Topological objects in Physics

Proseminar FS14

Philippe de Forcrand

Available topics (B/M for Bachelor/Master level)

1-A) (B) Homotopy theory
1-B) (B) Lie algebras

2-A) (B) Solitons in KdV equation
2-B) (B) Kinks in ϕ^4 and in Sine-Gordon theory

3-A) (B) Spontaneous symmetry breaking, Goldstone theorem
3-B) (B) Bose condensation ($U(1)$ breaking)

4-A) (B) Vortices: superfluidity
4-B) (B^+) BKT transition

5-A) (B) Vortices in fluid dynamics
5-B) (B^+) Cosmic strings and Kibble mechanism

6-A) (B) Aharonov-Bohm effect
6-B) (B) Berry phase

7-A) (B^+) Graphene and "emergent spin" (Berry phase)
7-B) (B^+) Hofstadter's butterfly

8-A) (B) Dislocations in crystal – melting
8-B) (M) Skyrmions: Adkins-Nappi-Witten and phenomenology

9-A) (M) U(1) monopoles: Dirac and Wu-Yang
9-B) (M) Yang-Mills theory

10-A) (M) 't Hooft-Polyakov and BPS monopoles
10-B) (M) Instantons

11-A) (M) Theta-vacuum – Haldane conjecture
11-B) (M) Higgs mechanism ($T = 0$)

12-A) (M) Higgs mechanism ($T > 0$) – baryogenesis
12-B) (B^+) Braid groups in Quantum Mechanics

13-A) (M) Topological quantum computing: theory
13-B) (M) Topological quantum computing: practice

Some references

- 1-A) (B) Homotopy theory
  Actor, Rev. Mod. Phys. 51, 461 (1979), App. I; Kenna: cond-mat/0602459
- 1-B) (B) Lie algebras
  Prosem. Ch. 1; Georgi *Lie algebras in particle physics*
- 2-A) (B) Solitons in KdV equation
  Eilenberger, *Solitons*, Ch. 2; young.physics.ucsc.edu/250/mathematica/soliton.nb.pdf
- 2-B) (B) Kinks in ϕ^4 and in Sine-Gordon theory
  Eilenberger, *Solitons*, Chs. 5&6; Coleman, *The use of instantons*, Secs. 1&2
- 3-A) (B) Spontaneous symmetry breaking, Goldstone theorem
  Prosem. Ch. 2; Ryder, *Quantum field theory*, Sec. 8.2
- 3-B) (B) Bose condensation ($U(1)$ breaking)
  MOKA Secs. 4.1-4.2; Kapusta & Gale, *Finite-T field theory*, Secs. 2.1-2.4;
  Cohen-Tannoudji, *BEC: An Introduction*
- 4-A) (B) Vortices: superfluidity
  Prosem. Ch. 12
- 4-B) (B^+) BKT transition
  Prosem. Ch. 8; Kenna: cond-mat/0602459
- 5-A) (B) Vortices in fluid dynamics
  Acheson, *Elementary fluid dynamics*, Ch. 5
- 5-B) (B^+) Cosmic strings and Kibble mechanism
  Kolb & Turner, *The early universe*, Ch. 7; hep-ph/9411342
- 6-A) (B) Aharonov-Bohm effect
  Prosem. Chs. 9-11
- 6-B) (B) Berry phase
  Prosem. Chs. 9-11
- 7-A) (B^+) Graphene and "emergent spin" (Berry phase)
  G. Semenoff, Phys. Rev. Lett. 53 (1984) 2449; arXiv:1308.3672; arXiv:1309.6714
- 7-B) (B^+) Hofstadter's butterfly
  Phys. Rev. B 14 (1976) 2239; Phys. Rev. B 65 (2002) 045310
- 8-A) (B) Dislocations in crystal – melting
  Prosem. Ch. 4
- 8-B) (M) Skyrmions: Adkins-Nappi-Witten and phenomenology
  Adkins et al., Nucl. Phys. B228 (1983) 552; hep-ph/9907554
- 9-A) (M) U(1) monopoles: Dirac and Wu-Yang
  Ryder, *Quantum field theory*, Sec. 10.3; Prosem. Ch. 3
- 9-B) (M) Yang-Mills theory

Peskin & Schröder, Chs. 15-16

- 10-A) (M) 't Hooft-Polyakov and BPS monopoles
  Ryder, *Quantum field theory*, Sec. 10.4; Prosem. Ch. 3
- 10-B) (M) Instantons
  't Hooft, hep-th/0010225, Sec. 4; Coleman, *The use of instantons*, Secs. 3-6
- 11-A) (M) Theta-vacuum – Haldane conjecture
  Coleman, *The use of instantons*, Secs. 3-6; Haldane, Phys. Rev. Lett. 50 (1983) 1153; arXiv:1204.4913
- 11-B) (M) Higgs mechanism ($T = 0$)
  Peskin & Schröder, Ch. 20; Prosem. Ch. 2
- 12-A) (M) Higgs mechanism ($T > 0$) – baryogenesis
  Kolb & Turner, *The early universe*, Ch. 6; hep-ph/9809291
- 12-B) (B^+) Braid groups in Quantum Mechanics
  Prosem. Ch. 16
- 13-A) (M) Topological quantum computing: theory
  Prosem. Chs. 13-15
- 13-B) (M) Topological quantum computing: practice
  Prosem. Chs. 13-15

MOKA:
Click on chapters at: theory.physics.helsinki.fi/ moka

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