Expert opinion on the Karlsruhe Physics Course

Commissioned by the German Physical Society

Contact:
STD Rudolf Lehn, DPG-Vorstandsmitglied für das Ressort Schule
(sfz@uni.ulm.de)

Expert group:

Prof. Dr. Matthias Bartelmann, Theoretische Astrophysik, Universität Heidelberg
OStR Fabian Bühler, Störck-Gymnasium Bad Saulgau
Prof. em. Dr. Dr. h. c. mult. Siegfried Großmann, Theoretische Physik, Universität Marburg
STD Wolfhard Herzog, Staatliches Seminar für Didaktik und Lehrerbildung Heidelberg
Prof. em. Dr. Jörg Hütner, Theoretische Physik, Universität Heidelberg
STD Rudolf Lehn, Störck-Gymnasium Bad Saulgau und Schülerforschungszentrum Südwürttemberg
STD i. R. Dr. Rudolf Löhken, Staatliches Seminar für Didaktik und Lehrerbildung Heidelberg
Prof. Dr. Karlheinz Meier, Experimentelle Physik, Universität Heidelberg
Prof. Dr. Dieter Meschede, Institut für Angewandte Physik, Universität Bonn
Prof. Dr. Peter Reineker, Wilhelm und Else Heraeus-Seniorprofessor für die Weiterentwicklung der Lehrerausbildung im Fach Physik, Universität Ulm
Prof. Dr. Metin Tolan, Experimentelle Physik, Prorektor für Studium an der Technischen Universität Dortmund
Prof. Dr. Jochen Wambach, Institut für Kernphysik, Universität Darmstadt
Prof. Dr. Werner Weber, Theoretische Physik, Technische Universität Dortmund

Bad Honnef, February 28th, 2013
Deutsche Physikalische Gesellschaft e.V., Hauptstr. 5, 53604 Bad Honnef
Summary

Physics is one of the fundamental sciences of our culture and civilization. Its main task is to trace back the diversity of phenomena in the material world to as few fundamental laws as possible. For this reason it has proved to be successful because its methods are based on three fundamental principles:

- Concepts that are essential for the structure of physics are based on precise definitions or measuring instructions.
- The so-created concepts are connected by model representations.
- Physical statements which contradict experiments are considered wrong

Physical statements are objectively verifiable on account of these principles. As physical statements must be substantiated by measurement, they must also be quantifiable. Therefore, mathematical equations are set up in physics, which relate key observables to each other. This mathematical formulation of their essential assertions requires a precise use of clearly defined terms. An (international) understanding of physics also requires that standardised systems of concepts are used.

It is the conviction of the German Physical Society (DPG) that physics must and can be taught at all levels of education in a way that its essential character is unmistakably clear: Physics is an empirical natural science, which, due to constant and strict orientation along experiments, reaches objectifiable statements. The DPG supports considerations and efforts, to implement this as comprehensively as possible in school classes, but considers it also as its task to criticize failed attempts.

The Karlsruhe Physics Course (KPC) does not meet the above-formulated goals. It builds essentially on concepts that are either arbitrarily chosen, or cannot be confirmed experimentally, or partially contradict measurements. These concepts are introduced solely for didactic considerations and largely serve to keep up with analogies across the entire represented physics. Thus, the KPC creates a fundamentally wrong perception of physics. The rigor of scientific thinking and the empirical approach are violated by the KPC.

Hence, we emphatically advise the German Physical Society that the KPC should not be used for teaching, nor should educational plans be based upon it.

These statements are supported by the following few and especially significant examples.
Example 1: **The concept of the momentum current in mechanics**

In an effort to consider flow processes as a basic element in the presentation of as many parts of physics as possible the KPC introduces within mechanics the concept momentum current instead of force. This is backed up by the notion that a momentum current would be a much clearer observable than force because it suggests comparisons with other processes of flowing. While according to the Newtonian law of motion, force is the cause for the change of the momentum, the KPC claims that a body changes because a momentum current flows into a body, respectively out of it. Now one could suppose that momentum current is simply another word for force. However, this is not so, because the application of momentum current instead of forces leads to contradictory and in part even wrong statements. This is justified in the following.

