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# Determination of relaxation times at weak and strong coupling

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Using linear response theory, we derive [1] conditions for the retarded Green's function so that the linearized equation of motion of a dissipative current is reduced to a relaxation-type equation of the Israel-Stewart type [2]. We prove that this reduction can be done, if the singularity of the retarded Green's function closest to the origin is a simple pole on the imaginary axis. The relaxation time coefficient is then given by the location of this pole in the complex plane. This implies that previous attempts to derive the relaxation time from the generic long-wavelength, low-frequency (i.e., fluid-dynamical) limit of the retarded Green's function, via an expansion in terms of gradients of the fluid-dynamical variables, in general fail to give the correct result.

For a dilute gas, this prescription gives a value for the shear relaxation time that, under certain simplifying assumptions, coincides with the one derived by matching relativistic fluid dynamics to kinetic theory [3]. This shows that transient fluid dynamics is determined by the slowest microscopic and not by the fastest fluid-dynamical time scale. This has important implications for the description of the collective motion of matter formed in ultrarelativistic heavy-ion collisions, where microscopic time scales and the lifetime of the system itself can be of the same order. We also prove that the long-wavelength dynamics of the shear stress tensor in a strongly coupled N=4 SYM plasma is not described by relaxation-type equations as in Israel-Stewart theory [2].

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