Cassirer and Energetics

An Investigation of Cassirer's Early Philosophy of Physics

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UNIVERSITÀ
DEGLI STUDI
DI TORINO

Introduction

- **1840s–1850s**: simultaneous discovery[*] of the energy principle (Mayer, Helmholtz)
- **1860s-1870s**: consensus[†] among physicists, impact on culture (Rankine, Thomson and Tait)
- **1860s-1870s**: new science of energy (Helm, Ostwald)[‡]

energetics: unification all of physics through the sole concept of energy without relying on mechanical '*models*' or pictures of phenomena

[*] Kuhn 1959.
[†] Elkana 1975.
[‡] Deltete 1983.

Introduction

Tageblatt

der 67. Versammlung der Gesellschaft

Deutscher Naturforscher und Aerzte in Lübeck

vom 16. bis 21. September 1895.

Herausgegeben von den Geschäftsführern: Senator Dr. W. Brehmer und Dr. med. Th. Eschenburg.
Redigirt von Dr. med. Franz Ziehl.

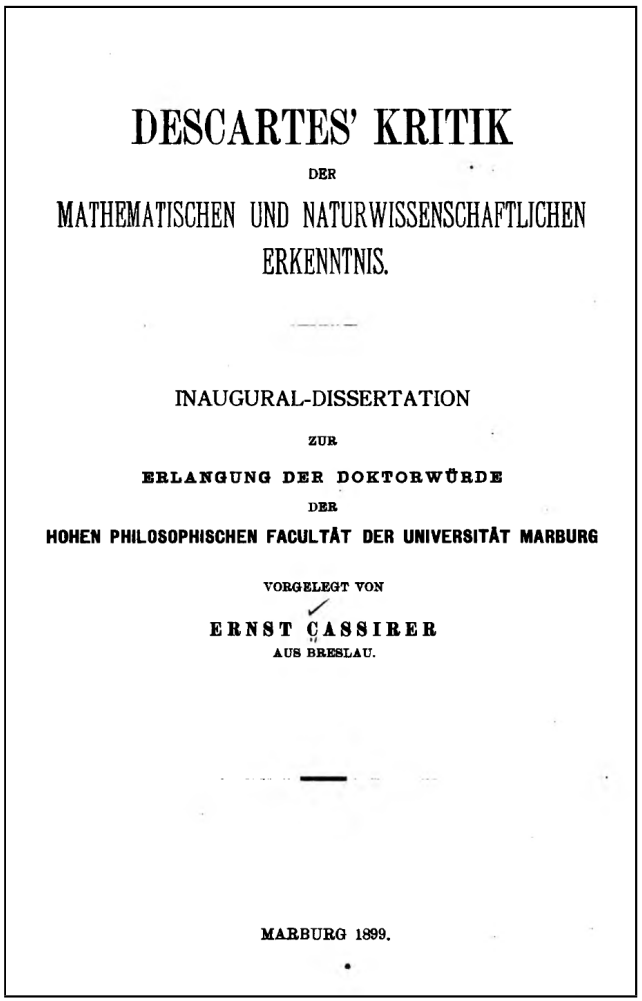
Helm, Ostwald vs. Planck, Boltzmann

Introduction

- energetics in the history of physics $\Longrightarrow$ Deltete (1983)
- energetics in the history of philosophy $\Longrightarrow$?

Cassirer's confrontation with the energetic movement is crucial to understanding the origin and the interplay of the main themes of his early philosophy of physics

Introduction



DESCARTES' KRITIK

DER

MATHEMATISCHEN UND NATURWISSENSCHAFTLICHEN ERKENNTNIS.

INAUGURAL-DISSERTATION

ZUR

ERLANGUNG DER DOKTORWÜRDE

DER

HOHEN PHILOSOPHISCHEN FACULTÄT DER UNIVERSITÄT MARBURG

VORGELEGT VON

ERNST CASSIRER

AUS BRESLAU.

MARBURG 1899.

- **1896**: Cassirer arrived at Marburg (Cohen, Natorp)
  - energetics was well known in Marburg (Lasswitz)
- **1898-1999**: *Preisaufgabe* on Leibniz
- **1899**: dissertation on Descartes
- **1902**: book on Leibniz*

*Ferrari 1988.

Introduction

Leibniz's contributions to the discovery of energy principle

historiography of physics:

- concept of **work**: Descartes in statics, Leibniz in dynamics

philosophy of physics:

- energy principle not a 'principle of conservation' (*Erhaltungsprinzip*), but as a **principle of coordination** (*Zuordnungsprinzip*)*

the energy principle does not postulate the existence of an entity which remains **identical** behind all natural processes; it establishes the quantitative **equivalence** of different phenomena with respect to a common measurement standard (**work**)

*Ryckman 1991.

