《电动力学（英文版）》课程教学大纲

一、课程基本信息

英文名称	Electrodynamics	**课程代码**	PHYS3107
课程性质	Major Core	**授课对象**	Physics (international)
学　分	4 credits	**学　时**	72 hours
主讲教师	Chengjie Zhu （朱成杰）	**修订日期**	Sep. 2021
指定教材	Griffiths, David J. Introduction to Electrodynamics. 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1998		

二、课程目标

（一）总体目标：

Electrodynamics is the advanced course to Electricity-Magnetism and Optics. The prerequisite courses include: General Physics II (PHYS1026); Optics (PHYS3126); Method of Mathematical Physics (PHYS3103).

Using advanced mathematical tools, including vector analysis and solving partial differential equations, electrodynamics teaches the students the general theories of electromagnetic wave. The topics include: electrostatics and magnetostatics, Maxwell’s equation, Electromagnetic waves, Radiation and Special Relativity.

Through in-depth discussion of relevant issues in middle school physics teaching, and new technology applications in teaching, students will strengthen their understanding of the basic concepts and principles of electrodynamics, so that students can understand physics ideas and scientific methods , To better understand the nature of science, form a dialectical materialist world view and a scientific view of time and space, and cultivate students' scientific thinking ability, problem analysis and problem-solving ability.

（二）课程目标：

课程目标 1：By systematically learning the basic laws of electromagnetic fields, students can master the general laws of electromagnetic phenomena such as electrostatic field, static magnetic field, and electromagnetic field propagation, deepen their understanding of the basic properties of electromagnetic fields, and form a dialectical materialist world view and a scientific view of time and space.

课程目标 2：Master the methods in the process of establishing the theoretical configuration of the course. Cultivate students' scientific thinking such as model construction, analysis and

synthesis, reasoning and analogy. Apply the general methods and abilities of mathematical methods such as field theory to analyze and solve physical problems for the following courses. Build the necessary foundation for solving practical problems alone.

课程目标 3：Apply electromagnetic field theory to analyze and discuss the problems in middle school electromagnetics. Introduce some cutting-edge topics related to this course, and cultivate students' ability for scientific research.

课程目标 4：Through learning and understanding the history of electrodynamics development, major scientific events and physicist stories, students can experience the thoughts and scientific spirit of physicists, cultivate students' patriotic enthusiasm, explore the unknown, pursue the truth, and have a sense of responsibility and mission to climb forever. Through the teacher's humanistic demonstration, it will give students a positive influence, cultivate students' strong ideals and beliefs. Take the responsibility of cultivating morality and fostering students as our own responsibility, and establish the professional ideal of learning to be a teacher and behave in the future.

（三）课程目标与毕业要求、课程内容的对应关系

表 1：课程目标与课程内容、毕业要求的对应关系表

<table>
<tr><th>课程目标</th><th>对应课程内容</th><th colspan="2">对应毕业要求（及对应关系说明）</th></tr>
<tr><td>课程目标 1</td><td>Chap.1: Introduction & Vector Analysis
Chap.2-4: Electrostatics
Chap.5-6: Magnetostatics
Chap. 7-8: Conservation Laws and Maxwell’s Equation
Chap. 9: Electromagnetic Wave
Chap.10-11: Potential and Radiation
Chap. 12: Electrodynamics and Relativity</td><td rowspan="2">7-2
Have the consciousness of lifetime learning. Understand the frontiers of physics, the field of physics teaching and international development trends.</td><td>Grasp how to use advanced mathematics and vector analysis to deal with electrodynamic problems. Through the introduction and study of the concept of "field", students should understand the basic properties of static and dynamical electromagnetic fields, as well as the space-time view of special relativity.</td></tr>
<tr><td>课程目标 2</td><td>Chap.1: Introduction & Vector Analysis
Chap.2-4: Electrostatics
Chap.5-6: Magnetostatics
Chap. 7-8: Conservation Laws and Maxwell’s Equation</td><td>Through learning to apply advanced mathematics and vector analysis to deal with electrodynamics problems, students should grasp scientific thinking methods such as model construction, analysis and synthesis, reasoning and analogy. To cultivate students'</td></tr>
</table>

