



Cultivation of Scientific Thinking Ability and Innovation Ability in the Teaching of Electrodynamics

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Abstract

As the important part of the theoretical physics, the electrodynamics is a theoretical basic course of the physics and relative subjects. To adapt the demands for cultivating the target of highly-quality talents in the 21st century, students' scientific thinking ability and innovation ability should be mainly cultivated in the teaching. Based on practice experiences, this article describes the establishment of the new physical theory, narrates the development of the subject and its application in the modern scientific technology, and studies the cultivation of students' two abilities combining with scientific researches.

Keywords: Electrodynamics, Cultivation of abilities

Electrodynamics is the theory system which systematically expatiates on the basic property and the motion law of the electromagnetic field and the mutual function between the electromagnetic field and the charged matters based on the electromagnetism. It is the important part of the theoretical physics, and a theoretical basic course of the physics and relative subjects. In the construction of the electrodynamics course, students' scientific thinking ability and innovation ability can be cultivated from three aspects such as teaching thought, teaching content and teaching method. As the theoretical base course, its task is not only to educate students to study and learn basic concepts and basic theories, but to cultivate student's primary ability to flexibly utilize relative knowledge and create new knowledge. Therefore, the teaching of course is not only a process of knowledge transfer, but the composing part of the prophase stage to cultivate students' scientific research ability, which is completely consistent with the requirements for students to contact and participate in scientific researches in the undergraduate learning stage. Knowledge is the base of innovation, and the innovation ability is the sublimation of knowledge accumulation. Based on that, the knowledge transfer and the ability cultivation should be closely associated and combined organically to cultivate students' two abilities in the teaching of electrodynamics course.

1. Describing the establishment of two new physical theories in the course to cultivate students' two abilities

The contents of the electrodynamics should include Maxwell's electromagnetic theory and Einstein's special theory of relativity, which are two new physical theories with the function of milestone in the development history of physics. New physical theories have some universal characteristics. At the beginning of the course, teachers can explain three characteristics of new physical theories to students, i.e. new theories contain the reasonable core part of original theories, new theories can illuminate the physical phenomena that original theories can not explain, and new theories could predict new physical effect and be validated by future scientific experiments. For the establishment of two theories, teachers can concretely analyze it according to three characteristics, and make students to know the relationship of inheritance and development between the new theory and original theory, where the innovation of new theory could be reflected in the new theory, how to analyze and evaluate a new physical theory, what is the basic direction to create a new physical theory. New physical theories are always generated in the process to discover and solve conflicts. When narrating the establishment of Maxwell's electromagnetic theory, teachers can point out the serious conflict between the basic law, law of electric charge conservation, with the situation when the law of static filed is extended to the change with the time, and help students to understand the rationality and the science property of the introduction of displacement current from the teaching form and the physical essential. When narrating Einstein's special theory of relativity, teachers should point out the irreconcilable conflict between the space-time view of the classical mechanics and the Maxwell's electromagnetic theory which has been validated by the experiment, and two basic principles of the special theory of relativity could solve this conflict, and develop a new space for the development of physics. Teachers

should deeply know the important meaning and function of being good at discovering problems and solving problems to understand the objective world. The organizers of the new physical theory have strong spirit of exploitation and innovation. Faraday put forward the profound idea of the field, and successfully found the law of electromagnetic induction when seeking the inverse effect that electric currents generated the magnetic field, but he didn't further analyze though the changing magnetic field could generate the changing electric field, the changing electric field could also generate changing magnetic field. But Maxwell discovered this physical law, and put forward the concept of displacement current, and created the universal theory to describe the whole macro electromagnetic law. When the narrow relativity theory was generated, there were several approaches to solve this conflict, but Einstein modified the Newtonian mechanics which was natural for people in a long term. The mathematical form of the Lorentz Transformation describing the space-time view of relativity occurred before the relativity theory, but there were no people to point out the profound physical meaning of this transformation then, which fully reflected Einstein's extraordinary science insight and spirit of exploitation and innovation. Teachers integrate these contents into the teaching could help students to stimulate their innovational spirit and innovational ability. The establishment of new physical theory completely accords with the epistemology law of the dialectical materialism. And teachers could lead students to review the establishment process of Maxwell's electromagnetic theory and Einstein's special theory of relativity. First, based on the discovered experiment law of the electromagnetic phenomena, comprehensively analyze relative experiments, second, introduce the scientific hypothesis of displacement current, generalize and the electromagnetic law, and put forward Maxwell's equations in a creative way, third, validate the correctness of Maxwell's equations by large numerous scientific experiments, and instruct many scientific practices, and form the classic electromagnetic theory to reflect the objective laws. The above process is "practice-theory-further practice", and it is the classic example of the cognition law, i.e. "practice is the sole criterion for testing truth".

