Syllabus of course 00432140: "**classical electrodynamics**" (2021)

Introduction.---This course is expected to be taken by sophomore or junior undergraduate students, who have already taken the elementary courses including electromagnetics, mathematical physics, and classical mechanics. The main topics covered in this course will be divided into two parts. The first part will be introduced without the inclusion of the special relativity, including *vector and tensor analysis*, *Maxwell equations*, *electrostatics*, and *magnetostatics*. The second part will be presented after introducing special relativity, and the theoretical materials in this part will be formulated based on special relativity. The second part will cover the following topics: *fundamentals of special relativity*, *gauge invariance of Maxwell equations*, *action principle for Maxwell's theory*, *electromagnetic waves and wave guides*, *relativistic motion of charged particles*, and *radiation*. Selected advanced topics will be properly inserted into the teaching of conventional topics in the first and second parts, including *slow light in electromagnetically induced transparency*, *charge confinement*, *magnetic monopole*, *Van der Waals force*, *Casimir effect*, *gauge field theory*, *quantum Hall effect*, *topological insulator*, *topological field theory*, etc.

Time: Monday (7-8：15:10--17:00); Wednesday (3-4：10:10--12:00)
Location: 三教 504
Instructor: Xiong-Jun Liu (刘雄军), ICQM PKU; **Email**: xiongjunliu@pku.edu.cn
Office: W535, Physics Building
Office hour: Wednesday 3:00pm-4:00pm
Textbooks: Lecture notes to be distributed. Ref books: 1) Introduction to Electrodynamics, David J. Griffiths; 2) 电动力学, 郭硕红；3) Classical Electrodynamics, J. D. Jackson; 4) The Classical Theory of Fields, L.D. Landau and E.M. Lifshitz

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习题课：双周周五 10~11 节，教室：三教 106

Course Grading: Homework: 30%; Midterm: 30%; Final: 40%

Homework sheets will be sent to you by email.

You are encouraged to finish your homework independently, while discussions with your classmates are also allowed. However, copying other's results is forbidden. Once your homework is identified to be copied from others, even only partially, that whole homework will be graded as zero. A PKU student should not lie, cheat, or steal or tolerate those who do.

Exam Schedules: Midterm: after finishing part I of the course; Final: Jan 10 (下午), 2022

Content:
Ch1: Vector and tensor analysis
Ch2: Maxwell equations
Ch3: Electrostatics
Ch4: Magnetostatics
Ch5: Special Relativity and Electrodynamics
CH6: Action Principle for Maxwell's Theory
Ch7: Electromagnetic Waves and Wave Guides
Ch8: Relativistic Motion of Charged Particles and Radiation
Ch9: Selected Advanced Topics (to be properly inserted into Ch1 to Ch8)

详细内容提纲：

Ch1: Vector and tensor analysis

1.1 Definitions; 1.2 Algebra for scalar, vector, and tensors; 1.3 Differential calculations; 1.4 Einstein convention and further issues

Ch2: Maxwell equations

2.1 Introduction to Maxwell equations;
2.2 SI units and Gaussian units;
2.3 Macroscopic media; dispersion; phase velocity and group velocity; Electromagnetic induced transparency (EIT) and slow light; Kramers-Kronig relations; Causality
2.4 Boundary conditions;
2.5 Conservation laws (charge, energy, momentum, Poynting vector and Maxwell stress tensor);
2.6 Symmetries; Gauge invariance and AB effect.

Ch3: Electrostatics

3.1 Uniqueness theorem and Green theorem
3.2 Green function and boundary-value problems
3.3 Methods of imagine; Construction of Green functions and general solutions
3.4 Separation of variables. 3.4.1 Generic ideas; 3.4.2 Cartesian coordinates; Construction of Green functions and General solutions; .3. 4. 3 Separation in curvilinear coordinates; construction of Green functions and general solutions. Various examples (charge confinement).
3.5 Multipole expansion; Cartesian coordinates and spherical coordinates; Energy of multipole in external fields.
3.6 Dipole-dipole interaction; Van der Waals force (quantum fluctuation, fluctuation-dissipation theorem).

Ch4: Magnetostatics

4.1 Experimental laws:
4.2 Magnetically permeable media and boundary conditions
4.3 Solving boundary problems with vector potentials
4.4 Solving boundary problems with scalar potential (Magnetic materials)
4.5 Magnetic multipole expansion
4.6 Magnetic monopole and topology

Ch5: Special Relativity and Electrodynamics

5.1 Introduction
5.2 The Lorentz transformation
5.3 Four vectors and four tensors; Lorentz tensors; Proper time and four velocity
5.4 Tensor form of Maxwell equations
5.5 Lorentz transformation between E and B fields; The Lorentz force (the Lorentz force equation)
5.6 Action principle of charged particles
5.7 Particle motion in static E and B fields
5.8 Unconventional and conventional Landau levels, and quantum Hall effect

Ch6: Action Principle for Maxwell's Theory

6.1 Invariants of the electromagnetic field
6.2 Action principle for electrodynamics; Inclusion of sources; Proca theory
6.3 Energy-momentum tensor for scalar field

6.4 Energy-momentum tensor for the electromagnetic field and conservation laws
6.5 Topological field theory
Chern-Simons term for 2D and 4D quantum Hall effects; Topological insulators; Topological magneto-electric effect and axial field theory in condensed matter physics

Ch7: Electromagnetic Waves and Wave Guides
7.1 Electromagnetic wave in vacuum; Polarization
7.2 Reflection and refraction
7.3 Electromagnetic wave in conductor, skin effect (EM field in superconductor, Meissner effect)
7.4 Classical model for dispersive media; Drude formula
7.5 Wave guides. TEM, TE, TM modes; resonant cavities
7.6 Casimir force
(Topological photonics)

Ch8: Relativistic Motion of Charged Particles and Radiation
8.1 Retarded potentials
8.2 Lienard-Wiechert potentials
8.3 Electric and magnetic fields of a moving charge
8.4 Radiation by accelerated charges; Larmor formula and applications
8.5 Angular distribution of the radiated power
8.6 Frequency distribution of radiated energy (Synchrotron Radiation)
8.7 Frequency spectrum for periodic motion
8.8 Cerenkov radiation
8.9 Thompson scattering

Ch9 Radiating systems
9.1 Fields due to localizing currents
9.2 Multipole expansion
9.3 Electric dipole radiation
9.4 Electric quadrupole radiation
9.5 Linear antenna

本课程特点：
1. 观念比较现代（Maxwell理论+相对论时空观；格林函数等系统化理论方法）；
2. 和前沿研究密切、自然的联系；
3. 注重概念准确，清晰简洁的物理图像，启发性讲授和讨论；
4. 充分覆盖经典知识；
5. 设计习题和教学内容相辅相成。
6. 难度：1）计算方面：中等偏上；2）开拓性思维要求：较高。