ENGLISH SUMMARY

The book *Ernst Mach-Physics-Philosophy-Education* is a sequel to *Brno Ernst Mach Days 2008* that took place in the year of the 170th anniversary of his birth in Brno-Chrlice. Ernst Mach was a world famed scientist in the field of experimental physics and philosopher of science, as well as an outstanding teacher and thinker. The book comprises papers by experts in different disciplines specialising in fields that brought fame to Ernst Mach.

The first section *Ernst Mach – Looking Back (Brno-Graz-Prague)* mapping places and events related to his life and work, is followed by sections titled *Physics, Philosophy and Education*.

The section *Physics* canonically covers three topics: Mach's number, Mach's principle and Mach's atomism.

The section *Philosophy* maps his way from physics through physiology (perceptions and sensing) to psychology and finally philosophy, showing their use in education.

The section *Education* includes papers with Mach-Newtonian topics, as well as those dealing with issues of categorising the contents of natural science education.

Abstracts of contributions published in sections *Ernst Mach - Looking Back; Physics; Philosophy; Education* conclude the book.

Jiří Bičák

MACH'S PRINCIPLE IN CONTEMPORARY COSMOLOGY

Despite a possible scepticism as regards the role of Mach's principle in contemporary cosmology, most of the standard treatises on the subject do include a discussion of the principle. In the paper Cosmological perturbation theory, instantaneous gauges, and local inertial frames we (J. Bičák, J. Katz, D. Lynden-Bell) adapted as a starting point Bondi's formulation of the principle: "Local inertial frames are determined through the distributions of energy and momentum in the Universe by some weighted average of the apparent motions."Solving Einstein's equations for linearized FRW models we were able to define the cosmological frames associated with the "Machian gauges". The inertial frames are then identified by their "accelerations and rotations"with respect to these frames.

Martin Černohorský

THE ERNST MACH MEMORIAL TABLET IN BRNO-CHRLICE MOUNTED THREE TIMES

On the occasion of his 100th birthday, the outstanding physicist and philosopher Ernst Mach (18 Feb. 1838–19 Feb. 1916) was honoured in a ceremony on 13 February 1938 with a commemorative plaque that was placed on the front side of his birthplace in Chrlice, then a village which later has become a part of the city of Brno. The bronze plaque was cast from a design created by sculptor Karl Korschann, professor at the German Technical University in Brno. Its size was 140 x 90 cm, in the central field (59 x 71 cm) it bore a portrait of Mach in half-relief, and to the left and right of it inscriptions in Czech and German. This commemorative plaque endured a history filled with vicissitudes that are here - insofar as it is possible - sketched in on the basis of archival materials and the testimony of witnesses. After the ceremonial unveiling in 1938, the plaque was preserved in its original condition for only a short time: during the occupation of Czechoslovakia by the Germans the word "československý"(Czechoslovak) was painted over in the Czech text, and in 1943 a massive campaign to collect metal for war purposes led to the removal of the plaque; fortunately though, it could be preserved from being melted down. The place where it was kept for the following five years could not be determined. In 1948, by decision of the Local National Committee the plaque was again put up in a low-key event. However, as early as 1950 it was again removed - this time secretly in a night time operation and undoubtedly for political reasons; it was transported to the municipal library and later stored in the basement of the nearby mansion. There, boys who were playing found the plaque at the end of the fifties and cut out an approximately 40 x 30 cm piece in order to sell the metal.

Soon after that the damaged plaque was no longer in its place. Since then there has been no trace of its whereabouts; it probably ended up in the local melting furnace in 1965. The approaching 150th birthday of Mach led, in the eighties, to renewed interest in the plaque. A massive search was unsuccessful, which led to the commissioning of a simple granite commemorative plaque, the unveiling of which occurred on 14 May 1988 during the celebration of Ernst Mach Days in Brno: Mach's birthplace again had a commemorative plaque after a long period of anonymity. Should Korschann's plaster model of the bronze commemorative plaque appear again, then a new cast of the original plaque could be made: then the image of Mach could again (for the third time) be put up - and Goethe's "You have to say it three times"(Faust I, Line 1531) would thereby be fulfilled.

