Complementary education course for physics teachers 2011. *The empirical basis of modern physics.*
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4. MEANINGS AND THEIR CARRIERS

The elements of reality

Space, time, entities, phenomena, and the properties of the entities and phenomena represent the reality such as it opens itself to us in the *primary perception*, *i.e.* our sensory experience of nature. Also the *mutual relations of the properties* perceived as *affecting* of the entities on each other and as *causing*, belong to these basic gestalts. *They constitute our primary mental imagery about the reality, our surroundings and about the relation of the self to the nature.* The linkage of these elements to the observations is an intuitive interpretation, which is beyond the reach of the ordinary empiry and belongs, thus, to *metaphysics.*

The natural *language* is based on the primary perception. This can be seen in the structure of language. The reality of nature is discussed in terms of concepts, which represent and describe these *"elements of reality".* The words have, or they are experienced to have, genuine existing counterparts in the reality. The *nouns* represent entities, the *verbs* correspond to phenomena and the properties of entities and phenomena are described by *adjectives* and *adverbs*. The "elements of reality" belong to the gestalts born through observations and to their representative concepts, as *carriers of meanings (*also called *referents).* This linkage forms the metaphysical core of the meanings, on which the experience of understanding is based.

Such an interpretation is *naïve realism,*[1] including both the ontological and epistemological dualism. It is thought, that *there is an observer-independent reality, the object of our observations, and that the observations transmit "true knowledge" about it.*

The understanding, based on mental imagery, is *qualitative* by nature. It is represented by concepts of the qualitative level. It is built by qualitative research aiming at identification of entities and phenomena and creation of mental images concerning their nature and their mutual relationships. Conventionally, the quantitative character of physics is emphasized. Then, however, the primary qualitative aspect of the researches as creators of the mental images, is easily ignored . One essential purpose of my lectures on this course is to draw attention to the way, how, also in the context of the foundations of modern physics, the very qualitative significance of the researches has been decisive for the progress of understanding, so that the meanings of their quantitative results derive from it.

The life-work of FARADAY is a good example. It concentrated, for the most part, on qualitative research. The, minor role of "formulae" in his scientific production is striking. Sometimes, he was even blamed for deficient mastery of mathematics. Perhaps most important for the progress of physical understanding was his research on the induction phenomena, which lead to the identification of the fields as independent entities of nature.

Quantification of properties into quantities leads to the quantification of the whole qualitative interpretation, to its representation in terms of quantitative concepts. In quantification, *quantities* are created from properties, *laws* from dependences and causal relationships, and *theories* from the causal models.

Quantification does not create new meanings. It just transmits the meanings of the qualitative concepts into the meanings of the corresponding quantitative concepts and attaches *the sense of orders of magnitude* to their perception. However, as I emphasised in my first lecture, the quantitative concepts offer, a basis for development of qualitative understanding in further perception, to be quantified again. It is such a spirally-proceeding process, which is developing "physics", as it is understood in the conventional language: *Quantitative research and quantitative cognitive structure*, with its empiry based on measurement of *quantities.*

In passing to modern physics, it is important to realise the metaphysical – i.e. fictitious – nature of the carriers of meanings and to take this into account in one's efforts to distinguish the observation from the interpretation. Otherwise, it doesn't become possible to liberate one's thinking from its strong ties to the primary perception, to accept the compulsion for change created by the new empiry.

Within the framework of *the classical physics* one does not necessarily pay any attention to this, because all classical concepts have a meaning, directly related to the elements of this fictitious reality. Classical concepts are experienced as a language speaking about the reality. It is language of the naïve realism. This can, downright, be regarded as a definition of the classical physics:

> *Classical physics is that part of physics, which does not lead into contradiction with the naïve realism resulting from primary perception.*

[1] "Naïve" in a neutral sense, not derogatory.

Classical physics is an extreme extrapolation of the primary perception, realised through extension of the senses by equipment developed for observation and measurement.

