

Topological Aspects of Insulators, Superconductors and Semimetals

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Abstract. Topology is a branch of mathematics that studies properties of objects invariant under smooth deformations. It allows to define topological invariant that characterizes objects that can be deformed into each other. Examples of such invariants include the winding of curves or the Euler index of two dimensional surfaces. In the context of condensed matter, topology allows to characterizes robust properties of vector fields. The first example includes the description of defects of an order parameter fields : vortices, dislocations, disclinations, etc. More recently, topology has been used to describe the properties of an ensemble of abstract vectors describing the quantum states of particles in a gapped phase, or a semi-metallic phase. In these examples, the vectors belong to a Hilbert space, and are parametrized by a quasi-momentum belonging to the first Brillouin zone. These ensemble of vectors define the ground state of the phase we consider. In these lectures I will describe the basic idea being the topological characterization of these vectors fields. I will then discuss the manifestation of these topological properties as edge or surface states. I will give a particular emphasis on superconductors, building on the other lectures of the school by M. Houzet for the fundamental aspects. I will also describe the properties of semi-metallic phases, which can be viewed as topological defects of these vector fields, but in the Brillouin zone. The practical session will be devoted to the study of simple models and the numerical determination of their topological property.

There already exists several good review articles and books on topological properties of phases, listed below. The book by A. Bernevig is particularly recommended.

References

- [1] B. A. Bernevig with T. L. Hughes, *Topological Insulators and Topological Superconductors* (Princeton University Press, Princeton, NJ, 2013)
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