**What is meant by momentum current?**

The image of the KPC regarding the momentum current should be explained with the help of fig.1 which is taken from the schoolbook based on KPC [1]. A trolley is pulled by a person with the help of a rope and at the same time accelerated. One supposes that the direction of the movement runs along the x-axis. According to the KPC the trolley speeds up because the momentum along the rope flows into the trolley and the flow direction is fixed as follows: A positive momentum flows into the trolley when the momentum of
the trolley increases in the direction of the positive x-axis. The direction of the so defined momentum current, which in the following we call "KPC momentum current", is linked with the direction of the x-axis which is as a rule oriented from the left to the right.

With the traditional concept of force one describes the process in fig. 1 as follows: The trolley is accelerated because force is exercised on the trolley via the rope. This points in the direction of the acceleration. For reasons of clarity we let the force always attack the center of gravity. If force or KPC momentum current accelerate the trolley to the same extent, then both units would be the same size in magnitude and direction. While this is true regarding the magnitude, there may be differences in the directions, shown as follows.

![Figure 2](image)

Figure 2: A truck travels once to the right (a) and once to the left (b). Both times the clutch rod is under tensile stress and both times the x-momentum flows in the negative x-direction. (This part of the figure with caption corresponds to Fig 2:27 of the KPC textbook [1], only the arrows for the forces and directions of the x-axis have been added). The added Figure (c) shows the situation when the x-axis is rotated.

**Behavior under rotations**

How the directions of the KPC momentum current and the force behave under rotations, will be explained in figures 2a to 2c. In fig. 2a a truck pulls a trailer to the right (this situation is comparable with the one from Fig. 1). The
KPC momentum current points to the left, while the force-arrow points to the right. In the next fig. 2b the truck-trailer combination has been turned around by 180°: According to the KPC [1] the direction of the KPC momentum current has not been changed with the transition from fig. 2a to 2b. However, the direction of the force has followed the rotation of the truck-trailer combination by 180°: In both cases the force points in the direction of the tractor unit (fig. 2a and 2b). This is reasonable because the tractor unit is the cause for the acceleration of the trailer.

Can a pupil understand the different behavior of force and momentum current at a rotation of 180°? One can set up the situations in class which are shown in fig. 2a and 2b, by replacing truck and trailer with two pupils who are connected with each other by a rope. The pulled pupil will immediately confirm the direction of force shown in fig. 2a and 2b. But he cannot detect with his senses that the momentum current has not changed direction when the truck moves in the other direction.

In fig. 2c the result of another rotation is shown. Here, not the truck is turned, but the coordinate system. In this new situation the positive x-axis points to the left. As a consequence the direction of the KPC momentum current has also changed as fig. 2c points out. Because of the acceleration of the trailer to the right, its momentum becomes more and more negative. Thus, (positive) momentum must flow out of it.

The comparison of fig. 2a and 2c clearly illustrates that the direction of the KPC momentum current is closely connected with the position of the coordinate system. This leads to the following problems: If one does not know the position of the coordinate system, one cannot determine the direction of the KPC momentum current. Such situations can occur easily when i.e. the truck drives through a forest where no x-axis is marked on the ground. Another difficulty occurs if, e.g., two pupils cannot agree on the direction of their coordinate system. They will give different answers to the question in which direction the KPC momentum current flows and both answers can be correct at the same time! In consideration of such problems one starts asking whether an objective reality can be assigned to the direction of the KPC momentum current and if it is not only an arbitrary stipulation. These considerations will be looked at more closely in the next section.