After all, the mental images forming the basis of understanding, are *metaphysical* by nature, *interpretations without empirical evidence*. However, at the same time they form *the foundation of the understanding of classical physics.* They are born from empirical compulsion in the way how perception always creates an *empirical compulsion*. They are *"finished gestalts"*, intermediate stages of the perception process, with the empirical justification based on the combined internally consistent support of different sensations, observations and experiments. This gives them a validity on the validity area covered by the observations and experiments.

At the entrance gate of modern physics the *empiry extending to new areas* questions this justification and creates an empirical compulsion for re-evaluation of the intuitive starting points of these mental images. It sets the classical foundations of understanding into the position of *preconceptions* to be rectified.

This requires *tightened empiry*, paying stricter attention on the distinction of interpretation from observation. This is the only possibility for a progress to a new higher hierarchical level of structural perception, where *new mental imagery, leaning on the new empiry,* is created. The concept of photon, discussed on the previous lecture is a good example.

At the same time, the concrete classical mental images of the elements of reality form the only possible starting point for the progress to modern physics. Their "easiness" is only apparent in many respects. It is therefore necessary to consider their nature more closely. They must be taken safely into one's possession, before one can start pondering about what in them can be amended and what must be amended on the basis of the empirical evidence.

Time and space

The concepts of *space and time* are somewhat aside from the main themes of this course. Only the lecture by HEIMO SAARIKKO on Thursday is related to the empirical basis of their modern meanings. They are, however, tightly linked with the nature of the other elements and can, therefore, not be omitted in this context.

In the structure of the classical mental imagery based on the primary perception, time and space form the "stage" for the existence of the entities and for the occurrence of phenomena. In this imagery, *the space* is *continuous empty space,* where the entities occupy at every moment of time definite *positions. The time* is flowing continually, independently of the space, everywhere simultaneously at the same pace, as the common background of all existence. The phenomena take in this "flow of time" definite *moments of time* or *time intervals*.

The *independent existence* of time and space, i.e. their ontological absoluteness, lacks, however, any empirical foundation. They become perceived only through the entities and phenomena. The distances and sizes of entities and the durations and time intervals of phenomena create the mental images of space and time. *There is no space without entities and no time without phenomena.*

The mental image of an existent space was concretized by linking to it the entity-like mental image of *the ether*, a continuous, weightless and elastic fictitious matter, until the *electromagnetic field* of FARADAY replaced it as an immaterial entity filling the whole space.

The linkage of the "empty-space" image to the existence of entities becomes fulfilled in the *quantum theory of fields*, where each particle species – the fundamental particles of matter (the fermions) as well as the carriers of interactions (the bosons) – is represented by its own "species-field". The quantum mechanical *zero-point vibrations* of all these fields – as a manifestation of the Heisenberg uncertainty principle – fill the vacuum of the space. One can even measure the "vacuum pressure", which can be interpreted as a consequence. In this sense the vacuum can quite well be called – in accordance with the end remark of my previous lecture – *"the field of potential occurrence of all degrees of freedom of existence".* Coupling of the space to the entities and phenomena destroys, thus, the ground under the mental image of the independent existence of time and space, but offers, at the same time, a modern equivalent for the ether as the carrier of meanings related to the existence.

Already on the classical side of physics the ontological problem of the existence of space and time gets traced back to the epistemological question of the *relativity or absoluteness* of observations concerning entities and phenomena, when asking whether the observations depend on the motion of the observer or not. Classically, the observations of time are considered absolute, independent of the observer, which makes also the distances and sizes of bodies absolute.

Replacement of continuous phenomena by momentary and pointwise events, to which we shall return on the next lecture, is accompanied by a change of linkage of the concepts related to time and space, necessary for the understanding of the theory of relativity. Instead of the distances and sizes of entities and durations of phenomena, the considerations of the geometry of time and space must be based on the *distances and time intervals of pointwise and momentary events*.

