**PHYSICS 7560 WINTER 2013**

**“Structure, Order, and Phase Transitions in Condensed Matter Physics”**

Instructor: P.H. Keyes, 239 Physics Research Bldg., tel. 577-2606 , [keyes@wayne.edu](mailto:keyes@wayne.edu)

Office Hours: Mon 3 - 4 p.m., Thur. 2 - 3 p.m., and by appointment.

Text: *Principles of Condensed Matter Physics,* P.M. Chaikin & T.C. Lubensky, Cambridge University Press 1995 and subsequent reprintings with corrections.

Mid-Term Exam: Friday, March 8.

Final Exam: 8:00 a.m. – 10:30 a.m., Tues., April 30.

Grading: mid-term exam 15%, final exam 30%, homework exercises 20%, term paper 20%, participation 15%.

(Approximate) Course Schedule:

Week 1: 1/7 - 1/11 Overview , Chaps. 1 & 2

Week 2: 1/14 – 1/18 Chap. 2

Week 3: 1/23 – 1/25 Chap.2

Week 4: 1/28 – 2/1 Chap. 2

Week 5: 2/4 - 2/8 Chaps. 3 & 4

Week 6: 2/11 – 2/15 Chap. 4

Week 7: 2/18 – 2/22 Chap. 4

Week 8: 2/25 – 3/1 Chaps. 4 & 5

Week 9: 3/4 - 3/6 Chap.5; **3/8 MID-TERM EXAM**

Week 10: 3/18 – 3/22 Chap. 5

Week 11: 3/25 – 3/29 Chaps. 5 & 6

Week 12: 4/1 – 4/5 Chap. 6

Week 13: 4/8 – 4/12 Chaps. 6 & 9

Week 14: 4/15 – 4/19 Chap. 9

4/22 Summary

**4/30 FINAL EXAM**

# Structure, Order, and Phase Transitions in Condensed Matter Physics

Structure and Order:

* Overview: gas, liquid, and solid; short-range and long-range order; symmetry; defects; fluctuations
* Crystal Structure: structures for the elements, compounds, molecular crystals, perovskites
* Disorder: liquids, amorphous solids, glasses, orientational disorder in molecular crystals
* Order Mixed with Disorder: liquid crystals
* Symmetries of Crystal Structures: lattices, unit cell, basis, point groups, space groups, quasi-crystals, incommensurate structures
* Scattering: x-rays, neutrons, electrons, and light; diffraction; Bragg’s law; the reciprocal lattice; effects of symmetry; magnetic structures; diffraction from non-crystalline materials and from fluctuations, the phase problem
* Macroscopic Properties and their Relation to Symmetry: tensors of different ranks, stress, strain, dielectrical properties, piezoelectricity, elasticity

Phase Transitions:

* Review of Thermodynamics and Statistical Mechanics: the three laws of thermodynamics, equations of state, thermodynamic potentials, derivatives, equipartition theorem, partition function, phase transition thermodynamics
* The Order Parameter: symmetry breaking, discrete and continuous symmetries
* Models: the Ising model, n-vector models, Bragg-Williams mean-field theory
* Landau Theory of Phase Transitions: macroscopic order parameter, correlation length
* Liquid-Vapor Transition: van der Waals equation, Maxwell construction via Landau theory
* Liquid-Solid Transition: Lindemann and Hansen-Verlet criteria, hard sphere freezing
* Displacive Transitions: soft modes, ferroelectrics
* Liquid Crystals: nematic isotropic transition, nematic-smectic A transition and the superconductor analogy
* Multicritical Points: Tricritical, Bicritical, Landau point, and Lifshitz point
* Critical Exponents and Scaling Laws
* The Ginsburg Criterion: fluctuation effects and the breakdown of mean-field theory
* The Renormalization Group Approach: Kadanoff construction, recursion relations, fixed points, n and d dependence
* Defects: points, lines, and walls; topological defects, topological-order and the Kosterlitz-Thouless transition, bond-orientational-order and the hexatic phase
* Nucleation Transitions: the Freedericksz transition, cholesteric and smectic C\*unwinding
* Critical point dynamics, critical slowing down
* Pattern Selection in Condensed Matter Systems