Pressure melting and regelation
The viscous drag on solids moving through solids

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Abstract

The early works of the Thomson brothers, James and William (Lord Kelvin), and of Michael Faraday mark the beginnings of a sustained scientific fascination with “regelation”, involving the pressure-induced thawing and refreezing of ice at solid boundaries. The Thompson theory of pressure melting has been invoked to explain phenomena as diverse as the mobility of glaciers and the reduction of sliding friction on ice skates. It is also the subject of well-known classroom experiment involving the passage of a solid wire through a block of ice, leaving scarcely a trace.

Nye [1], overlooking a previous work by Ornstein [2], presents an insightful and more general mathematical theory for the motion of a circular wire through ice, with rates controlled by a lubrication flow in a thin interfacial water layer and conduction of heat through wire, ice and water layer. He gives analytic solutions based on angular symmetry of the associated single-harmonic temperature fields, and his general theory predicts a sort of Stokes-law drag for the creeping motion of one solid body through another.

Numerous careful experiments [3] show agreement with the Nye theory in some cases but not in others, owing possibly to interesting physical phenomena such as freezing-front instability with “mushy zones”, or van der Waals forces in superficial layers of "premelted" water on ice postulated by Faraday. Both are the subjects of contemporary research.

After a brief review of basic theory and experiment, this talk discusses some recent work [4] showing that Nye’s theory admits other single-harmonic solutions for the translation and rotation of symmetrical bodies such as elliptic cylinders and spheroids, whenever the thermal resistance of the water layer is negligible. This work suggests a simpler regelation experiment involving measurement of the torque on slowly rotating elliptic cylinders in a stationary block of ice, which could shed light on some of the phenomena mentioned above