	Chap.9: Electromagnetic Wave Chap.10-11: Potential and Radiation Chap.12: Electrodynamics and Relativity		critical thinking and questioning ability, and develop the habit of independent thinking.
课程目标 3	Chap.2-4: Electrostatics Chap.5-6: Magnetostatics Chap.7-8: Conservation Laws and Maxwell’s Equation Chap.9: Electromagnetic Wave		Through the application of electromagnetic field theory to analyze and discuss the problems of electromagnetics in middle school, and introducing some frontier issues related to this course, students should understand the frontiers of physics. To broaden students' horizons, and cultivate students' interest and ability in scientific research.
课程目标 4	Chap. 7: Maxwell’s Equation Chap. 9: Electromagnetic Wave Chap.10-11: Potential and Radiation Chap.12: Electrodynamics and Relativity		Through learning and understanding the history of electrodynamics development, major scientific events and physicist stories, students can experience the scientific thought and spirit of physicists. To cultivate students' patriotic enthusiasm, explore the unknown, pursue the truth, and have a sense of responsibility and mission to climb forever. To foster morality, and establish the professional ideal of learning to be a teacher and behave in future.

三、教学内容

Chapter 1: Introduction & Vector Analysis

1. 教学目标

Grasp the vector algebra needed through the whole course

2. 教学重难点

Operators: Gradient, Divergence and Curl; physical understanding

3. 教学内容

Session 1 Introduction to Electrodynamics

1) What is electrodynamics. Being a major core, what is its relationship to general physics courses and major selective course.
2) Prerequisites, knowledge required before this course. Urge students to get prepared with basic knowledge of optics and electromagnetism and mathematical tools.
3) Principal Events in the story of the electromagnetic field. How optics, electricity, magnetism were combined to become electrodynamics.
4) Electrodynamics is still development. The most fascinating development in the field of electromagnetism.

Session 2 Mathematics concepts needed

1) Scalar and Vector. Magnitude and unit vector. Review Basic concept and physical quantities
2) Vector Operations: Basic operations required and practice, including: Addition of vectors: commutative and Associative; Multiplication by a scalar; Dot product and its geometrical definition; Cross product of vectors, brief introduction of tensor; Scalar triple products and vector triple products

Session 3 Field Operation

1) Concept of fields. Emphasize on physical examples. Introduce del operator
2) Gradient operation. Its physical interpretation and mathematical operation
3) Divergence operation. Curl operation. Scalar- (Vector-) type operation. Physical meaning and geometrical picture.
4) Gauss theorem and Stokes theorem. Required. Mention its mathematical proof (not required)

Session 4 Derivation of Important Equations

1) Derive very important mathematical equations to be used in class

$$\nabla\times\nabla f=0 \quad \nabla\cdot\left(\nabla\times\vec{A}\right)=0 \quad \nabla\times\left(\nabla\times\vec{A}\right)=\nabla\left(\nabla\cdot\vec{A}\right)-\nabla^2\vec{A}$$

2) Position vector related derivations.
3) Delta function and important relations

$\nabla^2\left(\frac{1}{r}\right)=-\nabla\cdot\frac{\vec{r}}{r^3}=-4\pi\delta(\vec{r})$ is required.

4) Other coordinate systems

Cylindrical coordinate: $\nabla=\frac{\partial}{\partial r}\hat{e}_r+\frac{1}{r}\frac{\partial}{\partial\theta}\hat{e}_\theta+\frac{\partial}{\partial z}\hat{e}_z$

Spherical coordinate: $\nabla=\frac{\partial}{\partial r}\hat{e}_r+\frac{1}{r}\frac{\partial}{\partial\theta}\hat{e}_\theta+\frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}\hat{e}_\phi$

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 2-4: Electrostatics

1. 教学目标

Review the concept of electrostatics .