Lorentz transformation, the quantitative starting point of the special relativity, follows from the absoluteness of the speed of light, which, inevitably, makes the time intervals of pointwise events relative. As to its meaning, it is the relation between the observations of two observers, in uniform motion relative to each

other, who measure the distance and time interval of two events. This relation leads to many odd predictions, like the Lorentz contraction of the lengths of bodies and the time dilatation of the durations of phenomena, which become "understandable" only through this basic meaning.

Linguistic practices, where this basic change of linkage is omitted, is a continual problem of popularisation of the theory of relativity. The common habit to speak of time, which, depending on the motions of the coordinate systems, flows in one coordinate system faster or slower than in another one, obscures essentially the understandability of the considerations, because it ties the concept of time just to that mental image of flowing time, arising from the basic perception, which one ought to get rid of.

Entities and phenomena

The entities, in the ontological sense, are "*subjects of nature*", something which exist and act. In the epistemological sense, they are objects, targets of observations and research.

The phenomena are what happens in nature, how the entities behave and what happens to them as a function of time.

In the classical structure of mental imagery, the existence of entities is continuous. There are two kinds of them, the *material entities* and the *fields*, which are immaterial. The entities possess permanent characteristic properties, the basis of their identification, and properties varying in the phenomena.

Classically, all *phenomena are continuous*. They are identified on the basis of the related relations between observable properties, with quantitative representation by the laws of phenomena. One can distinguish the phenomena of single entities, *i.e.* their *motion* and the *change of properties,* and the *interactions* of entities, *i.e.* phenomena in which the entities affect on each other.

A phenomenon happens in some area of space, and it has some duration. The changes occurring in it are continuous in respect of both time and space. Momentary and pointwise events do occur in classical physics just as idealised models.

Particularly, the concept of motion is bound to the *continuity of time and space.* Speaking of motion of an entity is possible only, if the entity exists continually and can all the time be identified as the same entity, possessing, thus, a *permanent individual identity*.

The material entities

Material entities include *bodies* (*or particles*) *and matter*, more generally, any material systems.

The bodies are "macroscopic entities". They exist continuously, and they can be identified as separate individuals. They possess an *individual identity*. Each body has all the time its own position, orientation, size and shape. In any motion of the bodies they change continuously so, that every body has its own continuous *trajectory*.[2] Motion is represented by its trajectory and the dynamical variables, momentum, angular momentum and kinetic energy, which are continuous.

A particle, in classical physics, signifies most often a model of a body, idealised as a "point mass", with translation as its only degree of freedom. Otherwise, particles are just small bodies.

Classical *matter*, of which all bodies constitute, is *continuous* by nature. The (chemical) kind is the identification property of matter, giving it a "*species-identity".*

The bodies and the matter possess an enormous amount of different kinds of *properties* and corresponding quantities. The bodies and the matter are carriers of the meanings of these quantities.

The *macro properties* of the bodies derive from the properties of matter, which are continuous functions of space and time. The pointwise and momentary properties and the related laws are *micro properties and micro laws*. They are treated as macro properties and macro laws of *infinitesimal matter elements* at different points. In this way they get a representation as pointwise and momentary *differential quantities and laws.* In reverse, one can return from them to the macro properties and laws by integration. In the classical physics of matter, there are, thus, *two levels of treatment, the macro level and the micro level*. The connection of the levels is based on the continuity of matter and all of its properties.

The matter elements are "infinitesimal bodies" also in the sense, that they possess *individual identity* . The motion of matter, in classical considerations, consists of the motions of these elements, each with their own trajectory, which can be followed.

The fields

The fields are extended immaterial entities, continuous in time and space, covering some area or the whole space.

The history of the concept of field begins from the *problem of distant interaction*, which troubled the physicists for a long time after Newton. Transmission of energy, momentum and angular momentum *without*

[2] The trajectory of a system, as a general concept, is the set of the time dependences of all coordinates of the system.

contact was a severe problem on the level of mental imagery. Newton passed this problem by stating simply that "the idea works".

Perception of the interaction as an independent "element of reality" was the great basic idea of classical mechanics. In the basic perception of mechanics, the interactions are classified as "cause phenomena" regardless of their nature.

