

SOCIETA' ITALIANA DI FISICA

---

RENDICONTI

DELLA

SCUOLA INTERNAZIONALE DI FISICA

«ENRICO FERMI»

LXXII CORSO

*Problems in the Foundations  
of Physics*

ITALIAN PHYSICAL SOCIETY

---

PROCEEDINGS  
OF THE  
INTERNATIONAL SCHOOL OF PHYSICS  
« ENRICO FERMI »

COURSE LXXII  
edited by G. TORALDO DI FRANCA  
Director of the Course

VARENNA ON LAKE COMO  
VILLA MONASTERO

*Problems in the Foundations  
of Physics*

1979



NORTH-HOLLAND PUBLISHING COMPANY, AMSTERDAM - NEW YORK - OXFORD

## **Library of Congress Cataloging in Publication Data**

Varenna, Italy. Scuola internazionale di fisica.  
Problems in the foundations of physics.

(Proceedings of the International School of Physics  
« Enrico Fermi »; course 72).

At head of title: Italian Physical Society.

Added t.p.: Problemi dei fondamenti della fisica.

Course held July 25-Aug. 6, 1977.

Bibliography: p.

I. Physics—Congresses. I. Toraldo di Francia,  
Giuliano, 1916. II. Società Italiana di Fisica.  
III. Title. IV. Title: Problemi dei fondamenti della  
fisica.

QC1.V29 1979

530.1

79-13069

ISBN 0-444-85285-9

Copyright © 1979, by Società Italiana di Fisica

Proprietà Letteraria Riservata

Printed in Italy

SOCIETA' ITALIANA DI FISICA

---

RENDICONTI  
DELLA  
SCUOLA INTERNAZIONALE DI FISICA  
«ENRICO FERMI»

LXXII CORSO  
a cura di G. TORALDO DI FRANCA  
Direttore del Corso

VARENNA SUL LAGO DI COMO  
VILLA MONASTERO  
25 LUGLIO - 6 AGOSTO 1977

*Problemi dei fondamenti  
della fisica*

1979



SOCIETÀ ITALIANA DI FISICA  
BOLOGNA - ITALY

SOCIETÀ ITALIANA DI FISICA

SCUOLA INTERNAZIONALE DI FISICA « E. FERMI »

LXXII CORSO - VARENNA SUL LAGO DI COMO - VILLA MONASTERO - 25 Luglio - 6 Agosto 1977



## Foreword.

« *Allez en avant, la foi viendra* ». This exhortation attributed to D'ALEMBERT seems to reflect very well the attitude taken by many of the great founders of science. Some of them were perhaps even unaware of the unfirm ground they were treading on; they just went boldly forward, and their success seemed to represent the best justification for the starting assumptions.

Somebody has even remarked that science is not founded upon its foundations. That remark certainly contains a great deal of truth; but it is not the entire story.

It is true that a good many, perhaps the majority, of the great achievements of science were not the result of a brick-by-brick construction, gradually carried out from the foundations to the top, like the construction of an old-time building. Pythagoras' theorem was discovered much before the time when EUCLID settled geometry as a well-founded science. Differential calculus yielded the most brilliant results in celestial mechanics much before CAUCHY, RIEMANN and WEIERSTRASS set out to justify its procedures. Today quantum mechanics can be said to have perfectly fulfilled the task for which it was first introduced: *i.e.* to interpret with great precision all atomic phenomena and radiation processes. Yet the foundations of quantum mechanics still present a number of puzzling problems that are currently challenging the ingenuity of many workers. Ironically, it can be said that in several cases physicists have obtained full success and exciting results before they knew exactly what they were talking about.

It would nevertheless be wrong to derive from these and other countless examples the conclusion that the study of the foundations is « useless », and represents only an academic pastime. The foundational problems of a discipline are likely to arise only when the discipline is fully developed and ripe. But, when finally the scientific community becomes aware of them and subjects them to a critical appraisal, a major breakthrough can occur and a more advanced discipline can arise.

Mechanical clocks of comparatively high precision had existed for centuries, when Einstein's keen examination of how time is measured and simultaneity is ascertained paved the way to special relativity. Euclidean geometry had provided for millennia the firm basis for science, when a critical analysis of its foundations led to a conceptual revolution, and eventually to general

relativity. As a third example, let us recall that, if physicists had gone on taking for granted the elementary and « evident » fact that any quantity can in principle be measured with any precision, independently of other quantities, we would never have built quantum mechanics.