Martin Černohorský

TWENTY YEARS SINCE THE CELEBRATIONS OF ERNST MACH IN PRAGUE AND IN BRNO

The introduction to the pre-conference workshop „Physics, Philosophy, Education“, held as a part of the "Brno Ernst Mach Days 2008", reminds the events connected with the year 1988: 1. The conference "Ernst Mach and the Development of Physics", Prague, 14–16 Sept., 1988 2. Brno Ernst Mach Days 1988 3. Curious events connected to the designation of Mach's birthplace.

Martin Černohorský

THE MANUSCRIPT OF J. T. BLACKMORE ET AL.: ERNST MACH'S PRAGUE 1867 TO 1895

This informative paper refers to the manuscript "Ernst Mach's Prague 1867 to 1895"of the authors, the subtitle of which goes: "New information on his family, life with colleagues and historic circumstances that led him to pay more attention to the defence of his approaches to science."

Martin Černohorský

NEWTON'S TRANSLATIONAL-ROTATION FORMULATION OF THE FIRST LAW OF MOTION

The generally accepted translation of Newton's first law of motion in the sense of the law of inertia of the translational movement only is incorrect. Newton's formulation applies to rotation as well. This is supported firstly by the transposition of Newton's

two-sentence explicit translational-rotation formulation from his manuscript *De Motu Corporum* ([1], p. 307) into an equivalent expression in his *Principia* ([2], p. 12) as a single-sentence axiom with a commentary stating three examples of translation, rotation and their superposition. The incorrectness of the commonly used wordings translated from Latin was first pointed out in 1975 [7], detailed analysis can be found in Czech articles [8, 9]. In English, its results have been published in articles [10, 11]. There, they have been put in context with Mach's ([4], p. 53; [5], p. 227) and the more recent Cohen's ([6], p. 109-110) answers to the alleged redundancy of the first axiom in Newton's (Newton's, not Newtonian) mechanics.

Michal Černý

REQUIREMENT FOR INTERDISCIPLINARITY IN THE EDUCATION PROCESS

Ernst Mach had the ability to wash off borderlines between different fields of science (not only natural science), take a distance and reflect the world in a complex way. Mathematics and physics were not mere computation tools to him, but the way how to observe the world. From this point of view the present-day school structure, which is strongly monodisciplinarised, arises questions on education system as a whole. Is its objective to teach students how to solve problems and provide them with a sum of knowledge and skills, or can its role be conceived as enabling the educated people to think about the world on a wider and more complex level, as well as providing them with an adequate theoretical background? As a matter of fact, Newton, Galileo, Aristotle and other great figures of what has nowadays been called physics, were rather philosophers than "counters", which is documented not only by the contents, but namely by the structure and spectrum of their works. Should we try to achieve the same approach also in education process at both secondary schools and at the universities?

Jiří Dan

ERNST MACH AND THE CONTEMPORARY PSYCHOLOGY OF PERCEPTION

Ernst Mach has been known first of all as a physicist and philosopher. Attention should also be drawn to his contribution in the field of psychology and pedagogy. Mach's contacts with psychologists of his period and his influence on them deserve a deeper analysis. The goal of this analysis was a search for direct references (links) to Mach's ideas in contemporary Central European psychological literature. They have been found in the present psychology of perception.

Jiří Dokulil

EXPERIENCE CONTINUOUSLY PROVOKED BY THEORY

To remember the world famous physicist Ernst Mach during his jubilee year was the motivation of this short essay. Mach's book on mechanics asserted that the basis of all scientific knowledge and its concepts consist of sense experience. He thus wanted to sidestep metaphysics, not wanting to explain anything but describing all phenomena on the basis of elemental sense impressions traced by means of attentive observation.

This contribution pays attention to the historically preceding intellectual tradition. Quoting real examples it shows that we are able to predict from models which, in reality, must function in some other way, or again, we well know that contemporary science also works with concepts being vehicles of meanings totally outside of any illustrative experience. Three questions have been asked here: 1) From the viewpoint of "sense data"(and inductivism) do we not act foolishly? 2) Is the rising amazement concerning the results of science legitimate? 3) If in the past theories followed practice, isn't the contemporary sequence reversed?

