Regularized 13 Moment Equations for Maxwell and Hard Sphere molecules

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The regularized 13 moment equations of rarefied gas dynamics provide a stable set of macroscopic equations to approximate to the Boltzmann equation within the super-Burnett order. The transport coefficients in the equations depend on the molecular interaction model. To give insight into the origin of the equations, I will outline the derivation of the R13 equations for a monatomic hard sphere gas in the linear regime. The equations are based on an extended Grad-type moment system, which is systematically reduced by means of the Order of Magnitude Method [Struchtrup, Phys. Fluids 16(11), 3921-3934 (2004)]. The derivation of the appropriate boundary conditions from the relevant Grad distribution function will be outlined.

The resulting R13 equations include the linear Burnett and super-Burnett equations, which are obtained by Chapman-Enskog expansion. While the Burnett coefficients agree with literature values, this is the first time that super-Burnett coefficients are computed for a hard sphere gas.

To highlight the influence of the molecular interaction potential, some simple problems are considered for Maxwell molecules and the hard sphere gas, and differences are discussed.

Results for 2-D cavity flows for the non-linear Maxwell gas show intricate flow and heat flux patterns that are also observed in solutions of the Boltzmann equation, but unattainable with the laws of classical hydrodynamics (Navier-Stokes and Fourier laws).