

**APPPHYS 377: Literature of Condensed Matter Physics.**

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Goal: i) Broad exposure to modern topics.  
ii) In-depth understanding of one or two subjects.  
iii) Experience of leading a group discussion on a current topic.

Methods: a combination of instructor lecture and student lead discussion.

Requirement: i) Attend the lectures participate in the discussions; ii) Lead two discussion sections. When required to lead the discussion, upload a ppt file to the group web site 48 hrs before the class time, provide cited references.

- Mott transition and Mott insulators
- high-temperature superconductivity
- unconventional pairing symmetries in cuprates and ruthnates
- anisotropic superconductivity in  $\text{MgB}_2$
- colossal magnetoresistance in manganites, charge-spin-orbital ordering, nano-scale phase separation and mesoscopic texture in strongly correlated materials,
- quantum criticality and superconductivity on the boarder of itinerant-electron ferromagnetism
- organic conductors and charge density wave, electronic properties of carbon nano-tubes and nano-clusters
- Kondo effect in nano-structures
- disorder and Coulomb gap phenomenology
- hidden order
- resistivity saturation
- unconventional properties under high-pressure and/or high magnetic field
- recent progress in modern experimental techniques and data analysis methods:
  - STM and scanning probe microscopes
  - modern photoemission and scattering techniques
  - nano-structure fabrication and atomic manipulation
  - high pressure cells
  - modern optics and pump-probe experiments.
  - Maximum Entropy Method
- energy Related Topics
  - Basic Research Needs for Solar Energy Utilization
  - Basic Research Needs for the Hydrogen Economy

Selected review of modern topics in condensed matter physics - references:

- Mott transition and Mott insulators
  - Mott / Anderson /Hubbard original papers – [N.F. Mott, Proc. Phys. Soc. London A 277 (1949); P.W. Anderson, Phys. Rev. 115, 2 (1959); J. Hubbard, Proc. R. Soc. London A 277, 237 (1964); A 281, 401 (1964).]
  - Metal insulator transition in transition metal compounds (Adler, RMP 40, 714 (1968)).
  - Conventional textbook descriptions – see advanced solid state physics books.
  - Zaanen, Sawatzky and Allen scheme on transition metal oxides ( PRL 55, 418 (1985))
  - Hubbard model / Emery model (three band Hubbard model) /t-J model ( search papers in the high-Tc era, Anderson 87, Emery 88, Zhang and Rice, 88, Kotliar, Lee, Affleck, and following papers).
    - Spectroscopic evidence for the models – NiO (Sawatzky/Allen PRL 53, 2339 (1984)), Cuprate (Shen, PRB 36, 8414 (1987)), single-hole (Wells, PRL 74, 964 (1995))
  - Complexities in real world Mott insulators – tendency of coupling to orbital and lattice degrees of freedom – see Dagotto review on Manganite (Physics Reports, 344, 1-153 (2001), t-J polaron problem.
- High-temperature superconductivity
  - Physical properties of high-temperature superconductors – edited by D.M. Ginsberg – book, world scientific.
  - Millis and Orenstein Review – Science 285, 1241 (2000)
  - Review of ARPES – Damascelli, Hussain, Shen, RMP 75, 473 (2003)
  - Kirtley/Tsuei – order parameter symmetry. – RMP 72, 969 (2000)
  - Neutron – spin fluctuations / phonons - search for names: G. Aeppli, H. Mook, B. Keimer, P. Dai, T. Egami, L. Pinchvius.
  - Optics / Ramam – electronic / phonons – search for names: S. Tajima, S. Uchida, D. van der Marel, D. Basov, T. Devereaux, R. Huckel. Devereaux/Huckel - RMP
  - STM – inhomogeneities – search for names: S. Davis, A. Kapitulnik, A. Yazdani.
- Unconventional pairing symmetries in ruthnates
  - Mackenzie and Maeno – RMP 75, 657 (2003)
- Anisotropic superconductivity in MgB<sub>2</sub>
  - Paul C. Canfield and George W. Crabtree, Physics Today, March, 2003, 34. I. Marzin, O.K. Andersen, S. Louie, M.L. Cohen
- Colossal magnetoresistance in manganites, charge-spin-orbital ordering, nano-scale phase separation and mesoscopic texture in strongly correlated materials
  - E. Dagotto, T.H. Hotta, and A. Moreo, Physics Reports, 344, 1-153 (2001)
  - Neil Mathur and Peter Littlewood, Physics Today, Jan. 2003, 25.
  - N. Nagaosa and Y. Tokura, Science, 03.
- Quantum criticality and superconductivity on the boarder of itinerant-electron ferromagnetism