Jan Fischer

ERNST MACH'S ATOMISM, OCCAM'S RAZOR AND THE THEORY OF FUNDAMENTAL PARTICLES AND FORCES

Mach's conception of atoms. Reality, or an economical description? An eternal problem across physics and its history. Distinguishing between description, "saving appearances", and explanation. Towards a unified theory of fundamental particles and forces of matter. Quarks and gluons: reality, or an economical description? Problem of infinite divisibility. Did Mach finally accept the existence of atoms?

Marie Fojtíková

BRNO ERNST MACH DAYS 1988 HINDSIGHT

The article provides the overview about activities held in Brno in 1988 on the occasion of the 150th anniversary of Ernst Mach birthday. In line with the main motive for their organisation facts relating to the spectacular circumstances of marking Mach's native house in Brno-Chrlice with a memorial tablet are mentioned. The text is structured into five paragraphs as follows:

1. The idea of the setting the Mach's native house with the memorial tablet and its realization outline.

2. Program framework of Brno Ernst Mach Days 1988.
3. Complicated fates of the original bronze memorial tablet from 1938 and a hopeless search for it.
4. Dated survey of steps leading to the ceremony of a simple granite memorial tablet 1988 being unveiled..
5. Information on Brno Ernst Mach Days 1988 proceedings (in Czech, 180 pp.) and on the article dealing with the unique case of Mach's memorial tablet (in German, 27 pp.).

Vladimír Havlík

ERNST MACH AND THE EVOLUTIONARY CONCEPTION OF SCIENCE

Mach's evolutionary conception of science is often neglected and did not receive sufficient attention in the course of interpretation of his work. This article aims to emphasize such aspects of Mach's philosophy of science as his evolutionary epistemology, biological function of science, variable and historical character of all theorizing, theory laden character of observation and holism. All these aspects show that biological motives are substantial for Mach's conception and that from this perspective it could be understood as a compact and logically interconnected system. This view suggests a more adequate interpretation of Mach's work and leads, through the evolutional perspective, to much more consistent understanding of his approach.

Josef Krob

MACH'S CONTRIBUTION TO PHILOSOPHY - FROM ACOUSTICS TO EMPIRIOCRITICISM

The second half of the 19th century marked the end of the practically "idyllic"cumulative development of knowledge in the field of physics, philosophy and science in general, and the beginning of discussions on the nature of science, the appropriate means of obtaining knowledge of reality, even on controversies about the character of the reality itself. Many thinkers try to revise achieved knowledge; they revisit the bases of knowledge (or what they consider as the bases of scientific knowledge) and aim to construct modern science according to the model, or on the bases of logics, mathematics or physics (not anymore the Newtonian one). The author of the paper has tried to demonstrate the complex of influences and conditions which led Ernst Mach and many other thinkers of the second half of the 19th century to many important formulations in the field of

natural science and philosophy. Mach's case and his journey from experimental physics to philosophical conclusions will illustrate the complex of various types of causes, conditions and connections that can have impact on the transformation of scientific attitudes and whole paradigms.

Olga Krupková, Jana Musilová

NON-HOLONOMIC FORCES AND MACH'S PRINCIPLE IN SPECIAL RELATIVITY THEORY

Our contribution presents a specific look at the context of special relativity theory with Mach's principle, formulated by Mach himself very generally, on the border of physics and philosophy. Our approach leading to discover this connection is based on the understanding of a relativistic particle as a typically non-holonomic mechanical system, i.e. a system subjected to constraint conditions limiting the particle motion not only in the configuration space, but also in the space of velocities. It appears that such a concept and the corresponding mathematical treatment provides not only standard equations of motion, but, in addition, their generalisation, conjectured by Dicke within his effort to adapt the general relativity theory to Mach's principle.

Jiří Langer

MACH AND EINSTEIN

The philosophies of science of Ernst Mach and Albert Einstein are compared. Einstein always stressed Mach's influence on his physical ideas but there was a substantial difference in their approaches. The influence of Mach and Einstein on the school of logical empiricism and the traces of their epistemology in modern physics are also discussed.