There is a sort of feed-back in the construction of physical science. First a new chapter is built on shaky grounds; then, when it is fully developed, it starts to react on its own foundations. It is only at this later stage that workers begin to realize what these foundations are and to pinpoint the more delicate questions of principle. Perhaps, the increasing interest in the foundational problems of physics which we are witnessing today is due to the unprecedented developments which physics has experienced in this century and to the vast amount of knowledge which is at our disposal today. An increasing number of physicists are becoming more and more critical and want to know « what it is all about ».

The present volume, a response to this demand, cannot encompass, for obvious reasons, all the foundations of physics. It contains the lectures given at the LXXII Course of the International School of Physics « Enrico Fermi ». The topics and the speakers were selected so as to give at least the highlights of several critical subjects which are currently debated today, but no attempt was made to reach completeness.

The foundational problems of physics are certainly all connected with one another. But in many cases the connection is subtle and hidden at a profound level. This makes it very difficult to give a logical succession to the different topics. Accordingly, the Editor has decided to publish the contributions in the alphabetical order of the names of the authors.

G. TORALDO DI FRANCA

PROCEEDINGS OF THE INTERNATIONAL SCHOOL OF PHYSICS  
« ENRICO FERMI »

Course I

**Questioni relative alla rivelazione delle particelle elementari, con particolare riguardo alla radiazione cosmica**  
edited by G. PUPPI

Course II

**Questioni relative alla rivelazione delle particelle elementari, e alle loro interazioni con particolare riguardo alle particelle artificialmente prodotte ed accelerate**  
edited by G. PUPPI

