Theoretical Seminar:

Statistical Physics

Sommersemester 2023

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Dates and structure

- **Time: Fridays 9.15 - 11.00, Start: Fr 21. April 2023**
  Venue: SR 106, 1st floor, Philosophenweg 12, 69120 Heidelberg; in-person, no online participation.
- **Prerequisites: Lectures on Quantum Mechanics, and**
  Statistical Physics (MKTP1; can be attended in the same semester). Seminar language is English.
- **Distribution of topics: In the 1st seminar on April 21 the talks will be assigned. The first 3 talks will be distributed in advance.**
- **Tutors: Maurice Larsson, maurice.larsson@stud.uni-heidelberg.de**
- **Alessandro Rizzi, alessandro.rizzi@stud.uni-heidelberg.de**
- **Prepare test talk ≥ 1 week before the seminar with a colleague (or tutor).**
- **max. 60 min talk (beamer plus blackboard; max 40 slides) + about 15- 30 min discussion.**
- **pdf of slides to be submitted to GW ~1 week after the talk; appears on seminar page.**
- **LaTeX/ pdf extended summary for each talk ≈ 10-20pp, with references to the original papers (and also advanced textbooks). To be submitted ~1 week after the talk to GW; will be published on seminar page.**
- **6 ECTS-Credit points for oral presentation, pdf of slides, written pdf summary, participation in discussions.**
- **Participation is mandatory, please send advance email to GW if not attending.**

List of topics

1) 28.04. Topological phase transitions (BKT): Jakob Steck / Tutor Alessandro Rizzi (AR)

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_1.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_1s.pdf

(please copy into your browser)

2) 05.05. One- and two-dimensional Ising model: Thanush Sivagnanalingam /Tutor Maurice Larsson (ML)

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_2.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_2s.pdf

(12.05. no seminar)

3) 19.05.23 Phase transitions and critical phenomena: Colin Kühne / ML

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_3.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_3s.pdf

4) 26.05. Boltzmann equation and H-Theorem: Romain Chazotte / AR

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_4.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_4s.pdf

5) 02.06. Master equation, Markovian and non-Markovian processes: Sophia Vent / ML

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_5.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_5s.pdf

6) 09.06. Langevin- and Fokker-Planck equation: Gerrit Gerhartz / AR

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_6.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_6s.pdf

7) 16.06. Physical basis for the direction of time: Mateo Cárdenes Wuttig/ ML

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_7.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_7s.pdf

8) 23.06. Thermalization of gluons in relativistic collisions: Julian Rössler / AR

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_8.pptx
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_8s.pdf

9) 30.06. Pattern formation and self-organization in nature: Johannes Jung / ML

slides: www.thphys.uni-heidelberg.de/~wolschin/statsem23_9.pdf
summary: www.thphys.uni-heidelberg.de/~wolschin/statsem23_9s.pdf

General literature

Textbooks

Kerson Huang, Statistical Mechanics, 2nd edition Wiley (2008).

Leo P. Kadanoff, Statistical Physics: Statics, Dynamics and Renormalization,
World Scientific, Singapore (2000).

Lev Pitaevskii and Sandro Stringari, Bose-Einstein Condensation and Superfluidity,
International series of monographs on physics, Oxford University Press (2016).

Subir Sachdev, Quantum Phase Transitions, 2nd edition, Cambridge Univ. Press (2011).

John Cardy, Scaling and Renormalization in Statistical Physics, Cambridge Univ. Press (1996).

Nick Proukakis et al.: Quantum gases - finite temperature and non-equilibrium dynamics,
Vol. I, World Scientific, Singapore (2013).

Hannes Risken, The Fokker-Planck equation, methods of solution and applications, 3rd edition Springer (1996).

Nico G. Van Kampen, Stochastic Processes in Physics and Chemistry, 3rd edition, Elsevier (2007).

Steward Harris, An introduction to the theory of the Boltzmann equation, Dover (2004).

Topic-oriented literature: Original articles (selection); specific books

1) BKT

J.M. Kosterlitz and D.J. Thouless, Ordering, metastability and phase transitions in two-dimensional systems, J. Phys. C: Solid State Phys. 6, 1181 (1973).
Z. Hadzibabic et al., Berezinskii-Kosterlitz-Thouless Crossover in a Trapped Atomic Gas. In: Nature 441, 1118 (2006).
J.M. Kosterlitz, Kosterlitz-Thouless physics: a review of key issues. In: Rep. Prog. Phys. 79, 026001 (2016).

2) Ising model

E. Ising, Beitrag zur Theorie des Ferromagnetismus, Z. Physik 31, 253 (1925).
https://link.springer.com/article/10.1007/BF02980577
R. Peierls, Ising's model of ferromagnetism, Proc. Cambridge Phil. Soc., Band 32, 477 (1936).
T.D. Schultz, E. Lieb, D.C. Mattis, Two dimensional Ising model as a soluble model of many fermions, Rev. Mod. Phys. 36, 856 (1964).
S.G. Brush, History of the Lenz-Ising model, Rev. Mod. Phys. 39, 883 (1967).

