Study on the Main Methods of Simplifying Complex Problems in Physics

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Abstract. The simplification of complex problems is the basic research idea in physics. The work studied the main methods of simplifying complex problems in physics by exploring specific cases and summarizing the general practice. Meanwhile, we discussed the role of these methods in learning and research and how to enlighten students in teaching so that they can better understand and apply these methods.

Introduction

How to simplify complex problems is a problem that people focus on. A lot of researches on this issue have been done in art of leadership\cite{1}, business management\cite{2}, mathematics\cite{3}, medicine\cite{4}, etc. However, there are few researches discuss how to simplify complex problems in physics. Peilin Jie only discussed the issue from the perspective of the ideal model\cite{5}. There are many ways to simplify complex problems in physics. By exploring specific cases and summarizing the general practice, this paper studies the main methods of simplifying complex problems, that is, the ideal model, the special situation method, the analysis and synthesis method. Meanwhile, we discussed the role of these methods in learning and research and how to enlighten students in teaching so that they can better understand and apply these methods. Applying which methods to solve problems is also discussed.

The Ideal Model

The so-called ideal model is to seize the main factors of complex problems and ignore nonessential secondary factors, thus simplifying practical problems. It is impossible to solve the problem without ignoring nonessential secondary factors because the reality is too complex. Because of this, the ideal model is widely used, not only in physics, but also in mathematics, economics, finance, geography, etc. It embodies the idea of “approximately solving the problem”—generally, the ways approximately solving the problem can be called the ideal model. The ideal model is approximate to the reality, which will result in actual deviation. The significance of the ideal model is that it is successful and applicable if meeting our accuracy requirements with relatively small deviation; if not, the model needs to be modified. The general approach is to reconsider some important factors that are ignored. The model and the actual situation should be thoroughly analyzed when there are conflicts between ideal model and the actual result. From these analyses, we can usually be inspired to form a new scientific prediction. The crystal studied in solid state physics is complete without any defects, named ideal crystal. After the strength calculation with microscopic theory, it is found that the obtained strength is 1,000 times larger than that of the actual metal material. So some scholars predicted that the strength of mental material is weakened due to many defects in the actual material, resulting in the study of the point defect, the line defect, the plane fault and the volume defect. Furthermore, the prediction is confirmed in practice. For an ideal model, there is the scope of application. Once beyond the scope, it will cause larger deviation, and the model needs to be further modified. For example, the ideal gas model is successfully applied in the study of pressure and temperature, but causes unacceptable deviation in the study of energy. When studying the energy problems, the ideal gas model needs to be modified, and the gas molecules should be considered as free, elastic particle groups.
Establishment of the ideal model needs a thorough understanding of the problem studied. Only in this way can primary and secondary factors be distinguished, thus simplifying the practical problems. In physics, there are many cases of the ideal model, in addition to the common examples of the particles, the rigid bodies, and the ideal gases, the center of the positive and negative charge of a dielectric molecule is a very typical example. Obviously, the electric field generated by all the positive charges of a dielectric molecule is not strictly equivalent to that generated by the point charge gathering all the positive charges of a dielectric molecule. The electric field generated by the negative charges of a dielectric molecule is also the same. After making such a bold approximation, it is easy to analyze the changes of a dielectric molecule in the electric field, and the polarization charges on the surface of the dielectric in the electric field are easy to be understood. If this approximation is not done, the analysis of the change of the dielectric molecules in the electric field is difficulty. The Compton scattering is also a typical example. We regard the collision of photons with outer electrons as the collision with free electrons, and the collision of photons with inner electrons as the collision with the entire atom. It is a typical simplification of the complex problem by seizing the main factors and ignoring the secondary factors.

The ideal model is one of the most important methods in physics, and everyone who has studied college physics should master it. It is not only a basic method for research, but also a basic idea for analysis. When facing practical problems, we should first think about what are the main factors, which are the secondary factors, and then the actual problem is simplified by ignoring the secondary factors. The ideal model is an important part of college physics teaching. With the introduction of the ideal model, the abstraction becomes concrete, the complexity becomes simple. Meanwhile, the education of this method helps to cultivate the students' thinking ability. By teaching of the ideal model, we can educate students to learn how to perform scientific abstraction, that is, how to seize the main contradiction and ignore the secondary factors.