Course III

**Questioni di struttura nucleare e dei processi nucleari alle basse energie**  
edited by G. SALVETTI

Course IV

**Proprietà magnetiche della materia**  
edited by L. GIULOTTO

Course V

**Fisica dello stato solido**  
edited by F. FUMI

Course VI

**Fisica del plasma e applicazioni astrofisiche**  
edited by G. RIGHINI

Course VII

**Teoria della informazione**  
edited by E. R. CAIANIELLO

Course VIII

**Problemi matematici della teoria quantistica delle particelle e dei campi**  
edited by A. BORSELLINO

Course IX

**Fisica dei pioni**  
edited by B. TUSCHKE

Course X

**Thermodynamics of Irreversible Processes**  
edited by S. R. DE GROOT

Course XI

**Weak Interactions**  
edited by L. A. RADICATI

Course XII

**Solar Radioastronomy**  
edited by G. RIGHINI

Course XIII

**Physics of Plasma: Experiments and Techniques**  
edited by H. ALFVÉN

Course XIV

**Ergodic Theories**  
edited by P. CALDIROLA

Course XV

**Nuclear Spectroscopy**  
edited by G. RACAH

Course XVI

**Physicomathematical Aspects of Biology**  
edited by N. RASHEVSKY

Course XVII

**Topics of Radiofrequency Spectroscopy**  
edited by A. GOZZINI

Course XVIII

**Physics of Solids (Radiation Damage in Solids)**  
edited by D. S. BILLINGTON

Course XIX

**Cosmic Rays, Solar Particles and Space Research**  
edited by B. PETERS

Course XX

**Evidence for Gravitational Theories**  
edited by C. MÖLLER

Course XXI

**Liquid Helium**  
edited by G. CARERI

Course XXII

**Semiconductors**  
edited by R. A. SMITH

Course XXIII

**Nuclear Physics**  
edited by V. F. WEISSKOPF



- Course XXIV  
***Space Exploration and the Solar System***  
edited by B. ROSSI
- Course XXV  
***Advanced Plasma Theory***  
edited by M. N. ROSENBLUTH
- Course XXVI  
***Selected Topics on Elementary Particle Physics***  
edited by M. CONVERSI
- Course XXVII  
***Dispersion and Absorption of Sound by Molecular Processes***  
edited by D. SETTE
- Course XXVIII  
***Star Evolution***  
edited by L. GRATTON
- Course XXIX  
***Dispersion Relations and Their Connection with Causality***  
edited by E. P. WIGNER
- Course XXX  
***Radiation Dosimetry***  
edited by F. W. SPIERS and G. W. REED
- Course XXXI  
***Quantum Electronics and Coherent Light***  
edited by C. H. TOWNES and P. A. MILES
- Course XXXII  
***Weak Interactions and High-Energy Neutrino Physics***  
edited by T. D. LEE
- Course XXXIII  
***Strong Interactions***  
edited by L. W. ALVAREZ
- Course XXXIV  
***The Optical Properties of Solids***  
edited by J. TAUC
- Course XXXV  
***High-Energy Astrophysics***  
edited by L. GRATTON
- Course XXXVI  
***Many-Body Description of Nuclear Structure and Reactions***  
edited by C. BLOCH
- Course XXXVII  
***Theory of Magnetism in Transition Metals***  
edited by W. MARSHALL
- Course XXXVIII  
***Interaction of High-Energy Particles with Nuclei***  
edited by T. E. O. ERIGSON
- Course XXXIX  
***Plasma Astrophysics***  
edited by P. A. STURROCK
- Course XL  
***Nuclear Structure and Nuclear Reactions***  
edited by M. JEAN
- Course XLI  
***Selected Topics in Particle Physics***  
edited by J. STEINBERGER
- Course XLII  
***Quantum Optics***  
edited by R. J. GLAUBER
- Course XLIII  
***Processing of Optical Data by Organisms and by Machines***  
edited by W. REICHARDT
- Course XLIV  
***Molecular Beams and Reaction Kinetics***  
edited by CH. SCHLIER
- Course XLV  
***Local Quantum Theory***  
edited by R. JOST
- Course XLVI  
***Physics with Storage Rings***  
edited by B. TOUSCHEK
- Course XLVII  
***General Relativity and Cosmology***  
edited by R. K. SACHS
- Course XLVIII  
***Physics of High Energy Density***  
edited by P. CALDIROLA and H. KNOEPFEL
- Course IL  
***Foundations of Quantum Mechanics***  
edited by B. D'ESPAGNAT
- Course L  
***Mantle and Core in Planetary Physics***  
edited by J. COULOMB and M. CAPUTO
- Course LI  
***Critical Phenomena***  
edited by M. S. GREEN
- Course LII  
***Atomic Structure and Properties of Solids***  
edited by E. BURSTEIN

- Course LIII  
**Developments and Borderlines of Nuclear Physics**  
edited by H. MORINAGA
- Course LIV  
**Developments in High-Energy Physics**  
edited by R. R. GATTO
- Course LV  
**Lattice Dynamics and Intermolecular Forces**  
edited by S. CALIFANO
- Course LVI  
**Experimental Gravitation**  
edited by B. BERTOTTI
- Course LVII  
**Topics in the History of 20th Century Physics**  
edited by C. WEINER
- Course LVIII  
**Dynamic Aspects of Surface Physics**  
edited by F. O. GOODMAN
- Course LIX  
**Local Properties at Phase Transitions**  
edited by K. A. MÜLLER
- Course LX  
**C\*-Algebras and their Applications to Statistical Mechanics and Quantum Field Theory**  
edited by D. KASTLER
- Course LXI  
**Atomic Structure and Mechanical Properties of Metals**  
edited by G. CAGLIOTI
- Course LXII  
**Nuclear Spectroscopy and Nuclear Reactions with Heavy Ions**  
edited by H. FARAGGI and R. A. RICCI
- Course LXIII  
**New Directions in Physical Acoustics**  
edited by D. SETTE
- Course LXIV  
**Nonlinear Spectroscopy**  
edited by N. BLOEMBERGEN
- Course LXV  
**Physics and Astrophysics of Neutron Stars and Black Holes**  
edited by R. GIACCONI and R. RUFFINI
- Course LXVI  
**Health and Medical Physics**  
edited by J. BAARLI
- Course LXVII  
**Isolated Gravitating Systems in General Relativity**  
edited by J. EHLERS
- Course LXVIII  
**Metrology and Fundamental Constants**  
edited by A. FERRO MILONE, P. GIACOMO and S. LESCHIUTTA
- Course LXIX  
**Elementary Modes of Excitation in Nuclei**  
edited by A. BOHR and R. A. BROGLIA
- Course LXX  
**Physics of Magnetic Garnets**  
edited by A. PAOLETTI
- Course LXXI  
**Weak Interactions**  
edited by M. BALDO CEOLIN

## 内部交流

P.91/8

物理学的基础问题

(英 2-3/7081)