As to the distant interactions this classification is somewhat problematic. The first problem on the level of mental images, is due the concept of potential energy. The potential energy is linked expressly to the interaction as its property. Thus, the interaction is perceived as the carrier of the meaning of potential energy, evoking the image of an entity, able to receive and release energy. The magnetic interaction of moving charged particles causes another problem. It violates Newton's third law of force and counter force and, consequently, also the conservation of momentum.

The field as a transmitter of internal distant interactions and as an additional constituent of the system, solves these problems. The distant interactions get reduced to contact interactions between the fields and the material constituents. The potential energy of interaction is perceived as the energy of the field, and the momentum of the field saves the conservation law of momentum.

Identification of the electric and magnetic fields as entities with independent existence, is indeed, one of the most important conceptual results of the experimental research by FARADAY.

Identification of the fields.

In the classical physics there are three kinds of fields (field species), the field of gravitation, the electric field and the magnetic field – or only two, if the electric and magnetic fields are perceived as two components of the electromagnetic field. The fields are identified on the basis of their *properties, manifesting themselves separately at every point of the field*. The "presence" of these fields at a point, is recognised from the forces exerted by the fields on a particle sited at this point. On the basis of these forces one can determine the *field quantities*, indicating the strengths of these fields. According to the present names of quantities they are the gravitational field strength, which equals the local acceleration of free fall, the electric field strength and the magnetic flux density.

In perception of fields as entities some problems are encountered. The general linguistic meaning of the "field" (e.g. playing field), makes one easily to perceive it as the area itself, and not as something, which fills or covers the area in some way, as one should. Correspondingly, in speaking of *the shape of a field* one is tempted to think about the geometric shape of the area covered, while it merely signifies the functional form of the dependence of the field quantity, or the property presented by it, on position.

The traditional demonstrations of the field lines can well serve as illustrations of the field entity and its shape, provided that it is understood, how the presentation in terms of field lines expresses, in addition to the direction, also the strength of the field as a function of position. Otherwise, in the geometric perception of the shape of the field, one can lean only on *graphs*. However, because of the three-dimensionality of the fields and the vector nature of the field quantities, this possibility is restricted, by and large, to such straight lines, where the direction of the field quantity is fixed.

Quantity field and field entity.

Comparison of the field with *continuous matter* reveals the use of the field concept in two parallel meanings. The properties of continuous matter or quantities representing them, like temperature, density, pressure or stress etc., are treated as fields.[3] They are *"quantity fields"*, mathematical abstractions, representations of these quantities as a function of position and time. The field quantities of the electric, magnetic and gravitational field, as functions of position and time, are similarly quantity fields. The *field entities* considered here are carriers of the meanings of the quantity fields in the same way as matter is the carrier of the meanings of the quantities representing the properties of matter and of the fields formed by them.

The concept of field arises from a similar intuitive need as the ether in its time. When light turned out to have the nature of wave motion, it became necessary to ask: wave motion of what? Interpreted in the language of the perceptional approach: An observable wave motion necessarily implies some field quantity, with its dependence on position and time representing the shape of the wave. Further, for this quantity, it was intuitively necessary to find some entity as the carrier of its meaning, a medium possessing some property which would be represented by the quantity. The field and the field quantity related to the light was, however, not identified before Maxwell. The desired carrier was called the ether, and the tension related to its elasticity was perceived as the property to be represented by the field quantity. In this sense, the ether is a predecessor of the classical field concept.

The known field quantities and the quantity fields formed by them can be regarded as the conceptual starting point of the electric, magnetic and gravitational field. The carriers of their meanings were named as fields with the same names. As stated above, already before identification of the field quantities, there was a desire for carriers of the potential energies of distant interactions.

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[3] See the discussion of the concept of field in the book *Aaltoliikkeestä dualismiin.* (*From Wave Motion to Dualism.*(by K. & R. Kurki-Suonio (Limes ry., Helsinki, 5th edition 2005. Ch. 2.1.1.) In Finnish.