Grasp Special Techniques for electrostatic problems: Method of Image and Separation of Variables

2. 教学重难点

Special Techniques for electrostatic problems

3. 教学内容

Session 1: Coulomb's Law to field

1) Review Coulomb's experimental facts. Continuous charge distributions. The use of integral
2) Definition of Electric Field: force defines interaction. Field is a MATTER not a definition.
3) Field operation shall apply to electric field. Divergence and Curl of electric field. Gauss theorem to Gauss's Law. $\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$
4) Surface charge distribution to calculate electric field

Session 2： Electric Potential

1) Curl free nature of electric field. Apply $\nabla \times \nabla f = 0$ to define electric potential
2) Conservative Nature of electric field and its consequence to the properties of electric potential.
3) The reference point of the definition of electric field. The difference of electric field matters.
4) Energy to create a system with point charges in vacuum. Some interpretations: discrete charge to continuous charge distribution; some limit to apply when integrating to infinity; Electric field has energy (MATTER nature)

Session 3: Electric Field inside Matter

1) Definition of Matter in electrodynamics: conductor and dielectrics
2) Microscopic and macroscopic understanding of dipole: Classical interpretation of dipole; macroscopic dipole moments and its physical origin: polarization
3) The field of a polarized object and its consequence: surface bound charges and volume bound charges
4) Auxiliary field defined: The electric Displacement. Definition of dielectrics. Linear Dielectrics. The electric potential of dipoles and energy in dielectric systems.

Session 4: Conductor

1) Basic Properties of conductors
2) Boundary conditions cross surface. Difference between conductor and dielectrics.
3) Boundary conditions for electric potentials

Session 5: Electric potential in Matter

1) Electric potential of continuous charge distributions
2) Example class: given charge distributions, solve electrostatic problems either using electric field or electric potential. Review integration technique required.

Session 6: Laplace's Equation

1) Poisson's and Laplace's Equation. Historical view. What is the relation between the development of mathematics and physics.
2) Laplacian operator $\nabla^2 V = -\frac{\rho}{\varepsilon_0}$ $\nabla^2 V = 0$
3) Laplacian operator, delta function $\nabla^2\left(\frac{1}{r}\right) = -\nabla\cdot\frac{\vec{r}}{r^3} = -4\pi\delta(\vec{r})$ to prove Gauss's law.

Session 7: Uniqueness Theorem
1) Physical meaning of uniqueness theorem. Ground place for electrostatic problems.
2) Proof of uniqueness theorem with dielectrics and Dirichlet boundary condition. Students shall be able to derive with other situations.
3) One example of uniqueness theorem: Faraday cage. Short story of Snowden.
4) Examples to use uniqueness theorem to "guess out" solutions to electrostatic problems

Session 8: Special Techniques to solve electric Problems I: Separation of Variables
1) Laplace equation in spherical coordinate system
2) Detailed derivation how to use separation of variable to obtained general solutions to Laplace equation in spherical coordinate system
3) General solutions under azimuthal symmetry, convergence at r=0 or $r \to \infty$ r
4) Orthogonal relationship of Legendre function
5) Laplace equation in cylindrical coordinate system

Session 9: Special Techniques to solve electric Problems II: Method of Image
1) Classic Image Problem: relationship to Uniqueness Theorem
2) Two class of examples: a) Semi-infinite grounded plate problem; b) A grounded conducting sphere

Session 10: Other special Techniques to solve electric Problems
1) Green's function
2) Multiple Expansion
3) General solutions to Poisson's Equation

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 5-6: Magnetostatics

1. 教学目标

Understand the basic laws of static magnetic field

Grasp special techniques applied to electrostatics can be applied to magnetostatics.

Grasp the thought of analogy in physics.

2. 教学重难点

Tell the difference between electrostatics and magnetostatics.
Uniqueness of Magnetic vector potential.

3. 教学内容

Session 1: Lorentz Force to magnetic field

1) Review experimental facts of forces between wires with current. Moving charge leads to magnetic field
2) Work done by magnetic field. Cyclotron motion
3) Source of magnetic field: current. Continuous distribution of current
4) Continuity Equation. Charge conservation.

Session 2: Biot-Savart Law

1) Definition of magnetic field
2) Field operation shall apply to magnetic field. Divergence and Curl of magnetic field. Derive Ampere's Law: $\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$. Magnetic field is divergence free (sourceless).
3) Application of Ampere's law

Session 3: Magnetic Vector Potential

1) $\mathbf{B} = \nabla \times \mathbf{A}$, as its divergence free nature.
2) Magnetic vector potential is NOT uniquely defined. Difference to electric potential.
3) Gauge transformation (Coulumb gauge) to uniquely define magnetic vector potential. The expression of magnetic vector potential.
4) Boundary conditions of magnetostatics.

