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Sum Rules, Classical and Quantum – A Pedagogical Approach[1]

WILLIAM KARSTENS, Saint Michael's College, DAVID Y. SMITH, University of Vermont and Argonne National Laboratory — Sum rules in the form of integrals over the response of a system to an external probe provide general analytical tools for both experiment and theory. For example, the celebrated f-sum rule gives a system's plasma frequency as an integral over the optical-dipole absorption spectrum regardless of the specific spectral distribution. Moreover, this rule underlies Smakula's equation for the number density of absorbers in a sample in terms of the area under their absorption bands. Commonly such rules are derived from quantum-mechanical commutation relations, but many are fundamentally classical (independent of $\hbar$) and so can be derived from more transparent mechanical models. We have exploited this to illustrate the fundamental role of inertia in the case of optical sum rules. Similar considerations apply to sum rules in many other branches of physics. Thus, the "attenuation integral theorems" of ac circuit theory reflect the "inertial" effect of Lenz's Law in inductors or the potential energy "storage" in capacitors. These considerations are closely related to the fact that the real and imaginary parts of a response function cannot be specified independently, a result that is encapsulated in the Kramers-Kronig relations.

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