PHYSICS 6555 — ADVANCED SOLID STATE PHYSICS 1
Syllabus — Fall 2024, CRN 90491

Instructor:	Uwe C. Täuber
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Office hours:	Monday, Friday, 1.15 – 2.15 p.m., or by appointment.

Lectures:	Tuesday, Thursday, 9.30 – 10.45 a.m., Robeson 116.
Homework:	Weekly homework problems will be assigned (60 % of final grade).
Final exam:	Oral exam (will count 40 % for the final grade).
Prerequisite:	PHYS 5455, 5456, 5705 – Quantum and Statistical Mechanics; instructor's consent.

Literature: The lectures will draw from original papers and several texts, e.g.:

P.M. Chaikin and T. Lubensky, *Principles of condensed matter physics* (Cambridge, 1995)

C. Kittel, *Quantum theory of solids* (Wiley, 1963)

J.W. Negele and J. Orland, *Quantum many-particle systems* (Addison-Wesley, 1988)

D.R. Nelson, *Defects and geometry in condensed matter physics* (Cambridge, 2002)

P. Phillips, *Advanced solid state physics* (Westview, 2002)

S. Sachdev, *Quantum phase transitions* (Cambridge, 2nd ed. 2011)

F. Schwabl, *Advanced quantum mechanics* (Springer, 4th ed. 2008)

U.C. Täuber, *Critical dynamics* (Cambridge, 2014)

P.L. Taylor and O. Heinonen, *A quantum approach to condensed matter physics* (Cambridge, 2002)

Topics: Fall 2024 (PHYS 6555):

1. *Interacting bosons*
   - 1.1. Fock space, free boson thermodynamics
   - 1.2. Bosonic quasiparticles: phonons
   - 1.3. Spin waves (magnons)
   - 1.4. Boson coherent states
   - 1.5. Coherent-state path integral representation
   - 1.6. Perturbation expansion

2. *Superfluidity*
 2.1. Bose–Einstein condensation
 2.2. Ginzburg–Landau theory, superfluid hydrodynamics
 2.3. Vortices
 2.4. Dilute Bose gases: Gaussian correlations, quasi-particles
 2.5. Condensate depletion, superfluid density
 2.6. Superfluid helium 4, path-integral Monte Carlo simulations

3. *Critical phenomena and the renormalization group*
 3.1. Ginzburg–Landau functional
 3.2. Gaussian approximation
 3.3. General Gaussian correlations; spherical limit
 3.4. Wilson's momentum shell renormalization group
 3.5. Perturbation theory and ϵ expansion
 3.6. Crossovers, anisotropies, finite-size scaling

4. *Goldstone modes, critical dynamics, quantum phase transitions*
 4.1. Goldstone modes, coexistence singularities
 4.2. Non-linear sigma model
 4.3. 2d XY model: Berezinskii–Kosterlitz–Thouless transition
 4.4. Critical dynamics: relaxational kinetics
 4.5. Critical dynamics with reversible mode couplings
 4.6. Quantum phase transitions

Spring or Fall 2025 (PHYS 6556):
5. *Interacting fermions*
6. *Superconductivity*
7. *Localization and the Quantum Hall Effects*
8. *Linear Response*