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## Thoughts on the Karlsruhe Physics Course

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### Introduction

I believe that everybody present here will be greatly interested if I say that there is a physics course-book which can be used to explain, in a way readily comprehensible to the average senior high school students, and in one single class hour (40 minutes), the concept of “entropy” that has been considered to be so abstract and complicated, the definition of “heat pump”, and so on. This book expounds explicitly all three Newton’s laws of motion by using only one law; in addition, this book has solved the problems regarding the forms and transformation of energy by introducing the concept of energy carrier. You may ask: is there really such a book, and what kind of book is it? My answer is definitely in the affirmative. The course-book I have in mind is a German one entitled *Der Karlsruher Physikkurs (KPK)*, or Karlsruhe Physics Course (KPC) in English.

Karlsruhe is a city in southwestern Germany, where there is a university of the same name. It was here that Heinrich Rudolph Hertz, a great master of physics, discovered the electromagnetic wave in 1886. Now as the hard core of a team of physicists, Professor G. Falk (deceased) and Professor F. Herrmann, both of the University of Karlsruhe, and Doctor G. Job of the University of Hamburg, standing on a vantage point and taking a broad and long view, have been pondering on the history of the development of physics and examining the various established concepts and laws of physics. As a result, they find it absolutely necessary that traditional or classical physics should be systematized, trimmed, even restructured. After two generations of arduous work, a fairly integrated new system of physics has now taken shape; a number of new physics teaching materials at different levels are being compiled one after another.

To put it plainly, the work of the German physicists may be likened to that of a gardener working hard to weed a garden and revamp its layout until it takes on a completely new look; or it may be compared to archeologists trying to restore fragments of historical relics so that at long last they may appear in their original splendor of the days gone by; or again it may be compared to builders of tourist attractions constructing roads and cableways so that tourists no longer have to climb up hills along rugged mountain passes traversed by hunters and gatherers of medicinal herbs; and in this way a lot of time and energies are saved, thus enabling senior people and children to reach the hill top and admire nature’s beauty. As a matter of fact, these analogies fall far short of the contributions made by the German physicists. The real value of the contributions they have made consist in the fact that they have summed up the general structural characters, or the general laws, of the different branches of physics, and integrated those different branches in an organic and harmonious way, thereby making it much easier for students to understand and memorize the characters or laws, and to gain, with sufficient leeway, a thorough understanding by means of a comprehensive study of their subject, and also to enable them to draw inferences about other cases from a single instance. As a result of all this, study efficiency can be enormously raised.

I think that once you have had a true understanding of what the KPK Physics Course is really like, you may possibly utter a cry of astonishment and say: “Oh, I never imagined physics could actually be made to look like this!” As a matter of fact, the KPK physics course-books have been experimented on and been in use on a trial basis for over twenty years in Germany, with very good results. Up to now, they have been translated into several other languages including English, Italian and Chinese, and both teachers and students have benefited from them a lot. In China, authorities responsible for education have been paying close attention to the KPK teaching materials for a couple of years, and feasible measures are being taken to introduce them into the Chinese schools.

## Significance of educational reform for physics in China

As everybody knows, in China the problem of the reform of English teaching has been frequently voiced in recent years. From government leaders to teachers and students at all levels of education, people are becoming increasingly aware of the inefficiency of English teaching and learning. English is allocated more class hours on the curricula than all other subjects, and then the teaching and learning process lasts from the primary stage of education until the third year at college, but generally takes very limited effect. Consequently, it is often the case that after more than ten or even twenty years of study, the learner may remain weak in the four language skills, i.e. speaking, listening, reading and writing. Thirty years have elapsed since China began implementing its reform and opening policies, yet people who have attained a truly high level in English are still in very short supply, hence the crying need for change. By comparison, the need of reform in other basic disciplines does not seem to be at all so urgent. However, the fact is that to a greater or lesser degree, a similar state of affairs does exist in the teaching of science subjects as well — only the problems have not yet come to the surface. But this does not mean that they are not serious enough to warrant proper attention and the transformation that is so urgently needed.