Session 4: Magnetic field in Matters

1) Multipole expansion of magnetic vector potential. Magnetic dipole.
2) Paramagnetism, Diamagnetism and Feromagnetism
3) Magnetization. The field of a magnetized object. Bound surface current and volume current.
4) Auxiliary Field H (magnetic inductance).

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 7-8: Conservation Laws and Maxwell's Equation

1. 教学目标

Grasp Maxwell's Equation in Matter

Understand boundary condition of Maxwell's equation

Grasp basic Tensor calculation.

2. 教学重难点

Maxwell's Equation；Poynting Vector, Conservation of energy

3. 教学内容

Session 1 Maxwell's Correction

1) Review all experimental facts in electro- and magneto- statics.
2) Electromagnetic induction: Faraday's experiment
3) Len's law Faraday's Law: $\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$
4) Conservation of charge leads to Maxwell's correction to Ampere's law:

$$\nabla \cdot \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right) = 0$$

Session 2 Maxwell's Equation
1) Electromagnetic wave in vacuum: sourceless Maxwell's equation. Derive wave equation in three-dimension.
2) Electromagnetic wave in matters.
3) Boundary condition of Maxwell's equation cross surface (any difference to statics?)

Session 3 Conservation Laws
1) Derive charge conservation from Maxwell's equation
2) Energy of electromagnetic field. Poynting's theorem. Physical interpretation of energy density of electromagnetic field.
3) Continuity equation of energy
4) Conflict between Ampere's Law to Newton's third law. Momentum of electromagnetic field.
5) Maxwell's stress tensor and momentum conservation of electromagnetic field.
6) Mechanical effect of light. Tractor beam, optical tweezers, Solar sail.
7) Angular momentum conservation. Orbital and Spin angular momentum of light.

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 9: Electromagnetic Wave

1. 教学目标

Understand and solve the Wave equation

Grasp reflection and transmission from a semi-infinite dielectric

2. 教学重难点

Wave equation, Transmission and reflection, group and phase velocity

3. 教学内容

Session 1: Electromagnetic wave in vacuum
1) Speed of light. A constant determined by two constants derived and measured directly electrostatics (ε_0 from Coulomb's Law) and magnetostatics (μ_0 from Ampere's Law)
2) Hertz experiment. In class demonstration (using mobile phone)
3) Classic wave equation. Amplitude, phase, wave number, propagation directions.
4) Polarization of electromagnetic wave

Session 2: Monochromatic plane wave
1) Particular frequency traveling in a particular direction. Helmholtz equation.
2) Complex notation vs. experimentally measurable quantity. Del operator.
3) Electric/Magnetic field in vector notation. Poynting vector and momentum of electromagnetic field in vector notation.
4) Electromagnetic wave in matter. Speed of light in matter. Refractive index
5) Refraction and transmission at a boundary surface of two media
6) Impedance of medium.

7) Oblique incidence with semi-infinite media. Snell's Law. Incident polarization

Session 3: Application based on Snell's Law
1) Total internal refraction. Decay into both media. Optical fibers. Wispering Gallery mode. Goos–Hänchen Shift
2) Brewster angle. Ultra-transparent medium.
3) Mirage effect, optical coating. Transfer matrix method. Bianisotropic medium.
4) Recent research: photonic crystals, zero-index medium, artificial gauge field

Session 4: Electromagnetic wave in Conductor
1) Conductance. Microscopic understanding of free charges.
2) Conductor under steady-state conditions. Wave equation revisit. Complex wave number.
3) Skin depth and good/poor conductor conditions. Complex permittivity and its physical interpretations.
4) Complex impedance and revisit Snell's Law for conductors. Transmission and reflection.
5) Dispersion in medium. Group velocity and phase velocity.
6) Microscopic understanding of dispersive medium: classical model for the electrons in an atom
7) Introduction to plasmonics.