The compelling empirical evidence by Faraday on the existence of fields was, however, not yet obtained from the studies of the static fields, but only somewhat later from the studies of the induction phenomena. For Faraday the "field entity" signified, in the first place, the set of field lines (called "force lines" at that time), filling the space continuously – the active interaction of the lines with a circuit or conducting matter caused the induction currents.

Species-identity.
The fields are somehow linked with their originators[4], bodies or particles, which, on the basis of certain properties of the originator, are understood to create the fields and to "feel" their effect. There is a rather well established conception, that the originators are primary, i.e. that the fields are created by the originators. In physics teaching this view has a clear priority – partly due to the traditional mathematical emphasis. Certain ideal laws concerning the shape of the fields are taken as the starting point of the treatment, because they offer an ample source of computational exercises where field strengths of simple systems can be predicted. The gravitational and electric $1/r^2$-laws of Newton and Coulomb, for spherically symmetric systems, and the magnetic Biot and Savart $1/R$-law for an infinite straight conductor (or the corresponding Ampère and Laplace $1/r^2$-law, for a wire element or a moving charged particle) dominate the teaching to the extent that, when students are asked to "define" the field quantities, these laws are most often offered as definitions.

The fields can, however, not be identified as individuals on the basis of their linkage to the "originators". Locally and momentarily it is possible to observe only the characteristic field quantity, which makes identification of the field species possible. Such observations do not make possible identification of the sources. Observation of a field and measurement of the field quantity do not require any information about the sources. And, even if the originators are known, the field quantities observed do not contain any "addresses", which would make it possible to verify, what proportion of the field belong to which originator. The fields do not possess any individual identity. They have just their *species-identity.*

From the *lack of individual identity* it follows, that, actually, their exists just one electric field, one magnetic field and one gravitational field, each covering the whole space. Just the shapes of these fields, represented by the field quantities as functions of position, vary continually.

This leads to a totally different conception about the relation of the fields to their "originators". The fields exist independently of the "originators" as all-covering entities. The role of the "originators" is based on their interaction with the fields. Thus, the "originators" do not create the fields but just shape them. For example, a point charge modifies the shape of the electric field in its neighbourhood into the "mould shape" presented by Coulomb law.

The relativistic interpretation of the gravitational field as the curvature of the space-time is accordant with this conception. The idea is also supported by Faraday's induction experiments, which showed, that the field of a bar magnet does not rotate with the magnet.[5]

The epistemological point of view of *relativity and absoluteness* amends the mental images of the fields. The dependence of the electric field strength and the magnetic flux density on the state of motion of the observer, compels us to couple the electric and the magnetic field together into one *electromagnetic field,* which requires special relativity for proper treatment. This coupling concerns the quantity fields as well as the field entities. Their linkage together into one electromagnetic field entity is in a way confirmed in modern physics, when the photon is identified as the carrier of the electromagnetic interaction, and is responsible for both the electric and the magnetic interaction.

The gravitational field, on the other hand, acquires in the general relativity a representation as the curvature of the space-time. It is, thus, no more possible to perceive any kind of an existent entity as the carrier of meaning of the gravitational field quantity. What remains as the carrier, is the mathematical abstraction of the four-dimensional space-time.

Wave motion

Motion of a field is a problematic mental image. There are no local "field elements" which could be treated as individual entities be followed in the motion. It is possible to observe just the field quantity which depends on position and defines, thus, the varying shape of the field. Values of quantities, and their changes can be observed, but *quantities don't move.* Changes of the field quantity mean only that the shape of the fields is changing, but no observation of motion can be attached to it.

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[4] "Source" would sound natural here, but it is avoided because of its special meaning in field theory.

[5] In a recent e-mail discussion attention was drawn to a certain type of exercises occurring in physics textbooks. It is asked to determine the induced electric tension (voltage) between the wing tips of an aeroplane or the ends of the axles of a car or a train and its dependence on the direction of motion of the vehicle. Already the possibility to measure the induced tension is a problem as such. Then, the question arose, how does the rotation of the Earth affect on it, and would it be possible, by studying this phenomenon, to verify whether the magnetic field is rotating with the Earth or not. On the basis of Farady's results it does not.