As is well known, physics functions as the foundation upon which the development of science and technology depends. If China is provided with a massive army of research workers, engineers and technicians, all well-versed in the basic knowledge of physics, it will not be long before our country will have trained our own physicists ranking high in the world and Nobel laureates as well. Therefore, for the purpose of modernizing science it is of vital strategic importance to carry out the task of transforming the teaching of physics, a task of reform no less important than in the other disciplines. I am sure that once you have gotten an initial understanding of the KPK materials, you will feel an overwhelming desire for transforming the physics courses of study currently being used in China, including those intended for use in China's middle schools and universities as well as graduate schools. By researching, analyzing, and drawing on the advantages of the KPK Physics Course, we will certainly be in a position to make foreign things serve the needs of China, and play a positive role in transforming the physics teaching materials in China. In the final analysis, the competition of national strength between the countries of the world today is nothing less than a competition of scientific and technological strength, or rather, a competition for talented people. If we educate more of our talent in a faster and better way to build up a large and powerful contingent of people dedicated to science and technology, we will certainly be able to emerge victorious from fierce competitions as a really great country of the world.

## Main distinguishing features of KPK physics course

### 1 Contemplate in retrospect, and get rid of the historical burden

Traditional course-books or textbooks of physics usually make a systematic exposition in chronological order according to the history of the development of physics, and stick more or less to an old-fashioned or 'biological' way of presenting the relevant stages of development from one generation to the next. The fallacy of such a pattern often leads to a tendency of retaining in the teaching system the tortuous processes of development, and/or even some wrong or dated ideas, which are likely to turn out to be hindrances in the teaching and learning process. Standing on a commanding height of modern physics and looking back to the history of the development of physics, the writers of the KPK Physics Course have sifted and systematized the whole range of materials for physics education; discarding the dross and the false while retaining the essential and the true, they have successfully cast off the burden of history and simplified the theoretical system of physics in its entirety, thereby changing a senile old man, so to speak, into a robust young fellow. To illustrate the point, I will take mechanics for an example: the KPK Course has boldly discarded Newton's laws of motion used in traditional physics teaching as the main thread running through the section on mechanics and enables the teaching to take on an entirely new aspect. Another example is the introduction of such modern concepts as *field*, *current*, *etc.* which simplify the process of teaching and learning and hence makes the physics easier to comprehend.

### 2 A new structure with analogous branch structures made conspicuous

In the absence of the historical burden, the writers of the KPK Course have restructured the whole system of physics and made it clearer and more concise. What is more, the similarities or identities in its branches' structures, or the analogous structures of the different branches of physics are

brought to the fore and integrated into a unified common structure, so teachers and students alike find it easier to make use of the KPK. In a word, a short cut to physics teaching and learning has come into being, making it possible to train more students in a better and faster way. In KPK, the terms of physical quantities such as energy, momentum, electric quantity and entropy are referred to as extensive quantities. These quantities have a common characteristic: they can be regarded as being contained in a certain physical system and are capable of flowing from one system to another. Therefore they can be described as a *substance*, or as a substance-like quantity, as is often the case. Taking a substance-like quantity as the starting or central physical quantity, together with its current, KPK has constructed a new discipline of physics. In fact, KPK has not only integrated the different branches of physics, but also parts of chemistry, information science and modern physics, into a unified and harmonious system. Some new concepts embodied in the new system such as momentum current, entropy current and energy carrier have made it possible for us to view what physics is all about with a completely different light. By means of the new layout, it is not difficult to see that similar laws and structures repeat themselves in mechanics, electricity, thermodynamics and chemistry (see the table below), and to a certain extent in optics, acoustics and electronics. In consequence, the student only has to understand the structure and laws of

Table. An Analogy between Some Branches of Physics (Chemistry is also included)