Session 5: Good conductor and related microwave applications
1) Material of good conductor: boundary conditions to fulfill
2) Parallel plate waveguide, coaxial waveguide
3) Resonant cavity: separation of variable in Cartesian coordinate
4) Waveguide: cutoff frequency, dispersion, polarizations, mode profiles

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 10-11: Potential and Radiation

1. 教学目标

Understand scalar potential and vector potential of electromagnetic field

Grasp retarded potential and its physical implications

Analyze the radiation pattern, frequency dependence et al. of an electric/magnetic dipole

2. 教学重难点

Retarded potential；radiation pattern

3. 教学内容

Session 1: Maxwell's equation with arbitrary source
1) Redefine scalar potential and vector potential for electromagnetic field.
2) Uniqueness of scalar/vector potential. Lorenz gauge. d'Alembert Equation.
3) Retarded Potential: Solution to d'Alembert Equation. Time delay between source and electromagnetic interactions. (implies relativity)

Session 2 Lienard-Wiechert Potential
1) potential generated by a moving charge
2) Relativity effect can be derived. Slight mention Bremsstrahlung and Cherenkov radiation

Session 3 Radiation

1) Order of 1/r if a source can radiate. Static sources don't radiate.
2) Radiation of electric dipole (ideal dipole/radiation zone). Vector/scalar potential by electric dipole
3) Radiation pattern, Rayleigh scattering
4) Radiation of magnetic dipole. Comparison to electric dipole.

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

Chapter 12: Electrodynamics and Relativity

1. 教学目标

Understand difference between classical time and space understanding and relativity.
Solve problems with time dilation and length contraction
Explain causality and its relationship to Minkowski Space-Time diagram. Interval.

2. 教学重难点

Relativity, causality

3. 教学内容

Session 1 Introduction to relativity

1) Michelson-Morley experiment. Absolute frame: required by Maxwell's equation itself
2) Einstein's postulations
3) Time dilation and length contraction
4) Lorentz transformations

Session 2 Four-dimension vector

1) Einstein's notation: contravariant vector/covariant vector
2) $\bar{a}_\mu \bar{b}^\mu = a_\mu b^\mu$. Scalar product is invariant with respect to Lorentz transformation
3) Displacement 4-vector. interval between two events is invariant.
4) Minkowski Space-Time diagram: time-like, space-like, light-like; causality

Session 3 Four-dimensional electrodynamics

1) Other four-dimensional vectors: velocity vector. Proper time and proper velocity
2) Four-dimensional momentum. $E=mc^2$
3) Relativistic expression of Maxwell's equation

4. 教学方法

Lectures, discussions, etc.

5. 教学评价

Corresponding exercises and supplementary exercises after class.

四、学时分配

表 2：各章节的具体内容和学时分配表

章节	章节内容	学时分配
Chap 1	Introduction & Vector Analysis	4 hr
Chap 2-4	Electrostatics	12 hr
Chap 5-6	Magnetostatics	12 hr
Chap 7-8	Conservation Laws and Maxwell’s Equation	12 hr
Chap 9	Electromagnetic Wave	16 hr
Chap 10-11	Potential and Radiation	8 hr
Chap 12	Electrodynamics and Relativity	8 hr

五、教学进度

表 3：教学进度表

周次	章节名称	内容提要	授课时数	作业及要求	备注
1	Chap 1	Introduction to the course, Vector analysis	4	Grasp the vector algebra needed through the whole course Operators: Gradient, Divergence and Curl; physical understanding	
2	Chap 2,4	Coulomb’s Law to field,Electric Potential, Electric Field inside Matter	4	Review the concept of electrostatics, Microscopic picture of polarization and permittivity, Boundary Conditions of electric fields	

3	Chap 2	Conductor, Electric potential in Matter, Laplace's Equation, Uniqueness Theorem	4	Revisit electrostatics problems with the concept of electric potential Introduction to conductor Laplace Equation: Mathematics	
4	Chap 3	Special Techniques to solve electric Problems I: Separation of Variables, Special Techniques to solve electric Problems II: Method of Image, Other special Techniques to solve electric Problems	4	Special Techniques for electrostatic problems: Method of Image and Separation of Variables	
5	Chap 5	Magnetostatics	4	Magnetic fields and forces	
6	Chap 5	Biot-Savart Law Magnetic Vector Potential	4	Analogy between electric and magnetic fields	
7	Chap 6	Magnetic Fields in Matter	4	Magnetic fields in Matter	
8	Chap 7	Maxwell Eq.	4	Deduction of Maxwell's Equation	
9	Chap 7-8	Maxwell's Equation in Matter Boundary Conditions Conservation Laws: Charge and Energy	4	Maxwell's Equation in Matter Boundary condition of Maxwell's equation Poynting Vector Revisit of Uniqueness Theorems	