In general, *variation of the shape of a field* is called *wave motion.* Thus, wave motion is not motion of the field, but an interpretation following from the nature of the variation of its shape. Particularly, when in this variation, the same shape is proceeding continuously, the mental picture of motion arises.

The origin of the concept of wave motion is in concrete material waves, particularly in the surface waves of water. In such material waves the field quantity is the displacement vector of the matter elements. Its dependence on position makes the concept of the shape of the field concrete. Primarily, however, it is rather the geometric shape of the water surface conforming to the wave motion that is perceived as the shape of the wave, while, actually, the variations of the field shape means variations of the displacement vectors, and couples the motion of the matter elements to the wave motion.

The concrete mental image of the displacement wave can be used to illustrate the concepts of field and wave motion, but it is not merely useful. The related mental image of motion of the medium elements can evoke misconceptions. The common emphatic treatment of the pressure wave (sound) as a (longitudinal) displacement wave offers a cautionary example.

Another kind of example of the mental image of a moving quantity field is the so called *rotating magnetic* field, occurring as one principle of the electric motor and can be nicely demonstrated with help of the three-phase current.

Relation to the "originators".
The traditional idea about fields as created by their originators leads to a mental image, where the field of each "originator" moves as a whole with its "originator". When, instead, the field of an "originator" is perceived just as a shape of the independently existent universal field, moulded by the "originator" in its own close neighbourhood, such "motion of the field" turns out to be an externally forced propagating wave motion, where just the shape of the field follows the motion of the "originator". This mental image is well accordant with the conclusion from Faraday's induction experiment, that the field of a cylindrically symmetric rod magnet does not rotate with the magnet. It is rather obvious that the local field shape forced by the magnet is independent of the rotation of the magnet since the external symmetry of the situation is conserved.

Lack of individual identity.
Wave motion as variation of the field shape is tied to the species-identity of the field. The lack of individual identity concerns similarly also the wave motion. Changing of the field shape can be observed, but the observation cannot identify the variations of the field quantity as a set of different wave motions caused by different sources. At each observation the all-covering field shape is varying in some definite manner, which defines that specific wave motion. This is one phenomenal whole, which cannot be divided on any empirical basis into partial waves which could be individualised.

One should pay attention to this in the context of all interference and diffraction experiments[6]. They are commonly described as superposition of two or more individual wave motions. This is the point of view of theoretical explanation, based on the idea that the individualised wave motions are considered as well known. From the empirical point of view, every interference or diffraction experiment is, in principle, a two-or-more-phase experiment, where the wave motions caused by each different source are observed separately, and the wave motion caused by all sources together is compared to those caused by the individual sources.

This point of view is of particular importance in realisation and interpretation of the so called *double-slit experiment*, which belongs to the fundamental experiments of modern physics beside the F2k experiment considered on this course.

Energy transfer and the dynamics of wave motion.
One more mental image of motion, in the context of fields, is the idea of energy transfer by wave motion. The wave motion "carries" energy, as well as momentum and angular momentum, in a way, which looks like "*continuous propagation of energy etc. in the field".* This mental image is comparable with the propagation of the energy of tension waves (sound) in elastic matter.

Here, as before in the ponderings about the motion of the field, one should note, that energy is a quantity and "motion of a quantity" makes no sense. The mental image of motion is a part of the matter-likeness, following from the strong conservation properties of the energy and appearing in the general linguistic practices of physics – energy is discussed as if it were a matter-like entity. The matter-likeness may well be a useful mental image in considerations of the conservation laws, because the properties of matter make the meaning of conservation very concrete. It leads, however, easily also to misconceptions, which one must be able to repel.

The idea of "energy propagation" traces back to the question of interactions. In the context of the elastic wave motions of matter the nature of the phenomenon is clear. In an ideal elastic matter, energy is conserved in the contact interaction between any two matter elements. It is convenient to use, in this context, the

[6] In physics text-books, interference and diffraction are commonly discussed under different headings. One should note, however, that diffraction is just a special case of interference.