A 00410

# INDICE

G. TORALDO DI FRANCIA – Foreword. . . . .	pag. XI
---	---------

Gruppo fotografico dei partecipanti al Corso	fuori testo
--	-------------

E. AMALDI – Radioactivity, a pragmatic pillar of probabilistic conceptions. . . . .	pag. 1
---	--------

1. Gradual infiltration of probability's laws into physical sciences	» 3
2. The discovery of the law of radioactive decay . . . . .	» 6
3. Statistical fluctuations. . . . .	» 10
4. Early models of the nucleus. . . . .	» 15
5. Final remarks . . . . .	» 21

E. G. BELTRAMETTI and G. CASSINELLI – Properties of states in quantum logic.	
--	--

1. Introduction . . . . .	» 29
2. States as probability measures on propositions . . . . .	» 33
3. Propositions as closed sets of states . . . . .	» 41
4. Propositions as mappings of states . . . . .	» 48
5. Transition probability spaces. . . . .	» 55
6. Gleason's theorem and exceptional states . . . . .	» 62

J. BUB – The measurement problem of quantum mechanics.	
--	--

Introductory remarks . . . . .	» 71
PART I. - The statistical problem of measurement . . . . .	» 73
1. von Neumann's formulation of the projection postulate . . . . .	» 73
2. von Neumann's measurement problem . . . . .	» 79
3. The projection postulate as a probability conditionalization rule. . . . .	» 85

4. Hidden variables . . . . .	pag. 94
5. Conditionalization of non-Boolean possibility structures. . . . .	» 100
5'1. The 2-slit experiment. . . . .	» 100
5'2. The Einstein-Podolsky-Rosen experiment. . . . .	» 104
PART II. - The semantic problem of measurement . . . . .	» 108
1. The standard formulation of the measurement problem . . . . .	» 108
2. Bohr . . . . .	» 114
3. von Neumann . . . . .	» 119
Conclusion . . . . .	» 121
G. CASSINELLI and P. TRUINI - Toward a generalized probability theory: conditional probabilities. . . . .	» 125
M. L. DALLA CHIARA and G. TORALDO DI FRANCA - Formal analysis of physical theories.	
Introduction. . . . .	» 134
1. The inductive inference in physics . . . . .	» 136
1'1. What is an inductive inference? . . . . .	» 136
1'2. The many-to-all rule . . . . .	» 140
1'3. The OA rule. . . . .	» 142
2. Physical quantities and physical states . . . . .	» 147
2'1. Observation and operation . . . . .	» 147
2'2. Generalized operational definition of a physical quantity . . . . .	» 150
2'3. Deterministic and probabilistic quantities. . . . .	» 153
2'4. Physical states and physical situations. . . . .	» 159
3. Physical truth and physical theories . . . . .	» 163
3'1. Truth in physics. . . . .	» 163
3'2. Theories and subtheories . . . . .	» 169
3'3. Deterministic <i>vs.</i> probabilistic theories . . . . .	» 171
4. Logical problems of quantum mechanics . . . . .	» 176
4'1. The logician's dilemma of QM . . . . .	» 176
4'2. A formal version of nonrelativistic quantum mechanics . . . . .	» 177
4'3. Classical logic and quantum logic in QT . . . . .	» 179
4'4. A modal interpretation of QL. . . . .	» 187
4'5. Logical self-reference, set-theoretical paradoxes and the measurement problem in QT . . . . .	» 191
M. JAMMER - Some foundational problems in the special theory of relativity.	
1. Introduction . . . . .	» 202
2. Roemer's determination of the velocity of light . . . . .	» 205

3. The rise of special relativity . . . . .	pag. 208
4. The group-theoretical approach . . . . .	» 213
5. The light-geometric approach . . . . .	» 222
6. The nature of length contraction . . . . .	» 227

J.-M. LÉVY-LEBLOND – The importance of being (a) Constant.

1. The changing constants of physics . . . . .	» 237
2. Universal constants and conceptual synthesis; the example of $\hbar$ and quantum mechanics . . . . .	» 240
3. Hidden universal constants; from classical to modern physics . . . . .	» 245
3'1. The fate of universal constants . . . . .	» 245
3'2. The point of view of practice . . . . .	» 248
3'3. The hidden constants of particle physics . . . . .	» 251
4. The case of $c$ ; velocity of light (or is it?) and special relativity . . . . .	» 252
5. Newton constant $G$ ; gravitation and/or general relativity . . . . .	» 258