10	Chap 8	Momentum Conservation and Optical Force Dispersion of Permittivity Midterm	4	Momentum Conservation; Maxwell Stress Tensor Dispersions of Materials	
11	Chap 9	Electromagnetic Wave	4	Wave Equations, Boundary conditions, Electromagnetic Waves in Vacuum	
12	Chap 9	Electromagnetic Waves in Matter	4	Reflection and Transmission from a semi-infinite dielectric Electromagnetic Waves in Conductors Introduction to Lumerical and Student Projects	
13	Chap 9	Application based on Snell’s Law	4	Total internal refraction. Decay into both media. Optical fibers. Wispering Gallery mode. Goos–Hänchen Shift	
14	Chap 9	Microwave Devices: cavity, parallel plates, waveguides, 1D photonic crystal	4	Wave Equations with conductors Numerical/Microwave Experiment Demonstration	
15	Chap 10	Scalar and Vector Potential Retarded Potential	4	Understand retarded potential and electromagnetic potential Grasp the application of vector potential	
16	Chap 11	Radiation	4	Dipole Radiation	

				Antenna Radiation (Numerical Demonstration)	
17	Chap 12	General Relativity Relativistic Mechanics	4	Introduction to General Relativity Momentum 4-vector Movie: E=MC2	
18	Chap 12	Relativistic Electrodynamics Student Presentations	4	Electrodynamics in Tensor Notation Project Presentation	

六、教材及参考书目

1. 郭硕鸿，电动力学（第三版），高等教育出版社，2008
2. Jackson, J. D. Classical Electrodynamics. 3rd ed. Wiley Publisher, 1998
3. 蔡圣善 朱耘 徐建军，电动力学，高等教育出版社, 2005
4. Kong, Jin Au, Electromagnetic Wave Theory, EMW Publishing, Cambridge, Massachusetts, USA
5. Joannopoulos, J. D., Johnson, S. G., Winn, J. N., & Meade, R. D., Photonic Crystals: Molding the Flow of Light, 2nd ed. Princeton University Press, Princeton, NJ, 2008.
6. Elmore W. C. & Heald, M. A. Physics of Waves, Dover publication, 1969.

七、教学方法

Adopting blackboard and PPT, taking advantage of both traditional and modern teaching methods such as lectures, discussions, and flipped classrooms; always highlight student-oriented educational concepts in teaching, and attach importance to curriculum planning and construction. Formulate standardized syllabus and teaching schedule in accordance with the curriculum system to teach students in accordance with their aptitude, so that students can master the development context of physics and scientific thinking methods, change from passive learning to active learning, and truly achieve learning from being able to learn. Through heuristic teaching, students are trained with strong active thinking habits, focusing on the cultivation of college students' innovative thinking and practical problem-solving abilities. Students' understanding of the nature of electromagnetic fields and the dialectical materialist view of time and space are deepened, and students' scientific thinking ability and problem-solving ability is effectively cultivated by effective communication with students in a timely manner, assignment of homework, and exercises when

necessary; through some problems in middle school physics and related physics Discuss and analyze cutting-edge issues.

八、考核方式及评定方法

（一）课程考核与课程目标的对应关系

表 4：课程考核与课程目标的对应关系表

课程目标	考核要点	考核方式
课程目标 1	Related contents	过程化考试+平时学习表现
课程目标 2	Related contents	过程化考试+平时学习表现
课程目标 3	Related contents	过程化考试+平时学习表现
课程目标 4	Related contents	过程化考试+平时学习表现

（二）评定方法

1．评定方法

Homework (10%)

Flipped Classroom (12%)

Quiz: 3 times 6% each (18%)

Midterm: (20%)

Final （40%）.

