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Thermoelectric coefficients of a hot QCD medium in the limits of strong and weak magnetic field

We study the thermoelectric response of a thermal medium of deconfined quarks and gluons in the framework of relativistic kinetic theory. The response of the medium is quantified by the Seebeck and Nernst coefficients which relate the mutually longitudinal and transverse components, respectively, of the induced electric field and the temperature gradient. To obtain the above coefficients, we use the relativistic Boltzmann transport equation in the relaxation-time approximation, with interactions being incorporated via masses generated by thermal medium, extracted from one loop perturbative thermal QCD.

In the strong magnetic field regime ($|eB| \gg T^2$), thermal excitation of fermions to higher Landau levels is exponentially suppressed. As such, the lowest landau level (LLL) approximation becomes feasible which leads to fermion dynamics purely along the direction of the magnetic field, B (1-dimensional). Owing to this vanishing transverse motion, the Nernst coefficient vanishes.
In the weak magnetic field regime ($|eB| \ll T^2$), 2 prominent changes occur: 1) The fermion dynamics is no longer restricted which leads to non zero Nernst coefficient. Thus, the thermoelectric response becomes a 2×2 matrix with diagonal elements representing Seebeck coefficient and the off-diagonal elements, the Nernst coefficient. 2) The quasiparticle mass of the fermion evaluated using one-loop perturbation theory yields different masses for the left and right handed chiral quark modes, thereby lifting the degeneracy of the chiral modes.

The Seebeck coefficient of the medium (absolute values) is found to be a decreasing function of temperature (T) in both regimes of the magnetic field, B. However, its sign is negative in strong B and positive in weak B, suggesting that the direction of the induced electric field is flipped as $|B|$ decreases in the medium. The magnitudes in the weak $|B|$ regime are larger (~ 2 times) than that in strong $|B|$. Further, in the weak $|B|$ regime, the L-mode Seebeck coefficient elicits a larger response than the R-mode. The sensitivity of the Seebeck coefficient to changes in temperature is found to be comparatively enhanced in the strong $|B|$ limit. The Nernst coefficient is also a decreasing function of temperature with the L mode response being stronger than the R mode. It is zero in the LLL approximation (strong $|B|$ limit) as well as for $B = 0$. An interesting consequence of the non-degenerate chiral quark masses in the weak $|B|$ limit is that for certain values of T and B, the R-mode quasiquark mass comes out to be negative, which is unphysical. It is found that this happens in such a way so as to generate an upper bound for the ratio $|eB/T^2|$. For $|eB| = 0.2\, m_\pi^2$ and above, the condition $|eB|/T^2 \ll 1$ is thus enforced by the theory, consistent with the initial assumption.

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