P. MITTELSTAEDT – Quantum logic.

Introduction . . . . .	» 264
1. The lattice $L_q$ of subspaces of Hilbert space . . . . .	» 265
1'1. The Hilbert space . . . . .	» 265
1'2. The lattice of subspaces . . . . .	» 266
1'3. The relation of commensurability . . . . .	» 268
1'4. The material quasi-implication . . . . .	» 270
2. The logical interpretation of the lattice $L_q$ . . . . .	» 272
2'1. The relation between lattice theory and logic . . . . .	» 272
2'2. Elements of a language of quantum physics . . . . .	» 274
2'3. Commensurability and incommensurability . . . . .	» 277
2'4. The material dialog-game . . . . .	» 279
3. The effective quantum logic . . . . .	» 282
3'1. Formally true propositions . . . . .	» 282
3'2. The formal dialog-game $D_t$ . . . . .	» 284
3'3. The calculus $Q_{eff}$ of effective quantum logic . . . . .	» 286
4. The full quantum logic . . . . .	» 290
4'1. The quasi-implicative lattice . . . . .	» 290
4'2. The relation between $L_{qi}$ and the lattices $L_l$ and $L_q$ . . . . .	» 292
4'2.1. The lattices $L_{qi}$ and $L_l$ . . . . .	» 292
4'2.2. The lattices $L_{qi}$ and $L_q$ . . . . .	» 294
4'3. The principle of excluded middle . . . . .	» 295
4'4. The calculus of full quantum logic . . . . .	» 297

### C. PIRON – Galilean and Lorentz particles: a new approach of quantization.

1. An introduction to the formalism of the quantum physics	pag. 300
2. The notion of imprimitivity system . . . . .	» 301
3. The Galilean particle . . . . .	» 302
4. The Lorentz particle . . . . .	» 305

### I. PRIGOGINE and A. P. GRECOS – Topics in nonequilibrium statistical mechanics.

1. Introduction . . . . .	» 308
2. Irreversible thermodynamics . . . . .	» 311
3. Dynamical evolution . . . . .	» 313
4. Constants of motion . . . . .	» 318
5. Theory of subdynamics . . . . .	» 324
6. Linearized hydrodynamics . . . . .	» 332
7. Concluding remarks . . . . .	» 339

### B. C. VAN FRAASSEN – Foundations of probability: a modal frequency interpretation.

1. Introduction: probability in physics . . . . .	» 344
I. Absolute probability and frequency . . . . .	» 345
2. The axiomatic basis . . . . .	» 346
2'1. The question of additivity . . . . .	» 347
2'2. Equivalents of countable additivity . . . . .	» 348
2'3. The Radon-Nikodym theorem . . . . .	» 349
3. The strict frequency interpretation . . . . .	» 352
3'1. Failure of the probability axioms . . . . .	» 354
3'2. Implications of the laws of large numbers . . . . .	» 355
3'3. Polyá's proof: the separable atomistic Borel field . . . . .	» 358
3'4. Geometric probability . . . . .	» 362
4. The modal frequency interpretation . . . . .	» 365
4'1. Popper: the virtual sequence . . . . .	» 365
4'2. Kyburg: the many-world view . . . . .	» 367
4'3. A modal frequency representation . . . . .	» 369
II. Conditional probability . . . . .	» 372
5. Standard conditionalization . . . . .	» 372
5'1. Orthogonal and full measures . . . . .	» 372
5'2. Partition and orthogonal decomposition . . . . .	» 374
5'3. Teller's proof: conditionalization is unique . . . . .	» 376

6. Conditional relative frequencies . . . . .	pag. 377
6'1. Informal discussion. . . . .	» 377
6'2. The natural frequency space . . . . .	» 378
6'3. A partial algebra of questions. . . . .	» 381
7. Extended conditional probabilities . . . . .	» 384
7'1. Popper: axioms . . . . .	» 385
7'2. Renyi: quotients of measures . . . . .	» 387
7'3. Representation of extended conditional probabilities. . . . .	» 388

J. A. WHEELER - Frontiers of time.

1. Law without law . . . . .	» 395
2. The « past » and the « delayed-choice » double-slit experiment . . . . .	» 415
3. « Development in time » gives way to « correlation in time » . . . . .	» 420
4. Many-fingered time, « imbeddability », and the laws of physics . . . . .	» 425
5. Transcending time . . . . .	» 431
6. Causal order without causal order . . . . .	» 445
7. Asymmetry in time and the expansion of the Universe . . . . .	» 448
8. Memory and the arrow of time . . . . .	» 467
9. The gates of time . . . . .	» 469

# Radioactivity, a Pragmatic Pillar of Probabilistic Conceptions.

E. AMALDI

*Istituto di Fisica dell'Università - Roma*

When, years ago, I read the book by MAX JAMMER *The Conceptual Development of Quantum Mechanics* [1], I found very interesting and stimulating the presentation he gives of this fundamental subject. I should say, however, that I was slightly disappointed from Chapter 4, devoted to *The transition to quantum mechanics*, since it appeared to me too short, incomplete and in some way one-sided.