2. 课程目标的考核占比与达成度分析

表 5：课程目标的考核占比与达成度分析表

考核占比 / 课程目标	平时	过程化考试	总评达成度
课程目标 1	60%	60%	N/A
课程目标 2	20%	20%	
课程目标 3	10%	10%	

课程目标 4	10%	10%	

（三）评分标准

课程目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
课程目标 1	Completely master the basic knowledge of the course Fully understand the basic properties of electromagnetic fields and concepts of time and space Form a correct dialectical materialist world view and a scientific view of time and space.	Master the basic knowledge of the course, have a better understanding of the basic properties of electromagnetic fields and time and space Form a correct dialectical materialist world view and a scientific view of time and space.	A good grasp of the basic knowledge of the course A good understanding of the basic properties of electromagnetic fields and time and space Form a correct dialectical materialist world view and a scientific view of time and space.	Basically master the basic knowledge of the course Basic understanding of the basic properties of electromagnetic fields and time and space Form a correct dialectical materialist world view and a scientific view of time and space.	Without mastering the basic knowledge of the course Without understanding the basic properties of electromagnetic fields and time and space A correct dialectical materialist world view and scientific view of time and space have been initially formed.
课程目标 2	Deeply understand the physics thinking in the process of establishing the electrodynamics theory Forming scientific thinking methods such as model construction, analysis and synthesis, reasoning and analogy Being able to apply field theory and other mathematical methods	Experienced the physics thinking in the process of establishing the electrodynamics theory Formed scientific thinking methods such as model construction, analysis and synthesis, reasoning and analogy Being able to apply field theory and other mathematical methods to analyze and solve	Have a good understanding of the physical thinking in the process of establishing the electrodynamics theory Have formed a better scientific thinking methods such as model construction, analysis and	Basically experience the physical thinking in the process of establishing the electrodynamics theory Basically forming scientific thinking methods such as model construction, analysis and synthesis, reasoning and analogy Can basically apply field theory and other	Without understanding the physical thinking in the process of establishing the theory of electrodynamics Scientific thinking methods such as model construction, analysis and synthesis, reasoning and analogy have

课程目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
	to analyze and solve physical problems.	physical problems.	synthesis, reasoning and analogy Can basically apply field theory and other mathematical methods to analyze and solve physical problems.	mathematical methods to analyze and solve physical problems.	been initially formed The mathematical methods such as field theory cannot be used to analyze and solve physical problems.
课程目标 3	Properly apply electromagnetic field theory to analyze and discuss problems in middle school physics electromagnetics, and have a good scientific research ability.	Can better apply electromagnetic field theory to analyze and discuss problems in middle school physics electromagnetics, and have a good scientific research ability.	Can apply electromagnetic field theory to analyze and discuss problems in middle school physics electromagnetics, and have a certain scientific research ability	Basically be able to apply electromagnetic field theory to analyze and discuss problems in middle school physics electromagnetics, and form a preliminary scientific research ability.	The theory of electromagnetic field cannot be used to analyze and discuss the problems of electromagnetics in middle school physics, and the ability of scientific research is relatively weak .
课程目标 4	Experienced the physical thought and scientific spirit of physicists Has a high patriotic enthusiasm, and has consciously formed a high sense of responsibility and mission to explore the unknown Pursue the truth, and climb the peak	Experienced the physical thought and scientific spirit of physicists Have a high patriotic enthusiasm, and have consciously formed a high sense of responsibility and mission to explore the unknown Pursue the truth, and climb forever.	Have a good understanding of the physical thoughts and scientific spirit of physicists Have a high patriotic enthusiasm, and have formed a sense of responsibility and mission to explore the	Have basically experienced the physical thought and scientific spirit of physicists Have a high patriotic enthusiasm, and have basically formed a high sense of responsibility and mission to explore the unknown, pursue the truth, and climb	The sense of responsibility and mission of physicists are weak Unable to appreciate the physical thought Scientific spirit of physicists are relatively weak in exploring the unknown,

课程目标	评分标准				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
	forever Firmly established firm ideals and convictions, and established the professional ideal of learning to be a teacher and behaving in future	Established firm ideals and beliefs, and established the professional ideal of learning to be a teacher and behaving in future	unknown, pursue the truth, and climb forever Basically established firm ideals and beliefs, and established the professional ideal of learning to be a teacher and behaving in future	forever Basically established firm ideals and beliefs, and established the professional ideal of learning to be a teacher and behaving in future	pursuing the truth, and climbing forever .