Introduction

- **1906-1907**: *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit*
- **1907**: “Substanzbegriff und Funktionsbegriff” (lecture)
- **1910**: *Substanzbegriff und Funktionsbegriff* (book)

content of the energy principle

- function-concept vs. substance-concept

justification of energy principle

- *a priori*-principle vs. *a posteriori*-principle

Introduction

Cassirer's in recent literature

- structural realism (Gower, French)
- relativized *a priori* (Friedman, Ryckman)

energy principle as 'statement of principle' (1930s)

Cassirer recognized the importance of the 'meta' character of certain statements from physics*

*Lange 2016; see Giovanelli 2022.

Table of Contents

Part I

Coordination vs. Conservation

LEIBNIZ' SYSTEM

in seinen wissenschaftlichen Grundlagen.

Von

Dr. Ernst Cassirer.

Marburg.
N. G. Elwert'sche Verlagsbuchhandlung.
1902.

Leibniz and History of the Energy Principle

- **Dühring, Mach, Helm, Planck, etc.**: Leibniz's contribution to the discovery of the energy principle: conservation of *vis viva* in elastic collisions.
- **Cassirer**: the *vis viva* controversy was only an example of a more general problem: "[t]he question of the mutual measurability [*Meßbarkeit*] processes that pertain to different areas" of physics
  - qualitatively different mechanical effects to be quantitatively compared, the "general definition of an abstract unity" of measure is needed
  - choice of 'mechanical work' as a common denominator to establish the quantitative equivalence of qualitatively different phenomena

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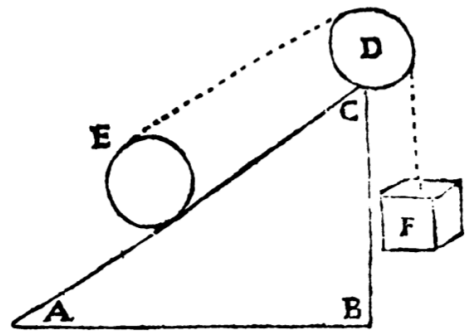
Descartes: The Concept of ‘Work’ in Statics



- **Galileo** $\Longrightarrow$ the ‘principle of virtual velocities’
  - $p : p_1 = v : v_1$
- **Descartes** $\Longrightarrow$ the ‘principle of virtual displacements’
  - $p : p_1 = s : s_1$.

> “In the concept of ‘work’ [ps] and in the *virtual principle*, [Descartes] found and exactly comparable and unified measure [to apply to all simple machines]”

(Cassirer 1902, 50)

Leibniz: The Concept of ‘Work’ in Dynamics

Leibniz $\Longrightarrow$ ‘conservation of conservation of mechanical work’

- $ps_1 : ps_2 = pv_1^2 : pv_2^2$
  - Leibniz: $(4p)s = p(4s)$
  - Galilei: $v_s = \sqrt{2s}$

$$ps = \frac{p}{2}v^2$$

Leibniz expresses the possibility of relating static phenomena to dynamic ones by means of a common unit of measure: **work**

Leibniz: The Concept of ‘Work’ in Dynamics

> “Leibniz arrives at the establishment of the general **concept of work** as the fundamental unit to which every physical process must be related [. . .] Everything that happens, no matter how dissimilar it may appear to subjective observation, must be able to be uniformly objectified in the pure **difference of work quantities**. [. . .] In this respect, it must necessarily be assumed that the measurement for the various basic units, the choice of which is initially **arbitrary**, yields identical results [. . .] Forces that are able to overcome the same gravitational resistance also correspond to identical performances in every other physical area. To deny this presupposition would mean to **abolish the exact and consistent lawfulness** of nature.”

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Cassirer 1902, 305 sq.

Leibniz: The Concept of ‘Work’ in Dynamics

- **Mach, Lasswitz**: Leibniz transformed mechanical work into a metaphysical entity.
- **Cassirer**: Leibniz substituted the “concept of being [*Seinsbegriff*] with with the concept of function [*Funktionsbegriff*]” (Cassirer 1902, 539)

The conservation of mechanical work does not postulate the ‘indestructibility’ of a thing (*Ding*) but imposes the condition (*Bedingung*) of the numerical correspondence (*Zuordnung*) between certain quantities

For any quantity that arises *ex nihilo* and disappears *ad nihilum* without being compensated for, the invariability of the chosen unit would not be granted.