"entitative" metaphor of energy transferring from one element to the other. The continuous succession of the elements in contact evokes then the mental image of continuous motion.

The concept of ether transferred this mental image as such to the electromagnetic wave motion. When ether was abandoned, the elastic interactions between "ether elements" were replaced by the coupled induction and inverse induction, which can be perceived as an energy-conserving internal interaction of the electromagnetic field, an interaction between its electric and magnetic component.

The wave motion, thus, involves unavoidably the mental image of an *"internal dynamics"* , characteristic to the field, responsible for the mediation of energy, momentum and angular momentum. In matter this dynamics is determined by the inertial and elastic properties, which depend also on the thermo dynamical state of the matter. This dynamics couples together the shape and motion of the wave.

The *degrees of freedom*[7] of the field clarify the consideration of the connection between the wave shape and the wave motion. As to the wave shape they represent the so called "waves of basic form", with definite wave length λ and frequency f possessing, thus, a sine shape in uniform propagation with the velocity $f\lambda$.[8] The mathematical (Fourier) representation of an arbitrary wave shape in terms of the sine-formed waves means, at the same time, breakdown of the field energy among the degrees of freedom into a spectrum.

In the electromagnetic field this speed of propagation of the sine shape is equal for all degrees of freedom, i.e. independent of the frequency.[9] This independence is, obviously, valid also for the gravitational field, although there is no direct empirical evidence about the speed of the gravitational waves. The same concerns also sound as a pressure wave in liquids and gases and, more generally the elastic wave in solid matter – except for very high frequencies.

This means that these fields, as well as matter in any specific state, possess a *characteristic wave velocity*, the speed of light and the speed of sound. As a consequence, a (plane) wave of any shape propagates with this velocity, keeping its shape unchanged. In practice, this is an important property, because the conservation of information in electromagnetic and acoustic transmission is based on it.

The connection of the sound velocity to the inertial and elastic properties of matter is, in the way explained, qualitatively obvious. One can also derive theoretical predictions for it, on their basis. Correspondingly, it was understood, that the properties of the ether determined the light velocity, whence an inverted reasoning offered the possibility to form, on the basis of the light velocity, a mental image about the properties of the ether.

Interactions

Contact interactions.

Meeting of two material entities belongs, in the classification of the elements of reality, clearly to the class of *phenomena*. In mutual contact the entities affect on each other's motions in a way which can be represented in terms of transfer of energy, momentum and angular momentum, from one entity to the other one. The collisions of macroscopic bodies are continuous phenomena, although of brief duration, why they are usually considered as idealised momentary events. The motion of a body in a medium takes place in continual contact. In the school physics mainly the consequent force acting upon the moving body, is considered, calling it the medium resistance.

The distant interactions grew into a problem, as stated in the context of fields. Newton perceived the gravitational interaction as an independent *phenomenon,* acting between two bodies, in the same way upon both[10]. Originally, this idea came, however, from Kepler.[11] Identification of the fields as entities, removed the problem. Just contact interactions, between material entities, between fields and matter and possibly between fields, were left in the class of phenomena.

Application of the idea of independent phenomenon on all interactions lead into the success of classical mechanics. The research of interactions, thus initiated, became a permeating theme of whole physics after

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[7] Cf. lecture 3. *The F2k experiments 2*.

[8] This velocity of shape propagation in the field is called *phase velocity*.

[9] In general, the dependence of the phase velocity of the frequency is called the *dispersion relation* of the (quantity) field. usually, it is represented in a, theoretically more adequate, form as the dependence of the angular frequency on the angular repetency (wave-number) $\omega = \omega(k)$. In principle, this is the same dispersion relation as the one considered by KARI ENQVIST in his lecture. There is, in between, just the quantum mechanical identification of the angular frequency and angular repetency with the energy and momentum (impuls in the non-standard terminology by KE).

