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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 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
  - 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 / Emergy 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, Afflect, and following papers).
  - Spectroscopic evidence for the models – NiO (Sawztzky/Allen PRL 53, 2339 (1984)), Cuprate (Shen, PRB 36, 8414 (1987)), single-hole (Wells, PRL 74, 964 (1995))

- High-temperature superconductivity
  - Kirtley/Tsuei – order parameter symmetry. – RMP 72, 969 (2000)

- Unconventional pairing symmetries in ruthnates

- Anisotropic superconductivity in MgB₂

- Colossal magnetoresistance in manganites, charge-spin-orbital ordering, nanoscale phase separation and mesoscopic texture in strongly correlated materials
  - N. Nagaosa and Y. Tokura, Science, 03.

- Quantum criticality and superconductivity on the boarder of itinerant-electron ferromagnetism
S. Sachdev

Hidden order in URu$_2$Si$_2$
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

Organic conductors and charge density wave, electronic properties of carbon nano-tubes and nano-clusters

Spin-orbital physics
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

Unconventional properties under high-pressure and/or high magnetic field
Superconductivity in Boron, M.I. Eremets et al., Science 272 (2001)

Recent progress in modern experimental techniques:
STM and scanning probe microscopes
Gerd Binnig and Hinrich Rohrer – RMP 59, 615 (1987)
Quasiparticle scattering in sp bands – fourier transform method
Modern photoemission and scattering techniques
High pressure cells
PRB 64, 100509.
Modern optics and pump-probe experiments.
  - Maximum Entropy Method

- Energy Related Topics