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Colloquium

Rigidity of solids: a thermodynamic origin story

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School textbooks tell us that the main difference between a solid and a liquid is the ability of the former to retain its shape. Any attempt at changing the shape of a solid is resisted by an internal elastic stress unless the deformation crosses a limiting value; at which point the solid fails. This naive viewpoint, although of great practical value, is, however, fundamentally incorrect. For example, one can argue that given enough time, atoms in the solid can always rearrange to eliminate stress no matter how much, or how little, the solid is deformed. Resolution of this paradoxical result lies at the core of our understanding of the behavior of solids under deformation.

Adapting ideas which were introduced recently to study glasses, we find that rigidity arises as a result of a hidden first-order phase transition between phases which differ in the way they respond to changes of shape [1]. When deformed by any amount, howsoever small, the rigid solid goes into a meta-stable state analogous to superheated water. Eventually, this meta-stable state always decays by nucleating bubbles of the stable, stress-free, solid by a process very similar to how bubbles of steam appear in a kettle of boiling water. This fresh conceptual viewpoint curiously allows us to study failure of perfect crystalline solids in quantitative detail without invoking specifics of many-body, defect–defect interactions, raising hope of a more unified description of materials in the future.

References:

[1] Nath et al. PNAS 115 E4322-E4329 (2018)

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4:00 PM (Tea/Coffee at 3:30 PM)

Auditorium, TIFR-H