spatial accuracy of our proposed methods by comparing to manufactured solutions to the Poisson equation with challenging discontinuous fields across an immersed surface. We repeat the tests for the immersed surfaces shown in figure 1, which includes cases with sharp corners. We then couple our method to the incompressible Navier-Stokes and continuity equations using a finite-volume projection method. We verify the spatial-temporal accuracy of the solver using manufactured solutions, and then simulate fluid flow and conjugate heat transport between a stationary cylinder and a rotating square.

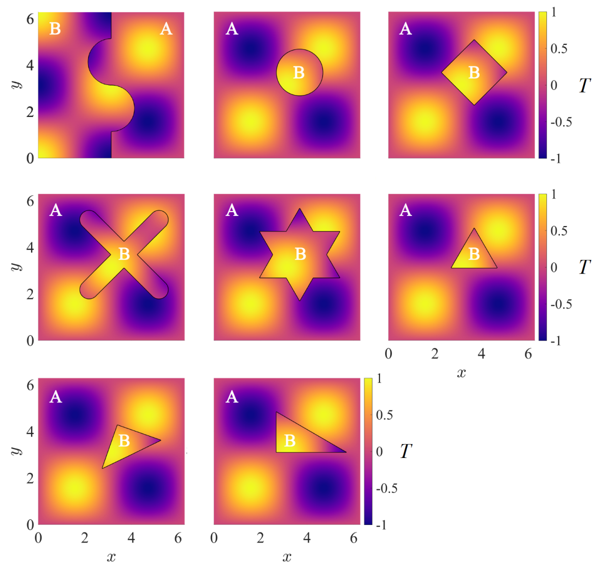

Figure 1: Eight geometries used to verify the method for the Poisson equation.

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