3) Phase transitions and critical phenomena

H.E. Stanley, Introduction to Phase Transitions and Critical Phenomena, Oxford University Press (1971).
M.E. Fisher, The renormalization group in the theory of critical behavior, Rev. Mod. Phys. 46, 597 (1974).
P. Papon et al.,The physics of phase transitions – concepts and applications, Springer, Berlin (2006).

4) Boltzmann equation and H-Theorem

L. Boltzmann, Weitere Studien über das Wärmegleichgewicht unter Gasmolekülen, Sitzber. Akademie der Wiss. 66, 275 (1872).
English translation: L. Boltzmann, *Further Studies on the Thermal Equilibrium of Gas Molecules. The Kinetic Theory of Gases. History of Modern Physical Sciences. 1, 262 (203), doi 10.1142/9781848161337_0015. See book by E. Harris for a modern derivation.*
G.B. Lesovik, A.V. Lebedev, I.A. Sadovskyy, M.V. Suslov, and V.M. Vinokur, H-theorem in quantum physics, Sci. Reports, 6, 32815 (2016), doi:10.1038/srep32815.

5) Master equation, Markov processes

W. Pauli, Über das H-Theorem vom Anwachsen der Entropie vom Standpunkt der neuen Quantenmechanik, In: Probleme der modernen Physik, Arnold Sommerfeld zum 60. Geburtstag, Hirzel, Leipzig (1928).
N. G. van Kampen (1981). Stochastic processes in physics and chemistry. North Holland. ISBN 978-0-444-52965-7.
C.W. Gardiner (1985). Handbook of Stochastic Methods. Springer. ISBN 978-3-540-20882-2.
J. Honerkamp (1998). Statistical physics : an advanced approach with applications ; with 7 tables and 57 problems with solutions. Berlin [u.a.]: Springer. p. 173. ISBN 978-3-540-63978-7

6) Langevin eq., Fokker Planck eq.

A. Einstein, Zur Theorie der Brownschen Bewegung, Ann. Physik 19, 371 (1906).
M. von Smoluchowski, Zur kinetischen Theorie der Brownschen Molekularbewegung und der Suspensionen, Ann. Physik 326, 756 (1906).
P. Langevin, Sur la théorie du mouvement brownien, C. R. Acad. Sci. (Paris) 146, 530 (1908).
A.D. Fokker, Die mittlere Energie rotierender elektrischer Dipole im Strahlungsfeld, Ann. Physik 43, 812 (1914).
M. Planck, Über einen Satz der statistischen Dynamik und seine Erweiterung in der Quantentheorie, Sitzber. Preuss. Akad. Wiss., 324 (1917).
A.N. Kolmogorov, Über die analytischen Methoden in der Wahrscheinlichkeitsrechnung, Math. Ann. 104, 415 (1931).

7) Physical basis for the direction of time

H. D. Zeh, The Physical Basis of The Direction of Time, Springer Heidelberg Berlin (2007).
S. Carroll, and J. Chen, Spontaneous Inflation and the Origin of the Arrow of Time. arXiv: 0410270 [hep-th] (2014).
D. Lazarovici and P. Reichert, Arrow(s) of Time without a Past Hypothesis, http://philsci-archive.pitt.edu/17468/ (2020).

8) Thermalization of gluons in relativistic collisions

J.-P. Blaizot, F. Gelis , J. Liao, L. McLerran, and R. Venugopalan, Bose–Einstein Condensation and Thermalization of the Quark Gluon Plasma, Nucl. Phys. A 873, 68 (2012).
J.-P. Blaizot, J. Liao and Yacine Mehtar-Tani, The subtle interplay of elastic and inelastic collisions in the thermalization of the quark–gluon plasma, Nucl. Phys. 956, 561 (2016).
G. Wolschin, Equilibration in finite Bose systems, Physica A 499, 1 (2018);
G. Wolschin, Nonlinear diffusion of gluons, Physica A 597, 127299 (2022); Aspects of relativistic heavy-ion collisions, Universe 6, 61 (2020).

[9) Evaporative cooling and thermalization of bosonic cold quantum gases

O. J. Luiten, M.W. Reynolds, and J.T.M. Walraven, Kinetic theory of the evaporative cooling of a trapped gas, Phys. Rev. A53, 381 (1996).
K. B. Davis and M.-O. Mewes and W. Ketterle, An analytical model for evaporative cooling of atoms, Appl. Phys. B 60, 155 (1995).
G. Wolschin, Time-dependent entropy of a cooling Bose gas, EPL 129, 40006 (2020).] ((talk skipped))

9) Pattern formation and self-organization in nature

Prigogine, I.; Nicolis, G. Hazewinkel, M.; Jurkovich, R.; Paelinck, J. H. P. (eds.), Self-Organisation in Nonequilibrium Systems: Towards A Dynamics of Complexity, *Bifurcation Analysis: Principles, Applications and Synthesis*, Springer Netherlands, pp. 3–12, doi:10.1007/978-94-009-6239-2_1, ISBN 9789400962392 (1985).
D. Walgraef, Spatio-temporal pattern formation, Springer, Heidelberg-Berlin-New York (1996).
S. Kondo, T. Miura, Reaction-Diffusion Model as a Framework for Understanding Biological Pattern Formation, Science 329, Issue 5999, pp. 1616-1620 DOI: 10.1126/science.1179047 (2010).

More detailed literature via tutor (if available), or GW.