[10] "And though the mutual actions of two planets may be distinguished and considered as two, by which each attracts the other, yet as those actions are between both, they do not make two but one operation between two terms. … It is not one action by which the sun attracts Jupiter, and another by which Jupiter attracts the sun; but it is one action by which the sun and Jupiter mutually endeavor to approach each other. Cajori F., ed., trans.. (l934. 1962). *Newton's "Principia," Motte's translation revised.* Los Angeles: University of California Press.

[11] In *Astronomia Nova* (1609) Kepler says: "Gravity is a mutual affection between parent bodies which tends to unite them and join them together."

Newton.[12] The interaction was perceived as a universal "scapegoat", cause-phenomenon, to which the explanations of all phenomena were reduced. The problem was just identification of the "*species*" of interactions and their *characteristic laws*, which could be traced back to the *mental images* of the mechanisms of interactions.

With the atomic structure of matter all macroscopic mechanisms of interactions were traced back to fields. In modern physics the *carrier-particles* replaced the fields as the mental image of the mediation mechanism of interactions.

Radiation

At the entrance gate of modern physics, new kinds of radiation, channel rays, cathode rays, x-rays, and the different kinds of radiations related to the radioactivity, assumed an important role.

Radiation is a phenomenon, which transfers energy from the source into a target. It involves

(1) *emission*, the birth of radiation – the release of energy from the source into the *energy of the radiation*.

(2) the *transmission* of energy with the radiation as the energy of the radiation, and

(3) hitting a material target followed by *absorption* – change of the radiation energy into the energy of the target –, or *scattering* – re-directing the propagation of the radiation in different directions.

Classical physics offered two alternative models for radiation. *Particle beam* and *wave motion* signified each a clear mental image of the mechanism of energy transfer by radiation, as well as for emission, absorption and scattering. Thus, every kind of radiation was submitted to the same inquiry in order to solve which of these two classes did it belong to.

Emission, *absorption* and *scattering* occurred in *interactions* of a material source or target with the beam particles or the electromagnetic field.

The *classical particle beam* consists of particles which can be identified as separate individuals. Each single particle has its own trajectory, and its motion along this trajectory can be followed, at least in principle. The radiation is born (emission), when, as a result of some particle reaction, particles are released from the source. Some binding energy of the source is released and changed into the energy of these particles. The "birth" or release of the particle from the source and hitting the target (absorption, scattering) are *momentary and pointwise events, where energy, momentum and angular momentum are conserved.* They can be considered under the common general title "collisions".

The *wave motion* possesses only the species-identity of the field, and it is not possible to distinguish in it any individual constituents, the motion of which could be studied. The wave motion is generated into the electromagnetic field (emission) by an oscillating (more generally accelerating) charged material system. The radiation energy is the electromagnetic energy of this wave motion. When the radiation hits a target with an electric structure, the oscillating field of the wave causes forced oscillations of the system. Then, radiation energy can be transferred into the energy of the target system (absorption) or into the radiation of the secondary radiation due to the oscillations of the target system (scattering). What's essential, is that these phenomena are *continuous, submitted to the conservation laws*, and frequency-conserving, except for the Doppler shifts due to the motion of the source and the target.

These are important elements of the basic mental imagery, since many decisive experiments of the modern physics involve interactions of matter and electromagnetic radiation. The *empirical compulsion* for amendment of the classical mental images is accumulating from experimental results which are systematically in strong contradiction with the predictions derived from the classical models conformable to the classical images, while, at the same time, the *quantisation of interactions*, as perceived from the empirical evidence from the experiments discussed on the preceding lectures, offered a starting point for a new structural perception, which required abandonment of the classical mental images, particles as well as wave motion.

[12] Cf. K. Kurki-Suonio: *Yhdentymiskehitys ja vuorovaikutukset. (The unification development and the interactions.)* (In Finnish) Complementary education course for physics teaches 1994. The history of physics. The course material. ed. Heimo Saarikko. Department of Physics. University of Helsinki. 1994. pp. 81–87.