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Variational method is a promising way to study the kinetic behavior and storage potential of carbon dioxide (CO2) at the porous scale in the presence of other phases. The current study validates variational solutions for single and two-phase Newtonian flow through angular pores for special geometries whose analytical and/or empirical solutions are known. The hydraulic conductance for single phase flow through a triangular duct was also validated against empirical results. These results were validated against empirical results derived from lubricant theory. The variational method predicted flux and hydraulic conductance through the chosen geometries within 2-5% error with one parameter, and <2% error for two parameters in circular geometry ratio. The results of this study indicate that this technique can potentially be applied to non-Newtonian and multiphase flow, and flow domains with irregular geometries. This provides a powerful technique for pore-scale network modeling of carbon sequestration reservoir flow.