The Special Situation Method

For a complex problem that is difficult to be dealt with, some valuable conclusions can be obtained by studying its special case that is easy to be solved, such a method called the special situation method. This method simplifies complex problems by studying the special situation which is easy to be solved. If a problem is too complex, and the main and secondary factors are difficult to be distinguished, the method can provide us the breakthrough point for research. It is an important research method which is widely used in physics. The quasi-static process in thermodynamics is a typical example. Strictly, the intermediate state of a thermodynamic process is non equilibrium state without identified temperature and pressure, which is difficult to study. The quasi-static process is the special situation of the thermodynamics process, and any intermediate state is the equilibrium state. This has brought great convenience for us to study the complex problem. Due to identified pressure and temperature as well as the ideal gas satisfying the state equation, it is easy to calculate the power, the heat and the entropy in the quasi-static process.

The special situation method is widely used in solving physical problems, economic problems, social problems, and even political issues. These problems are often very complex and are affected by many factors. Sometimes it is difficult to find out which are the main factors, and which are the secondary factors. Taking stock price as an example, there are too many factors that affect the stock price, and some incidental factors can make a great fluctuation in the price of a stock. It is difficult to find out which are the main factors, and which are the secondary factors that can be ignored. In this case, people put forward the concept of the effective market, which is a typical special situation of the stock market. On the basis of the effective market, a series of meaningful research results are obtained, such as the capital asset pricing model (CAPM), which is widely used in asset valuation, capital cost budget and resource allocation and other aspects

The special situation of complex problems, which is usually not obvious, is obtained by analysis and research. Therefore, using this method to study the problem, it is necessary to have a thorough understanding of the issues studied, and then find out the special situation of complex problems. The special situation can also draw many valuable conclusions. We have taken the quasi-static
process as an example, the Carnot theorem which pointed out an important direction for improving the efficiency of the heat engine did not exist if without the concept of quasi-static process. In the course of teaching, we can enlighten students by induced way. For example, when facing difficult problems, students can not give up, and should try to find a special situation that is easy to be solved as physics predecessors do, and some meaningful results can be obtained by studying the special situation of the complex problem.

The Analysis and Synthesis Method

“Analysis" is the method to divide the whole object into several simple parts, aspects, factors or levels for investigate and research respectively. “Synthesis”, based on analysis, is the method to combine the parts, aspects, factors or levels of the object to obtain their relationship. It is to find out the relationship between them and to grasp the essence and the rule of the whole object. This method simplifies complex problems by dividing complex problems into the superposition of simple problems. The analysis and synthesis method is the basic thought method, and an in-depth understanding of the object. This method is inseparable in the formation and development of scientific theory as well as the research and solution of practical problems.

The analysis and synthesis method is widely used. For example, in math, any vector can be divided into the superposition of simple vectors along three axes directions; a complex project in management can be divided into the combination of simple tasks. In physics, a complex motion can be divided into the superposition of simple motions by using the principles of motion superposition. For example, the horizontal projectile motion is divided into the superposition of the freely falling body and the horizontal uniform linear motion; a complex vibration is divided into the combination of simple harmonic oscillation with different frequencies; any color is divided into the combination of three basic colors—red, green, and blue. Similar examples in physics are very common.

Rivers are formed with small streams. The complex problems can be solved by completing series of small problems. The analysis and synthesis method provides a research way which is not the same as the ideal model and the special situation method. By decomposing the complex problem into a series of simple problems, the complex problem can be solved easily.

Conclusion

There are many methods to simplify complex problems in physics, and the most common methods are the ideal model, the special situation method, the analysis and synthesis method. The ideal model is to simplify the complex problems by seizing main factors and ignoring secondary factors; the special situation method is by studying the special situation which is easy to be solved; the analysis and synthesis method is by dividing complex problems into the superposition of simple problems. Three methods have different advantages, which can complement each other, and can provide valuable guidance for the solution of complex problems. In practice, applying which methods to solve problems requires a concrete analysis of each specific question. The ideal model is used for the situation that main and secondary factors can be distinguished; the analysis and synthesis method is used for the situation that complex problems can be divided into the superposition of simple problems. If the two methods are not feasible, we can try to find its special situation that is easy to be studied, and draw some valuable conclusions by studying the special situation.

References