Branch	Energy & its carrier	Potential	Current	Energy current
Mechanics	Energy $E$ & momentum $\mathbf{p}$	Velocity $\mathbf{v}$	Force $\mathbf{F}$	$I_E = \mathbf{v} \cdot \mathbf{F}$
Electricity	Energy $E$ & electric quantity $Q$	Electric potential $U$	Electric current $I$	$I_E = U \cdot I_Q$
Thermodynamics	Energy $E$ & entropy $S$	Temperature $T$	Entropy current $I_S$	$I_E = T \cdot I_S$
Chemistry	Energy $E$ & amount of substance $n$	Chemical potential $\mu$	Substance current $I_n$	$I_E = \mu \cdot I_n$

a single branch of physics to master another branch with ease. In this way, the student is able to comprehend the whole category by analogy and draw inferences of his or her own without help, and efficiency is enormously raised. "It is conducive to fostering the ability of *systems thinking and to reasoning by analogy*," as the Germans put it.

### 3 Laying stress on experiments & integrating theory closely with practice

The KPK Course writers have designed a large number of experiments characteristic of demonstration in order to aid students to comprehend the theoretical knowledge in their course-books. Most of the experiments, which are uniquely contrived and closely related to practical life, have achieved good results. The equipment or set-ups used to conduct the experiments is new and original and easy to make. Professor Herrmann, the chief writer, has provided the books with many illustrations made by himself; so that their readability is greatly enhanced, and the teaching and learning process hugely vivified.

### 4 Extensive range of knowledge covered and importance of innovation stressed

As is well known, people who have extensive knowledge are in a better position to put forth new ideas and draw inferences from what he knows about a particular subject, whereas those whose range of knowledge is very limited are rarely inspired with innovative ideas. The KPK Physics Course has substantial content, and a wide coverage of knowledge which, besides the content of traditional physics, touches upon chemistry, the science of information, solid-state physics, hydraulics and even the theory of relativity. In addition, it is related to many things in everyday life including household appliances, daily articles and such hot issues concerning environmental protection as greenhouse effect, global warming and energy-saving, etc. The KPK course-book also contains enlightening explanations of the latest scientific and technological achievements of the world in order to broaden the horizons of the students and develop their thinking, thereby making it possible for them to make associations between different notions or things and come up with creative sparks.

## 5 Explaining the profound in simple terms to achieve higher academic level

On the basis of a thorough rejuvenation of the old system of teaching materials, the teaching of KPK is able to be conducted in a brand new way in which the profound is explained in simple terms and higher academic standards are achieved. For instance, in KPK, mechanics teaching begins with the introduction of the concept of momentum, followed by an introduction of the concept of momentum current (i.e. the concept of **force** in traditional physics) in combination with the time factor. The result is that the old teaching pattern in which Newton's laws of motion are considered predominant principles is superseded. This change not only makes it more convenient to explain many of the mechanical phenomena, but also simplifies Newton's laws of motion themselves (One single law is used to expound what is contained in three laws). Besides, the introduction of the concept of *field* and that of relativity is a gain in profundity but not in difficulty. Another point worth mentioning is that the teaching of thermodynamics can begin directly with the concept of entropy (i.e. the amount of heat) to enable students, including senior middle school students in the first grade or even some junior middle school students, to comprehend without much difficulty the abstract concepts which used to be headaches for college students. Obviously, in this way the academic standard of the discipline of physics is raised. One more example: the fact that the idea of energy carrier supersedes the idea of energy form and its transformation helps students understand the important aspect of physics, moreover, it has kept teachers from being perplexed while giving lectures on related subjects. In short, such examples are too numerous to mention individually. All in all, I think the most significant aspect of the KPK is that it makes abstract ideas much easier to understand. Using the KPK, both teachers and students find it easy to interact with each other and the forced-feeding method finds less and less support.

To sum up, the KPK physics course-book is an excellent teaching material and it is hard to come by. It is certainly worthwhile for us to draw its strong points for our own use. "A rock from another mountain can be used to chisel your own jade," as the Chinese saying goes. I hope that by examining, analyzing, digesting and assimilating it, we can give more impetus to the reform of China's physics syllabus and modernize our physics teaching as soon as possible.