

## **Ph223c "Advanced Condensed Matter Physics" (2008 -- 2009)**

INSTRUCTOR: Professor Nai-Chang Yeh  
(Office: 128-36 Phone: x-4313 E-mail: [ncyeh@caltech.edu](mailto:ncyeh@caltech.edu) )

SCHEDULE: Monday & Wednesday 10:30 – 12:00

LOCATION: Downs 103

INFORMATION: [http://www.its.caltech.edu/~yehgroup/ph223c\\_2008](http://www.its.caltech.edu/~yehgroup/ph223c_2008)

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### **Ph223c**

#### **I. Interacting Bosons and Superfluidity**

- Basic formalism for interacting bosons at  $T = 0$ .
- Perturbation theory and Feynman rules.
- Weakly interacting bosons.
- Field theory of interacting bosons at  $T \neq 0$ .
- Bosonic superfluid in liquid helium.
- Bose-Einstein condensation in cold atoms and magnetic insulators.

#### **II. Conventional Superconductivity**

- Phenomenology of superconductivity.
- The Cooper instability and electron pairing.\*
- Microscopic theory of superconductivity by Bardeen, Cooper and Schrieffer (BCS).\*
- Thermodynamic properties of superconductors.
- Theory of quasiparticle and Cooper pair tunneling.

#### **III. High-Temperature Superconductivity in the Cuprates & Iron Pnictides**

- General properties of high-temperature superconducting cuprates.
- Microscopic models to high-temperature superconductivity from Hubbard and  $t$ - $J$  models.
- Recent development in phenomenology.
- A new class of high-temperature superconductors: the iron pnictides.
- Outlook.

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\* This section will only be handed out as notes but not covered in lectures because most of the material has been covered in Ph223ab this year. The purpose of this set of notes is for consistency in notation for later parts of the class notes.

#### **IV. Topological Field Theory & Fractional Quantum Hall (FQH) Effect**

- Topological objects: solitons, vortices, and hedgehogs – field theory beyond Feynman diagrams.\*
- Integer and fractional quantum Hall effects in two-dimensional electron gas.
- Braid groups, permutation groups, and fractional statistics.
- Effective theory of the FQH liquids and topological orders.
- Edge excitations of the FQH liquids.
- Basic properties of anyon models.<sup>†</sup>
- Candidate non-abelian anyons in FQH states & possible experimental verifications.<sup>†</sup>
- Quantum spin Hall (QSH) effect & topological insulators.<sup>†</sup>

#### **Reference Books:**

1. “*Quantum Theory of Many-Particle Systems*”, A. L. Fetter and J. D. Walecka, Dover Publications, Inc. (2003). [ISBN: 0-486-42827-3]
2. “*Methods of Quantum Field Theory in Statistical Physics*”, A. A. Abrikosov, L. P. Gorkov, and I. E. Dzyaloshinski, Dover Publications, Inc. (1975). [ISBN: 0-486-63228-8]
3. “*Quantum Field Theory in a Nutshell*”, A. Zee, Princeton University Press (2003). [ISBN: 0-691-01019-6]
4. “*Quantum Field Theory of Many-Body Systems*”, X.-G. Wen, Oxford University Press (2004). [ISBN: 0-19-853094-3]
5. “*Fractional Statistics and Quantum Theory*”, A. Khare, 2<sup>nd</sup> Edition, World Scientific (2005). [ISBN: 981-256-160-9]
6. “*Theory of Superconductivity*”, J. R. Schrieffer, Westview Press (1999). [ISBN: 0-7382-0120-0]

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<sup>†</sup> Elective topic, depending on the availability of time.