**Is the direction of the KPC momentum current measurable?**

The great thing about physics is that its statements can be verified experimentally. Hence, it is an important question whether the statements of
the KPC about the direction of the momentum current are experimentally verifiable. Water flows from a higher located reservoir to a deeper one. At any position one can clearly measure the flow direction by using a measuring device which is brought into the stream, e.g., a waterwheel or a cork, which is thrown into the water. In which direction does the momentum current introduced by the KPC flow, and how can its direction be measured? This question shall be discussed with the help of an example which comes from the school book of the KPC (fig. 2.30 from [1]) and is shown in fig. 3a. A spring is clamped in a yoke. All parts of the system are at rest. Nevertheless, the KPC asserts that a circular momentum current flows through the spring and the yoke, the respective directions are indicated by arrows. Since no movement can be seen in the system, a bright student would have to ask how one can actually prove that something is really flowing through the spring. A more difficult question could be: Why is one direction distinguished above the other on an obviously symmetric system? And if the teacher claims this, how can he prove it?

Pupils know from the theory of electricity that one cannot determine whether a current flows through a wire by simply looking at it, and if there is a current, one still does not know in which direction it flows. But pupils also know that there are devices for proving the strength and the direction of the electric current. Two such devices are shown in a circuit powered by a battery in fig. 3b: an electric light bulb and an amperemeter. The light of the light bulb indicates that current is flowing. Its brightness, which is a qualitative measure for the strength of the current, does not depend on the direction of the current. However, with an amperemeter, one can measure both the strength and the direction of the current.
Fig. 3: Measurement of KPC momentum currents and electric currents.
a. The figure corresponds to fig. 2.30 from [1] with the caption: „unpowered momentum current“.
b. Electric circuit with battery, electric light bulb and amperemeter.
c. Schematic representation of the arrangement fig. 3a with inserted system force meter.

Is there a device for the KPC momentum current comparable to the amperemeter? Such a device is not described in the KPC school book. There are those force meters which are well-known in mechanics, where the length of the strained spring is a measure for the strength of the force. But since for every force there is also an opposite equally strong counterforce (actio = reactio) and both of them are completely symmetrical, force meters cannot distinguish the direction as a matter of principle. Figure 3c shows how a force meter could be inserted into the test set-up of fig. 3a. According to the tension in the spring, the force meter is more or less stretched, without a preferred direction. The force meter is, therefore, comparable to the bulb in the electrical case, but not with the amperemeter.

The missing measuring device for the direction of the momentum current is replaced by the KPC with a set of rules (p.18 of [1]), for example:
When there is tensile stress, then the x- momentum flows into the negative x-direction. With such a definition a problem is created, since the direction of the x-axis can be arbitrarily fixed – and changed - in space, regardless of the physical events within the system. This means that the direction of the KPC momentum current can be arbitrarily changed, i.e. independently of events in the system, only by a new choice of the coordinate system. Hence, we conclude that the direction of the KPC momentum current is not a property of the system. However, there is a convention in electricity that defines the direction of electric current, e.g. from the plus pole to the minus pole. Yet, once all amperemeters have been calibrated according to this convention, the directions of current can always be measured in all systems without arbitrariness. For the measurement of the direction of the KPC momentum current there is nothing analogous.

Conclusion: The initial question whether the statements of the KPC about the direction of the momentum current are experimentally verifiable, must be denied. Therefore, the direction of the momentum current introduced by the KPC is an arbitrarily defined convention which has no objective reality: This current does not exist in nature. For this reason the KPC momentum current has no place in the existing framework of physics and most certainly not in physics classes.

**Example 2. Entropy and Heat in Thermodynamics**

The Karlsruhe Physics Course [5] uses an alternative approach to thermodynamics which is based not on the concepts of temperature and heat, but on the concepts of temperature and entropy. It is legitimate and desirable to seek other approaches to physics that facilitates its understanding for pupils, but they must also be convincing and, above all, scientifically correct.

Thermodynamics is an area within macroscopic physics which survived, in its core unaffected, the physical revolutions of the 20th century. It is built upon three basic laws: the zeroth law introduces the concept of temperature. The first law is about the conservation of energy and the second law deals with the properties of entropy.

