SOLVAY COLLOQUIUM

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Theory of liquids, fundamental bounds in condensed matter physics and fundamental physical constants

Theories of gases and solids are well developed and date back 100-150 years ago. In contrast, understanding most basic thermodynamic properties (eg energy and heat capacity) of the third state of matter - the liquid state - turned out to be a long-standing problem in physics [1]. Landau & Lifshitz textbook states that no general formulas can be derived for liquid thermodynamic functions because the interactions are both strong and system-specific. Phrased aptly by Pitaevskii, liquids have no small parameter.

Recent theoretical results open a new way to understand liquid thermodynamics on the basis of collective excitations (phonons) as is done in the solid state theory. Differently from solids, the number of phonons is variable in liquids and decreases with temperature [1,2]. This effect is quantified in a phonon theory of liquid thermodynamics and explains the universal decrease of liquid constant-volume specific heat with temperature. One implication of this theory is that liquids can now be consistently understood on par with solids and are no longer "Cinderella of Physics" as believed until recently [1]. I will also discuss how this picture extends above the critical point where the Frenkel line separates two physically distinct states on the supercritical phase diagram [3].

I will subsequently describe how this picture leads to the theory of minimal quantum viscosity in terms of fundamental physical constants including the Planck constant [4]. This answers the long-standing question discussed by Purcell and Weisskopf of why viscosity never drops below a certain value [5]. This also means that water and life and well attuned to the degree of quantumness of the physical world [5].

Our work on liquids stimulated recent findings that fundamental constants unexpectedly govern many other condensed matter properties: thermal conductivity, elasticity, speed of sound, thermal expansion and melting lines [6,7,8].

Understanding the origin of fundamental constants, the "barcodes of ultimate reality" [9], is viewed as one of grandest challenges in modern science [10]. However, the role of fundamental constants was discussed in high-energy particle physics and astrophysics only. I will suggest that deepening our understanding of how fundamental constants govern phenomena which continuously fill the range of length and energy scales that are between particle physics and astrophysics (eg condensed matter) prompts us to ask new questions about the origin of fundamental constants [11].

Tuesday 30 April 2024 at 4:00 P.M.

COFFEE AND TEA WILL BE SERVED AT 3:45 P.M IN FRONT OF THE SOLVAY ROOM

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