Jana Musilová

ROTATION IN THE FIRST AXIOM

The today already proved fact that Newton himself included the possibility of uniform rotation in his first axiom, gives a negative answer to the frequently asked question whether the first axiom is a consequence of the second one. A detailed analysis of Newton's original formulation discloses additional questions that, when asked and answered from the point of view of both possible interpretations corresponding to "Newtonian period"on the one hand, and the contemporary era on the other, can be fruitful for the development of thinking in physical terms for the students in Bachelor's degree basic

physics course. In the context of physics education, this paper deals with the following questions: What is or should be the meaning of the following words in the first axiom: "... in statu suo quiescendi vel movendi uniformiter in directum"? Is Newton's mechanics first axiom, in the interpretation admitting rotation, a consequence of both the second and the third ones? Is the first axiom a consequence of both the second and third ones from the contemporary point of view, and what could be its corresponding reformulation?

Jan Novotný

ERNST MACH, KURT GÖDEL AND THE UNIVERSE

The scientific work of Brno natives Ernst Mach and Kurt Gödel has an intersection, which is not extensive, but important and interesting. It is concerned with the question: Could the universe rotate? Mach - on the basis of his philosophical opinion - firmly refused this idea, Gödel, on the contrary, discovered an exact solution of the Einstein gravitational equations, which could be interpreted as the description of rotating universe. We discuss the relation of Mach and Gödel conceptions to the general theory of relativity, their connection to the thoughts of Isaac Newton and Albert Einstein and their reflections in modern physics. We conclude that the definite solution of the controversy was still not reached.

Jan Obdržálek

MACH'S OBJECTIONS TO NEWTON'S PRINCIPIA - THEN AND NOW

The paper is based on Mach's *Die Mechanik in ihrer Entwicklung*, 1883. It especially analyses those parts of Chapter 2 in the textbook that critically assess Newton's approach in formulating the principles of mechanics in his Principia. It confronts Mach's objections to the views of present-day mechanics.

Antonín Píštěk

ERNST MACH AND AVIATION

The paper deals with the air compressibility effects on high speed flight and the aerodynamic qualities of the airplane when reaching the speed of sound. This field is connected with the person of physicist Ernst Mach, who defined the ratio of the motion speed of an object to the speed of sound, now called after him Mach's number, which is one of the so-called dimensionless quantities in aerodynamics and has become important in

modern aviation. Also the history of the "sound barrier"story is described, the essence and consequences of the supersonic flight effects as sonic-boom and other phenomena connected with Mach's number or Mach's cone.

Klemens Rumpf

THE TIMES OF ERNST MACH AT THE UNIVERSITY OF GRAZ

Between 1864 and 1867 Ernst Mach held a professorship at the Karl-Franzens-University of Graz. He was the first one of numerous world-famous physicists acting at the Graz Institute of Physics in the course of time. His activity as a Professor of mathematics and later on of mathematical physics coincided with times of changes for the Physical Institute in Graz. Beside other work scopes Mach was particularly and intensively engaged with physiological phenomena and although the experimental possibilities were extremely constricted he performed experiments. Also after his leave Mach did not lose connection with the Institute and many years later he still kept in touch with colleagues from Graz. When he already held a chair for experimental physics in Prague he was strongly intended to return to the Graz Institute as successor of August Töpler in 1876, but at last Mach gave precedence for this position to Ludwig Boltzmann. Of course, the excellent experimental possibilities at the newly erected building of Graz Institute of Physics were a great allure for an experimentalist. Today some apparatus and instruments concerned with Ernst Mach still exist at the Institute of Physics in Graz.

Eberhard Schneider, Klaus Thoma

THE ERNST-MACH-INSTITUT: PRESENT FIELDS OF RESEARCH CONTINUATION OF MACH'S SHOCK WAVE INVESTIGATIONS

The present research program of the Ernst-Mach-Institut is presented. The Institute is one of 58 institutes of the Fraunhofer-Gesellschaft, all of which are working in fields of applied research. It was founded in 1959 by Hubert Schardin, a famous physicist working in fluid dynamics and ballistics. The institute's name was chosen in honour of the great achievements and merits in physics of Ernst Mach, especially in the fields of shock waves in air and high speed photography. It is presented how these topics have been further investigated for many years. Shock wave studies have also been extended for solid materials by means of special acceleration techniques. The main tools for this purpose are a variety of light gas guns - their operation principle is explained - forming a unique research facility in Europe. Respective masses of milligrams up to many kilograms can be accelerated from m/s up to 10 km/s. The main applications for this technology are the following: Experimental space debris simulation for spacecraft protection; Simulation of

natural high-speed impact phenomena; Ballistic missile defence tests; Terminal ballistic research. Other fields of work at the institute are the following: Dynamic material testing at very high deformation rates; Detonics; Development of high-speed visualization and testing equipment; Development of numerical simulation methods and material models; Security research. A fundamental working principle of the institute is doing both numerical and experimental studies in combination, whenever possible.