It is easy to teach pupils the concept of temperature. To their everyday experience we merely add an absolute temperature scale. Furthermore, the pupils have already certain preconceptions with the concept of heat and energy. This, however, is certainly not applicable to the concept of entropy. It is an important quantity for the understanding of processes in nature and
technology. Energy and entropy must be strictly distinguished. Both concepts are necessary to understand, for instance, the conversion of transmitted energy, such as from heat into work. And while heat plays a role in processes and, therefore, is called the process variable, the intrinsic energy and the entropy are state variables. Each body "has" intrinsic energy and entropy, just as it “has” mass, volume and temperature.

Entropy is known as one of the most difficult quantities in physics. Therefore, one is curious how the KPC is going to introduce it. On p. 5 one can read [5] (literal quotes stand in quotation marks):

“You should also know the second quantity that we need (besides temperature) albeit under a different name then is common in physics. It is what we colloquially call “quantity of heat” or simply “heat”. Its physical name is entropy, its symbol is S. and its unit Carnot, shortened Ct."

It is true that the entropy of a system can be changed by supplying or removing heat. But entropy is by far not the same as heat, and cannot be referred to as such, not even “colloquially”. Both have different measurement units, simply for this reason they cannot be identical. Heat is measured in Joule, entropy in Joule / Kelvin. The KPC bases its argumentation almost exclusively on the equation \( S = \frac{Q}{T} \), which in limited cases of a reversible supply or removal of heat \( Q \) at a temperature \( T \), states the entropy change \( S \).

Here, the KPC conceals the limitations of this equation:

1. It uses the equation unchanged even with irreversible processes, though \( S \geq \frac{Q}{T} \) is valid. Thus, it impedes access to the irreversible processes, which are so tremendously important for the understanding of our world. These run in one direction and are not reversible, because the entropy is able to increase spontaneously, but not able to decrease spontaneously! Therefore, the greater-than-sign and not the equal sign applies in the above mentioned relation.

2. There are important processes in which the above formula is not applicable at all, since entropy as a state variable varies without heat supply. Entropy can also vary because other state variables are varied, as state variables are connected with each other by equations of state. An example is the expansion of a gas by the volume \( V \). The result is that the entropy increases with \( S \geq V \cdot \left(\frac{p}{T}\right) \) where \( p \) is the pressure. The KPC cannot comprehensively explain such simple processes.
The above quoted definition of entropy is by no means a lapse, but is used on many pages to explain experiments and everyday phenomena leading to some questionable results. This is illustrated by three examples.

**Thermal equilibration**

In fig.1.5 ([5], p. 7, here with caption reproduced as fig. 4) a very important experiment is shown to pupils in which two bodies initially have different temperatures and are brought into thermal contact. The warmer body cools and the colder heats up, until both have assumed the same temperature. What happens in this experiment?

Pupils who know that a temperature rise is connected with heat supply (and a decrease by heat removal) would probably say that heat flows from the warmer to the colder body. They are right, at least according to all textbooks with the exception of the KPC. KPC’s explanation for this experiment is included in the caption of Fig.1.5, which is reproduced in our Fig. 4: What flows from the hotter to the colder body is entropy. Although it is correct that besides the heat also entropy flows, it is of crucial importance in thermodynamics that entropy is additionally created, so that after the temperature equalisation, there is more entropy in the system of both containers than at the beginning.

This is by no means a small effect which one might ignore but this entropy increase is the most significant aspect of this experiment! It is the actual reason for this process: The entropy increase induces that the heat is exchanged from the hotter to the colder container, but never vice versa.

This crucial aspect is simply concealed by the KPC. The correct caption under fig. 4 would have to be: „Heat flows from the internal container A to the external container B. Besides, the whole energy remains unchanged, while the whole entropy increases.“

---

![Fig. 4: Entropy flows from the inner container A into the outer container B. [This picture corresponds to fig. 1.5 in [5], p. 7.]](image)
Of course, one can also explain this attempt without entropy, without the pupils losing their intuitive understanding, by noting that heat flows from the hotter to the colder body, as long as a temperature difference exists. However, if one introduces entropy in the way the KPC does, and which is a complication in this example, then one also has to fully and correctly explain its role in processes of nature. Precisely this does not happen in the KPC.