The chapter consists of three sections. The first one, entitled *Applications of quantum conceptions to physical optics*, summarizes very effectively the work and conceptual background of A. FRESNEL, J. J. THOMSON, A. H. COMPTON, G. BARKLA, W. H. BRAGG and W. L. BRAGG, P. DEBYE and a few others. The second section, devoted to *The philosophical background of nonclassical interpretations*, can be, in some way, summarized by the following sentence by JAMMER himself: « certain philosophical ideas of the late nineteenth century not only prepared the intellectual climate for, but contributed decisively to the formation of the new conceptions of the modern quantum theory » [2]. The people quoted are C. RENOUVIER, E. BOUTROUX, F. EXNER, S. KIERKEGAARD, H. HØFFDING, and also H. POINCARÉ, L. DE BROGLIE, N. BOHR, C. G. DARWIN and a few others. The new conceptions are probabilistic conceptions which « differ fundamentally from the traditional notions of probability as used, for example, in classical statistical mechanics. In classical physics probability statements were but an expression of human ignorance of the exact details of the individual event, either because of the insufficient resolving power of our measuring instrument or because of the large number of events involved: the individual physical process, however, was always regarded as strictly obeying the law of cause and effect and the result was always considered as uniquely determined.

The new conception of probability, on the other hand, assumed not only that macroscopic determinism is a statistical effect but also that the individual microscopic and submicroscopic event is purely contingent » [3].

The third and last section of Chapter 4, entitled *Nonclassical interpretation of optical dispersion*, deals with the early work by N. BOHR, J. C. SLATER,



H. A. KRAMERS and by M. BORN, A. LANDÉ, R. LADENBURG and a few others.

With this presentation of the first attempts to solve the fundamental problem of optical dispersion, Chapter 4 is closed and the discussion of the transition to the new probabilistic conceptions is practically finished.

My first impression that this presentation is too hastily and too one-sided did not find further support from successive Jammer works such as the book on the *Philosophy of Quantum Mechanics* [4], since, in this case, an emphasis (or perhaps an over-emphasis) of the philosophical aspects of the subject is justified by the same title of the book.

My original impression was, on the contrary, strengthened by the article of P. FORMAN on *Weimar culture, causality and quantum theory, 1918-1927* [5], where the author states: ... « Jammer did not go very far towards demonstrating his propositions ... » the most important of which is « that extrinsic influences led physicists to ardently hope for, actively search for, and willingly embrace an acausal quantum mechanics ».

The aim of Forman's article (according to him) is not « to fill the gap left by Jammer » between « a variety of late nineteenth century philosophers » and « the development of quantum mechanics by German speaking central European physicists circa 1925 ». His aim is « rather to examine closely the lay of the land on the far side ... » with the result of a « overwhelming evidence that in the years after the end of the First World War, but before the development of an acausal quantum mechanics, under the influence of 'currents of thought' large numbers of German physicists, for reasons only incidentally related to developments in their own discipline, distanced themselves from, or explicitly repudiated, causality in physics ».

One of the main conclusions of Forman is that the « extrinsic influences » suggested by JAMMER are demonstrated in his article « but only for the German cultural sphere ».

Certainly I am not here to deny the interest of Jammer's point of view and the suggestiveness of the above propositions nor the cultural value of Forman's article, which deeply analyses the interrelations between the development of physical sciences in those years and their cultural and philosophical cradle and environment. What I would like to express in the following is my impression that, by looking at the problem of « repudiation of causality in physics » from the most general and far away point of view, one can be brought to over-estimate the « extrinsic influences » outlined above and overlook « intrinsic arguments » inherent to two parallel, almost independent developments. The first one starts from the kinetic theory of gases and passes through statistical mechanics, Planck original definition of quantum, the photons conceived as particles and the relations between emission and absorption of photons by atoms.

The other path, also intrinsic to physics, starts with the accidental discovery of radioactive substances, passes through the experimental recognition