2. Narrating the development of the subject and its application in the modern scientific technology to cultivate students' two abilities

Teaching content should not be close type, but open type. Because the subject continually develops, so teachers should tell students that the theoretical system is not perfect, and point out the problems which have not been solved and unknown domains in this subject, and lead them to pay attention to the relative production and technology projects closely related with this subject and the development direction of this subject. The application range, limitation and future development of the theories should be emphasized. For example, the classical electromagnetic theory could only be applied in the macro range, and with the development of the microscopic property of the electromagnetic field, the quantum electrodynamics occurs and develops. And the narrow relativity theory could only be applied in the inertial reference frame, and in the non-inertial reference frame, the general theory of relativity corresponding develops. For some basic concepts, theories and methods, the change and development should be introduced. For example, by introducing the Aharonov-Bohm Effect, teachers can point out that in the classical electrodynamics, force is an assistant quantity of descriptive method introduced for the mathematical convenience, and the gauge invariability is the requirement for this descriptive method. But in the quantum mechanics, force is the observable physical quantity, and its status is more important than in the classical mechanics. In the modern physics, the gauge transformation was introduced by the basic principle of the quantum mechanics, and the gauge invariability is an important physical principle. The development of the laser theory and technology also make people more profoundly understand the relationship between micro structure and the macro field of the electromagnetic field. Teachers should pay attention to introduce the new requirements of the modern production technology practice to the subject of the electrodynamics, for example, the new materials with special electromagnetic property and better electromagnetic functions change quickly and develop continually, and the researches about the electromagnetic characteristics of materials under extreme conditions have been concerned by people. At the same time, teachers should point out that new practice will continue to drive the new development of the electrodynamics, and people's cognition about the electromagnetic field is not exhaustive. The course teaching should closely associate with the new scientific technology and practical application. The electrodynamics contains the universal laws of all macro electromagnetic phenomena, so it is one of basic principals of the substance movement in the nature, and it closely associates with many domains in the modern science and technology, so it is very necessary to expatiate on this association. Though Maxwell's electromagnetic theory belongs to the classical physical theory, but it can describe the relationship with the modern science technology and its application. For example, the plasma, super-conduct and flux-quantization, magnetic monopole and charge quantization can be explained as viewed from the electrodynamics. When explaining the characters of the evanescent wave in the total reflection, teachers should associate with the laser accelerator, and when explaining the electromagnetic media, teachers should introduce the non-linear optics and the optical chaos, and when explaining the conductor spheres in an external uniform electric field, teachers should introduce the principle of the artificial dielectrics, which all reflect that the information science and technologies in the time of information are all related with the electromagnetic phenomena. The relativity theory is one of greatest achievements of physics in the 20th century, and it is the base of modern physics. Therefore, teachers should give attention to explain its association with the frontier researches and modern technologies,

the threshold energy reflected by the elementary particles, the Mossbauer Effect and its technology, the microwave background radiation of modern cosmology, the transverse Doppler Effect and the gravitational red shift.

3. Combining with scientific researches to cultivate students' two abilities

One of important approaches to cultivate students' two abilities is to participate in the practice of scientific research, and the task of the course teaching is to prepare and create conditions for students to contact scientific research, for example, enhancing the jumping-off point of course, and use the new opinion and new methods in the modern scientific research to explain the basic theory. And the content of classical physics should be explained by some modern opinions and methods. The teaching tool and the disposal method can utilize some modern analysis methods. For example, when explaining the vector and tensor, the concepts of the local coordinate and whole coordinate can be introduced to explain the total reflection could treat the vector and tensor operation from the symmetric tensor, and when explaining the electromagnetic radiation, the disposal method of projection operator can be introduced. For the physical characters and meanings, some new concepts and opinions can be adopted and introduced. For example, when explaining the gage transformation, the concepts about the transverse photon, longitudinal photon and the time photon can be introduced, and when explaining the characters of the basic equation of the electromagnetic field, and concepts about the dual transformation, dual field and the dual ovulation can be introduced, and teachers can also introduce the charge conjugation transformation C, the spatial alternation P and the time reversal T and CPT joint inversion to understand the classical electromagnetic law from new angle. When completing the teaching task, teachers should give attention to put forward the research task and implement the teaching research in the teaching practice. In the school-teaching period, teachers can dispose and instruct students to write small papers, which can combine students' learning with searching, and combine practice and research, and cultivate students' scientific research ability.