**Expansion of gas into vacuum**

The spontaneous and irreversible expansion of a gas into vacuum is another example which can illustrate the properties of entropy. In section 2.7 about irreversible processes (p. 40f) in [5], this phenomenon is also discussed by the KPC (see fig. 5). Picture and caption are not objectionable, but the accompanying text is, from which we quote in the following. At first the KPC notes: „Entropy is produced during the expansion of a gas into vacuum.“ Then the KPC raises the question whether the gas becomes warmer or colder during this expansion and puts two arguments in contrast with each other:

1. Entropy has been generated. If a gas is supplied with entropy, the temperature increases.
2. We had observed earlier that the temperature of a gas decreases when the gas expands, provided, however, we let the entropy remain constant.“

In the case under consideration, the KPC now argues that both effects were present, but which one predominates in the end, would not be easy to predict. As result it is stated: „With the expansion into the vacuum the temperature of a gas does not change. Both effects just about neutralize each other. “One could consider this „as a coincidence“, the KPC further writes.

![Fig. 5: The process is not reversible. With the expansion into a vacuum, entropy is produced. This figure corresponds to fig. 2.18 on p. 41 in [5].](image)
This discussion of the spontaneous expansion of a gas into vacuum is wrong in several ways:

Ad 1. Here the KPC stumbles over its own definition, namely that the entropy can be increased only when heat is applied and the temperature thus rises. Physically seen it is correct that the entropy increases but only because of the increase of the volume. The temperature remains constant in the process. However, pupils who are taught by the KPC method cannot know this.

Ad 2. Here the KPC refers to an earlier observation where with the expansion of a gas the temperature had sunk. This was an adiabatic expansion, in which the gas does work. The KPC appropriately stresses that with such a process the entropy remains constant, however the KPC uses this process – incomprehensibly to us - for explaining the expansion into vacuum, in which the entropy increases, just as the KPC itself ascertains in the end! Regardless of this, one immediately sees that the temperature of the gas does not change, because during the expansion into vacuum no work is being directed outwardly.

Conclusion: The two alleged KPC effects do not occur in the described situation at all, so that the result that the temperature remains constant during the expansion is by no means a coincidence, but necessarily must be so, even if not for the specified reasons given by the KPC. This result is strictly valid for ideal gases.

**Entropy conductivity**

„What determines the strength of the entropy current between two locations A and B?“ the KPC asks on p.13f in [5]. Behind the concept of entropy current probably is the analogy to water or electric currents. The strength of the electric current between two locations A and B depends on the voltage between A and B and the conductivity of the wire. The latter is calculated from the cross-section, length, and the specific conductivity of the wire. The concept of current can also be transferred directly to the heat conduction, where a material-dependent heat conductivity occurs. However, in contrast to energy, of which heat is one type, entropy is no preserved quantity (but a state variable!): More entropy comes in at point B than flows out from A, because the flowing is a case of an irreversible process, where entropy necessarily is produced. Here at the latest the analogy already collapses and with it also the concept of a material-dependent entropy conductivity. The KPC does not address this physical fact at all, but in table 1.3 ([5], p.14)
assigns entropy conductivity values to materials by simply dividing the heat conductivity by an arbitrarily chosen mean temperature. This is not acceptable, because once more the fundamental difference between energy and entropy is being obscured.

The attempt of the KPC to place not only the temperature but entropy in the focus of thermodynamics lessons, must be considered physically misleading and repeatedly results in wrong conclusions. It equates two different physical quantities and thus commits an elementary error. The fundamentally wrong identification of entropy and heat, which was stated at the beginning, immediately leads to contradictions. As the above mentioned examples show, even the authors of the KPC partly fall for it, as for example with the expansion of an ideal gas into vacuum. How could such an access to physics be easier for students to understand?

While the physically correct explanation of entropy is missing, namely that it decides on the course of irreversible processes and indicates how many states a system can assume, the KPC unnecessarily introduces it as a complication, where the concept of heat would suffice.