Hayo Siemsen

MACH'S SCIENCE EDUCATION, THE PISA STUDY AND CZECH SCIENCE EDUCATION

Ernst Mach was not only a physicist with outstanding questions, or a philosopher of science, he was also an excellent educator, both in his theory as well as his own lectures. Unfortunately, this aspect of his epistemology seems rather unknown nowadays [The most notable exceptions have been Blüh (1970), Hohenester (1988), Matthews (1988, 1990, 1994) and Hoffmann & Manthei (1991).], though it is therefore all the more worth to revive. His educational epistemology can now be empirically compared by the OECD PISA study as they have been partly implemented in Finland. Also in the Czech Republic, Machian ideas had an influence, but with a focus on experiments rather than the psychology of science education. This difference in focus seems also to result in empirically very different outcomes. For an introduction into the topic, we shall look at a prominent contemporary of Mach, William James, for his opinion on Machian education.

Zdeněk Stuchlík

INFLUENCE OF THE DARK ENERGY ON ASTROPHYSICAL PHENOMENA IN ACTIVE GALACTIC NUCLEI

The cosmological constant $\Lambda_0>0$ reflecting vacuum energy represents one of the strongest links between Einstein's General Relativity and Mach's ideas that substantially inspired the Einstein theory. A wide variety of cosmological tests indicate accelerated expansion of the recent universe caused by a dark energy close to $\Lambda_0 \approx 1.3\times10^{-56}\,\mathrm{m}^{-2}$. Surprisingly, such a small repulsive cosmological constant has a crucial influence on accretion discs around supermassive black holes in giant galaxies. There is an outer edge of the discs allowing outflow of matter into outer space. Extension of discs in quasars is comparable with extension of the associated galaxies suggesting that observed relict Λ_0 puts an upper limit on the galaxy extension. Jets produced in the innermost parts of accretion discs can be significantly collimated due to the cosmic repulsion after leaving the galaxy.

Emilie Těšínská

ERNST MACH, HIS PRAGUE PHYSICS STUDENTS AND THEIR CAREERS

Ernst Mach (1838–1916) worked at Prague University as Professor of Experimental Physics in 1867–1895. After the University split into two autonomous parts (Czech and German, in 1882), Mach continued as Professor at the German University. He was twice appointed Rector of the University - in academic years 1879/80 and 1883/84. A large number of students (aspiring to become secondary school physics teachers, pharmacists or medical doctors) attended Mach's lectures and the Institute of Physics during the 28-year period. Based on archives, written memoirs and literature on the history of science, this paper presents Mach's teaching activities in Prague and the careers of some of his Prague university students and assistants. Later university professors (in the Czech lands as well as in other parts of the Austro-Hungarian Monarchy), authors of physics textbooks or manufacturers of teaching aids and physics instruments can be found among them. Mach's work for the Prague (German) Association of Natural History "Lotos"is also mentioned as well as Mach's membership in the Association of Czech Mathematicians and Physicists and in the Royal Bohemian Society of Science.

Aleš Trojánek

MACH'S PRINCIPLE AND THE MECHANICS AT SECONDARY SCHOOLS

When explaining the inertial forces to secondary school students, one can expect to be asked questions about their origin. The paper attempts to formulate an answer to such questions.

Jan Zouhar

ERNST MACH AND EUROPEAN PHILOSOPHY AT THE TURN OF THE CENTURY

The intellectual background of this work is the situation in European philosophy in the late 19th and early 20th centuries and the placement of Mach's philosophical work in this context. The second part of the work characterizes Mach's philosophical perspective, his interest in epistemological questions, the principle of economy, and his philosophy of science. Finally, Mach's influence on literature and art is recalled.