4. Paying attention to the thinking methods and disposal methods to cultivate students' two abilities

Correct method can not only enhance students' learning quality and efficiency in the process of knowledge learning, but influence students' ability of science and research. Therefore, in the course of teaching, the thinking method and the disposal method should be emphasized to lead students to grasp and acquire knowledge and create knowledge. For example, in the electrodynamics even in the whole physics, one characteristic quantity often is introduced to describe the exponential decreased law, and the characteristic time will decrease with the change of time, and the characteristic length will decrease with the change of space. When teachers point out this universality, students can easily deeply understand the concepts such as the relaxation lifetime of the charge change in the conducting medium, and the penetration depth when the electromagnetic waves radiate into the conducting medium, and deeply grasp this descriptive method. The discussion about the physical meaning to introduce the new defined quantum is a universal problem in the whole physics, and the physical meaning of the new introduced quantum can be analyzed and deduced from the physical meaning of original quantum in the expression, and this thinking way can be used to explain the energy flux density, the momentum density, the momentum flow density, and many concepts of the electromagnetic field can be explained. Teachers should give attention to the method combining physics with mathematics. Based on the explanations of basic principle and laws, teachers can start from the physical premise, and implement mathematical description and deduction, discuss the physical meaning of mathematical result, and open out the physical image. For example, when explaining the Lorentz transformation, the requirements of two basic principles of the relativity theory to the space-time conversion can be first analyzed, and teachers could deduct the transformation form from the mathematical angle, and finally explain the new time-space view, so a series of physical deductions can be obtained. In some concrete mathematical deductions, to closely combine with physical analysis can not only help students to understand the physical meaning of each mathematical result, but simplify the mathematical operation some times. For example, when computing the electric dipole moment generated by the charges distributed by the form of cosine function on the spherical surface, and the magnetic dipole moment generated by the rotation of certain diameter surrounding on the charged sphere, teachers can analyze the direction of the moment from the angle of physics, give prominence to the physical images and simplify the computation process. Teachers should also emphasize the approximate disposal method. The essential of the approximate method is to solve problems by grasping the main conflict and ignoring the subordinate factors, and it has been largely utilized in the teaching and research of physics. This method can solve some problems which can not be solved strictly, and simplify some problems which can be solved, so it can well accord with the requirements of production and practice. In the explanations of basic theories such as electromagnet radiation and diffraction phenomenon of electromagnetism, this method can be adopted, and when solving some concrete problems, this method can also be used to instruct students. When seeking the penetration depth of the electromagnetic wave of the good conductor, and the reflectance of the good conductor to the electromagnetic wave, teachers should instruct students to consider the good conductors and make approximate simulation, and obtain simple result. For the radiated field and the quasi-static electromagnetic field, the approximate result of the fields of the charge system in different spaces can be pointed out, and teachers could explain that the quasi-static electromagnetic field has been extensively applied in the engineering technologies. And teachers should explain the method of same problem from different angles and approaches, and deduct the basic law by different methods, and embody this method

by many solutions, which can not more completely and profoundly help students to know the problems, but accept and understand the solution of the problems. For example, for the point charge and grounding conductor sphere system, the method of separation of quantity and the image method can be respectively used to solve it, and the results can be compared, and the relationship between this method and the corresponding Green's function can be explained. To analyze the interactive relationships among several representative methods of solving the problems in the static electric fields can not only help students to easily grasp the solution, but deepen their understandings about the unique solution of the static electric field.

In a word, in the teaching of electrodynamics, teachers should emphasize the establishment law, characters, scientific meaning and innovation of new physical theories in the courses, closely associate with new scientific technologies and practical application, utilize the opinions and methods of scientific research to enhance the jumping-off point of courses, combine with their own research experiences and results to help students enter the track of scientific research, emphasize the thinking methods and disposal methods to instruct students to grasp the scientific methods of acquiring knowledge even creating knowledge.

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