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Critical phenomena and scaling: from bubble breakup to kirigami mechanics

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Critical phenomena in statistical physics are mathematically singular behaviors of physical quantities as a function of thermodynamic variable at a critical point. Near the critical point, the singular behaviors are characterized by scaling laws. Although the critical point is non-universal, the scaling exponents are universal for any materials (or models) if they are in the same universality class. Understanding of physical or mathematical mechanism for the emergence of universality was one of the central topics in physics in 1960's and, currently, is a highlight in the master course in physics.

P. G. de Gennes noticed a deep analogy of this thermodynamic problem with scaling that appears in polymer physics, after he understood a preprint written by K.G. Willson. As a result, two papers, one by Willson and the other by de Gennes were published on February 28, 1972. This day revolutionized physics, specifically, the history of statistical physics and that of polymer physics, at the same time, leading to two separate Nobel prizes in 1985 and 1991.

In the first part of the lecture, we give a brief overview on physical understanding of critical phenomena and its relation to polymer physics. In the second part, we give two more analogies with the thermodynamic problem [1]. One is associated with the dynamics of bubble breakup, a topological transition of the shape [2]. The other appears in a mechanical transition when kirigami, a paper with cuts of a certain pattern, is extended [3]. We hope the audience will enjoy analogy in physics, from the three examples, which are all seemingly quite different but share common features!

[1] 奥村　剛、「印象派物理学入門」、214 頁、日本評論社(2020 年)
[2] Hana Nakazato, Yuki Yamagishi, and Ko Okumura, Self-similar dynamics of air film entrained by a solid disk in confined space: A simple prototype of topological transitions, Phys. Rev. Fluids 3, 054004 (2018)
[3] Midori Isobe and Ko Okumura, Continuity and discontinuity of kirigami's high-extensibility transition: a statistical-physics viewpoint, Phys. Rev. Research 1, 022001(R)(2019)