课程名称：凝聚态物理学新论

一、课程编码：1800001
课内学时： 32 学分： 2

二、适用学科专业：凝聚态物理专业，理论物理专业，化学物理专业等

三、先修课程：量子力学，固体物理学，凝聚态物理等。

四、教学目标

通过本课程的学习使研究生：

1. 了解当前凝聚态物理研究的最前沿以及凝聚态物理中重要的新问题；
2. 掌握理解这些前沿进展以及处理这些新问题时所用到的基本概念和方法；
3. 拓宽他们的眼界，培养他们对于凝聚态物理学的兴趣。

五、教学方式

课堂讲授，材料自学与课堂讨论，穿插例题分析。

六、主要内容及学时分配

1. 概论 3学时
   - 1.1 传统凝聚态物理学中几个重要的概念：对称破缺、序参量和元激发
   - 1.2 传统凝聚态物理学的两块基石：朗道费米液体理论和朗道对称性破缺理论
   - 1.3 霍尔效应以及量子霍尔效应初步
2. Geometry Phase (Berry phase) 5学时
   - 2.1 Geometric angle and parallel transport
   - 2.2 Berry phase: General formalism
   - 2.3 Example: two-level system and monopole
   - 2.4 Anomalous velocity and Effective dynamics of Bloch electron
   - 2.5 Time-reversal symmetry and Kramers' Theorem
3. Dirac Equation in Condensed Matter Physics 4学时
   - 3.1 Review of Dirac Equation
   - 3.2 Spin-orbit Coupling
   - 3.3 Tight-binding model and Slater-Koster method
   - 3.4 Dirac equation in 1D system: SSH model
   - 3.5 Dirac equation in 2D system: graphene
4. Topological insulators without time reversal symmetry 6学时
   - 4.1 整数量子霍尔效应 (QIH)
   - 4.2 Topological invariants: TKNN number (Chern number) and Hall conductance
   - 4.3 量子反常霍尔效应(QAH): Haldane Model
   - 4.4 Chern Insulators
   - 4.5 Zero modes in Dirac equation and surface state in topological insulators
   - 4.6 Magnetic Field on the Square Lattice: Harper Equation and Hofstadter

butterfly

5. Topological Insulators with time reversal symmetry 5学时
   - 5.1 Kane-Mele Model
   - 5.2 BHZ model and HgTe-CdTe Quantum Wells
   - 5.3 Topological invariants: Z_2
   - 5.4 Quantum spin Hall effect (2D topological Insulator) in Silicene, Germanene, and Stanene
   - 5.5 3D Topological Insulators: Weak and strong Topological Insulators
   - 5.6 Experimental Detection of Strong Topological Insulators and Proposals for Weak Topological Insulators
   - 5.7 Mirror Chern number and topological crystalline insulators
6. Topological semimetals 4学时
   - 6.1 Weyl semimetals and type-II Weyl semimetals
   - 6.2 Dirac semimetals
   - 6.3 Weyl and Dirac nodal line semimetals
   - 6.4 Fermi arc and chirality anomaly
7 Topological superconductors 5学时
   - 7.1 BdG Formalism
   - 7.2 chiral p-wave topological superconductors
   - 7.3 Time-reversal invariant superconductors
   - 7.4 Majorana Zero modes

七、考核与成绩评定

平时考情，作业、习题以及基于阅读多篇文献后的综合项目报告。

八、参考书及学生必读参考资料

1. 冯端,金国钧， 凝聚态物理学新论，上海科学技术出版社，2006.
2. 李正中， 固体理论， 高等教育出版社，2003.
3. P.M.Chaikin & T.C. Lubensky, Principles of condensed matter physics, Cambridge, 1995.
4. P.W.Anderson, Basic notions of condensed matter physics, Benjamin-Cummings, Menlo Park, 1984.
5. B. A. Bernevig & T. L. Hughes, TOPOLOGICAL INSULATORS AND TOPOLOGICAL SUPERCONDUCTORS, Princeton University Press, 2013.
6. D. Xiao, M. C. Chang, and Q. Niu, Rev. Mod. Phys. 82, 1959 (2010).
7. M. Z. Hasan and C. L. Kane, Rev. Mod. Phys. 82, 3045 (2010).
8. X.-L. Qi and S.-C. Zhang, Rev. Mod. Phys. 83, 1057 (2011).

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