Example 3: Magnetic charges and the concept of vacuum in electrodynamics

Magnetic charges

The volume of the KPC regarding electricity delivers a particularly impressive example of how striving for standardization of presentation by using arbitrary analogies can lead to statements which are not only experimentally unprovable, but also strikingly contradict experimental findings. The speculation that there could be magnetic charges and a magnetic monopole as elementary particle stems from Paul Dirac. The existence of magnetic charges would eliminate the asymmetry between the electric field strength and the magnetic induction in the Maxwell equations. Despite intensive efforts, isolated magnetic charges have not yet been able to be proven experimentally. The Maxwell equations (with div B = 0) as basic equations of electrodynamics are still valid. Causes for magnetic properties of matter are either the magnetic dipoles coupled to spins, or the magnetic dipole- or higher moments caused by current distributions. Contrary to this experimentally verified fact, which is also recognized in the electrodynamics-volume of the KPC [2] (p.15), the KPC assumes in the textbook for the
"Magnets can attract and repel. The attraction or repulsion originates in the magnetic charge $Q_m$. The areas of the magnet where the magnetic charge is located are called magnetic poles. The unit of the magnetic charge is Weber (Wb). Just as the electric charge, the magnetic charge can take on both positive and negative values. Areas carrying positive magnetic charge are called north pole, areas carrying negative magnetic charge south pole."

At a first glance this could sound convincing for a pupil. But then he will ask how one can separate these charges spatially, so that one can speak of real charges and not only of the properties of a bar magnet. The obvious experiment is to cut the bar magnet apart (cf fig. 6). As we already know, two new bar magnets are formed but no isolated charge. This is not a singular case, but as already reported above the search for magnetic monopoles.
remains unsuccessful. Thus, there is no experimental justification for magnetic charges so far. Although this fact is known to the authors of the KPC, they write in their school books [2]: „The question is not whether or not magnetic charges exist, but whether their introduction is convenient“. Now this is an argument which discredits completely the approach of the KPC in the eyes of reputable scientists. This is an evident example of how the KPC bends basic physical facts in favor of didactic convictions. It could be argued that there is a method for solving potential problems in electrostatics with certain symmetries of the charge distribution and the boundary conditions, where so-called mirror charges are introduced, which also cannot be experimentally verified. As the name already suggests, these mirror charges are a mathematical method for solving boundary value problems. Mirror charges are placed in areas that are physically irrelevant, and serve to satisfy the boundary conditions. From its mathematical derivation one can deduce that the calculated potential only counts in the physically relevant area and not in areas in which the mirror charges are located. The task force of the German Physical Society holds the view that only experimentally verifiable facts should be taught in school and for this only a didactic method must be sought, not the other way round where physical "facts" are allowed to be invented, so that the didactic method becomes as elegant as possible.

**Ether / Vacuum**

The KPC raises the question ([4], p. 46): “In what does the electromagnetic wave run? What acts as medium here?“ Although modern physics excluded the existence of such a medium, beginning with the experiments of Fizeau as well as Michelson and Morley, the KPC further writes ([4], p. 46): “As a result [apparently after those experiments] one assigned it [the medium] a new term, because too many outdated ideas were linked with the term Ether. This new term is ‘vacuum’, in German ‘the void’. The carrier of the electromagnetic waves is called, vacuum ‘. [...] When saying that in an area there is vacuum, it is meant that there, indeed, is no matter in terms of chemistry, but yet something else: the carrier of the electromagnetic wave. As long as no wave passes through the vacuum, the vacuum is in its ‘ground state‘. By means of the experiments of Fizeau, Michelson and Morley, physicists arrived at the conviction that there is no preferred reference frame for electromagnetic waves and, hence, no carrier medium. This led to the formulation of the theory of special relativity and Lorentz-Invariance which is experimentally verified today with a relative precision of $10^{-17}$. However, the KPC argues that the term ether had been abolished by the experiments, but nevertheless, the electromagnetic waves still had a carrier medium (similar to
the sound waves). Presented this way, an image is created that is at least misleading or even wrong. Electromagnetic waves originate from the fact that temporal changes of electric fields generate a magnetic circular voltage and temporal changes of magnetic fields produce electric circular voltages. Contrary to sonic or water waves, they do not constitute propagating disturbances of a carrier medium. They need neither ether nor vacuum as a carrier medium. On grounds of quantum field theory, one may consider vacuum as the modern successor to ether. However, the crucial difference to the classic ether is the fact that the vacuum of the quantum field theory is Lorentz-invariant, and thus satisfies the theory of relativity and does not distinguish a reference frame.