- S. Sachdev
- S.S. Saxena et al. Superconductivity on the border of itinerant-electron ferromagnetism in UGe<sub>2</sub>, Nature -2000
- High-Tc context, Varma, D-density wave, Charkravarty, Moore, Laughlin, Nayak
- Hidden order in URu<sub>2</sub>Si<sub>2</sub>
  - N. Harrison, M. Jaime, J.A. Mydosh, PRL 90, 096402 (2003); PRL 89, 287202 (2002)
- Physics of C60 and its related compounds
  - O. Gunnarsson RMP 69, 576 (1997)
- Saturation of Electrical Resistivity
  - O. Gunnarsson RMP 75, 1085 (2003)
- Organic conductors and charge density wave, electronic properties of carbon nano-tubes and nano-clusters
  - Density waves in solids – George Gruner, book.
  - R.E. Thorne, Physics Today, May 1996, page 42.
- Spin-orbital physics
  - Dissipationless quantum spin current at room temperature – Murakami, nagaosa, zhang, Science 301, 1348 (2003)
  - Recent development in spin-hall effects
- Kondo effect
  - Basic phenomenology
  - Kondo Hamiltonian, Anderson model and Kondo resonance, Gunnarsson/Shonhammer
  - Kondo effect in nano-structures
- Quantum Hall Effects
- Disorder and Coulomb gap phenomenology
  - A.L. Efros and B.I. Shklovski, J. Phys. C8, L49 (1975)
- Unconventional properties under high-pressure and/or high magnetic field
  - Superconductivity in Boron, M.I. Eremets et al., Science 272 (2001)
  - Phonon Density of States of Iron up to 153 Gigapascals, H.K. Mao et al., Science 292, 914 (2001).
- Recent progress in modern experimental techniques:
  - STM and scanning probe microscopes
    - Gerd Binnig and Hinrich Rohrer – RMP 59, 615 (1987)
    - J.A. Golovchenko - Science, 232 48-53 (1986)
    - Quasiparticle scattering in sp bands – fourier transform method
  - modern photoemission and scattering techniques
    - Damascelli, Hussain, Shen, RMP 75, 473 (2003)
    - Photoemission Spectroscopy, S. Huffner, book.
  - High pressure cells
    - PRB 64, 100509.
  - Modern optics and pump-probe experiments.
    - Shah, J. Ultrafast Spectroscopy of Semiconductors and Semiconductor, Nanostructures. (Springer-Verlag, 1999).

- Douhal, A. and Santamaria, J. (Eds) Femtochemistry and Femtobiology. (World Scientific, Singapore, 2002).
- Maximum Entropy Method
- Energy Related Topics
  - Basic Research Needs for Solar Energy Utilization. (Report on the Basic energy sciences workshop on Solar Energy Utilization: <http://www.sc.doe.gov/bes/hydrogen.pdf>; European Union Reports: PVStatusReport2003, PVStatusReport2004)
  - Basic Research Needs for Hydrogen Economy. (Report on the basic Energy sciences workshop on hydrogen production, storage and use: <http://www.sc.doe.gov/bes/hydrogen.pdf>).