The examples given here prove that the KPC makes wrong statements according to the current status of scientific knowledge, (existence of magnetic charges or monopoles) or causes wrong conceptions by using imprecise formulations (vacuum).

**Lacking Connectivity**

It is the task of physics lessons to present the current level of knowledge of physics in such a way that pupils can understand natural phenomena and technological devices of everyday life. This concerns pupils who shall be prepared for potential technical or scientific university studies, but in particular also those for which lessons at school are the only opportunity to be equipped with an appropriate physical world view. To this end, school physics must keep to the usual national and international concepts that facilitate the dialogue within and outside the physicist community and have been confirmed experimentally.

The momentum current of the KPC does not meet these requirements, which is evident from the fact that this concept does not occur in common national and international textbooks for students of physics at all. This may be confirmed just by looking only at the indexes of different textbooks. In the index of the textbook Gerthsen Physics [6] the concept of force is being referenced 14 times, but momentum current is not mentioned once. We have a similar situation with the textbook from Halliday, being a translation from the American: Here we find 13 references for force, but not one for momentum current. Furthermore, the KPC introduces the unit Huygens [Hy] as the unit for momentum. However, this unit does not appear in the school textbooks or in the Pocketbook of Physics [8]. Only force is being assigned to its own unit, the Newton. These statements do not only apply to the momentum current but also to the magnetic charges introduced by the KPC together with their associated unit Weber, which is already otherwise defined outside the KPC, or
to the unit Carnot for entropy. Thus, the KPC teaches concepts and units for which pupils have no use outside their KPC classes.

If authors think that physics should be presented differently because other concepts, other terms and other units were more adequate – for which there may be good reasons - then this discussion can only be led according to the rules of the empirical natural science physics, which have been established for more than 400 years. Otherwise, the claim to present physics scientifically well-founded cannot be kept. The Feynman Lectures [9] or the Berkeley Physics Course [10] are famous and successful examples of how new concepts of presentation have been even very fruitful. The KPC ignores this way.

Conclusion

Concepts like the momentum current, the magnetic charges or the vacuum acting as carrier of electromagnetic waves were introduced into physics by the KPC in the laudable intention to facilitate the understanding of the physical processes for pupils. However, even if these concepts were more plausible for pupils, they would not benefit from it, because pupils learn something which, from the scientific point of view, is questionable and partly demonstrably wrong. Furthermore, these concepts of the KPC are formulated in a way that no other engineer or scientist can understand.

KPC’s assertion that entropy is “colloquially called heat” is particularly and strikingly wrong and misleading. Entropy is a quantity, that should strictly distinguished from energy and, thus, also from heat, and should definitely be taught at school because of its fundamental importance. Then, however, it must be appropriately introduced as that state variable which decides which energy conversions are possible or in which direction certain processes take place like heat conduction or the irreversible expansion of a gas.

Physics lessons at school must at least be required to also represent physics in the future just as it is constructed and pursued: As an experimental science, which defines its concepts via measurement instructions and reaches objectifiable statements on the basis of precise definitions of its concepts.

The KPC does not convey a correct physics world view. In favor of a didactic conviction, it introduces questionable new concepts, ignores or bends experimental facts and accepts misleading analogies as well as wrong representations. No physics education can afford such a thing.
The KPC is equally unsuitable as a basis for physics education and as a guideline to formulate physical teaching and education plans. We recommend to the German physical society to emphatically oppose to the use of the KPC in physical education.
Literature