Leibniz: The Concept of ‘Work’ in Dynamics

“ The consideration of various concrete individual areas as are presented by experience [. . .] is taken as a basis; the first logical question that arises concerns the conditions under which a mutually **univocal coordination** [*gegenseitig eindeutige Zuordnung*] and an invertible correspondence between the elements of the different series is possible. [. . .] After a separate **unit of measurement** [*Maßeinheit*] has been defined for each of the areas to be compared, the requirement is that each quantitatively determined value in one **series** [*Reihe*] can be assigned one and only one variable in each other series. Under this condition, the particular measure of an individual area can continue to measure and represent every process within the overall system. As one can see, a purely ideal relationship is established between different points of comparison as they are given to the senses, without this being a **new reality** of its own that has a detached physical existence in addition to the special content under consideration. ”

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The Justification of the Principle of Mechanical work

- **metaphysical** justification: *causa aequat effectum*
- **empirical** justification: impossibility of a *perpetuum mobile*

trascendental justitication *ante litteram*

. . . caderet tota Scientia Dynamica, seu impossibile esset vires aestimare
(Leibniz to Johan Bernoulli, Aug. 24, 1695)

> The general idea of conservation first appears in Leibniz in the form of a demand for **fixed and univocal unit ratio** in the transition between the special areas of physics. But this demand, as Leibniz claims against Johann Bernoulli, means nothing less than **a condition of the possibility of dynamics as a science**. In this way, a general judgment has already been expressed about the relation of the fundamental principle to experience. The existence of certain equivalents for given processes must be shown **empirically**; but the general point of view of the comparison itself, which leads to research into fixed quantitative relationships, is not simply given by experience but, as we have seen, can only be gained via an **intellectual** operation. [. . .] In this sense, we can call the energy law an ***a priori* law**—provided that we use the expression of the *a priori* as the fundamental tool for gaining knowledge from the mere descriptions of existing facts.

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The Justification of the Principle of Mechanical work

If a stone falls to the ground and stays there, what becomes of the mechanical work initially given to it?

- **problem**: the quantity of mechanical work appears to be conserved only in elastic collisions, thus it is never conserved (Cassirer 1902, 321)
- **solution**: the mechanical work that is apparently lost in inelastic collisions must be redistributed to the motion of the bodies' minute parts (Cassirer 1902, 321).

Leibniz's Contribution to the Discovery of the Energy Principle

- Leibniz's confidence in the **universal validity** of his conservation principle paved the way to a completely general principle of energy conservation
- the mechanical work that seems to have disappeared in non-elastic collisions could be **measured** in the form of heat.

mechanical equivalent of heat (Mayer)

α mechanical units $= \beta$ thermal units

> "The discoverer of the equivalence law relied on the this very same principle [*causa aequat effectum*]. Mayer's conception shows surprising agreement with Leibnizian ideas, down to the last detail."
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Prehistory of Criticism

- **1901:** chapter of the ‘prehistory of criticism’ (Cassirer to Natorp, Nov. 26, 1901; ECN, Vol. 18, Doc. 43)*
- **1902:** “my work on the prehistory of the critique of reason” (Cassirer to Natorp, Dec. 13, 1902; ECN, Vol. 18, Doc. 55)
- **1905:** a systematic volume was required (Cassirer to Natorp, Jul. 31, 1905; ECN, Vol. 18, Doc. 70)
- **1906:** “physics, in particular, energetics” Cassirer to Natorp, 28-06-1906

*Ferrari 1988.

Das Erkenntnisproblem

DAS ERKENNTNISPROBLEM

in der Philosophie und Wissenschaft

der neueren Zeit

VON

DR. ERNST CASSIRER

ERSTER BAND

VERLAG VON BRUNO CASSIRER

BERLIN 1906

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DR. ERNST CASSIRER

ZWEITER BAND

VERLAG VON BRUNO CASSIRER

BERLIN 1907

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“ The equality of cause and effect is [. . .] a **postulate** with which we approach perceptions and according to which we categorize them in fixed, constant orders. If we stop at the mere sensory observation, the events are first broken down into completely **heterogeneous series** [*Reihen*] [. . .] In order to **mutually coordinate** to one another and measure them one with respect to the other, one must first establish a **conceptual unity** [*begriffliche Einheit*] in which they are connected. Whatever **qualitative differences** the phenomena may have among themselves: there must be a point of view that makes them **quantitatively equivalent**. Leibniz discovered in the **concept of work** [. . .] a **common measure** of their performance [*Leistungsfähigkeit*]. If there were no such measure, it were found that two ‘forces’ have the same effects within the area of physics, [. . .] lead to different results in other areas. The **entire dynamic science would collapse** ”

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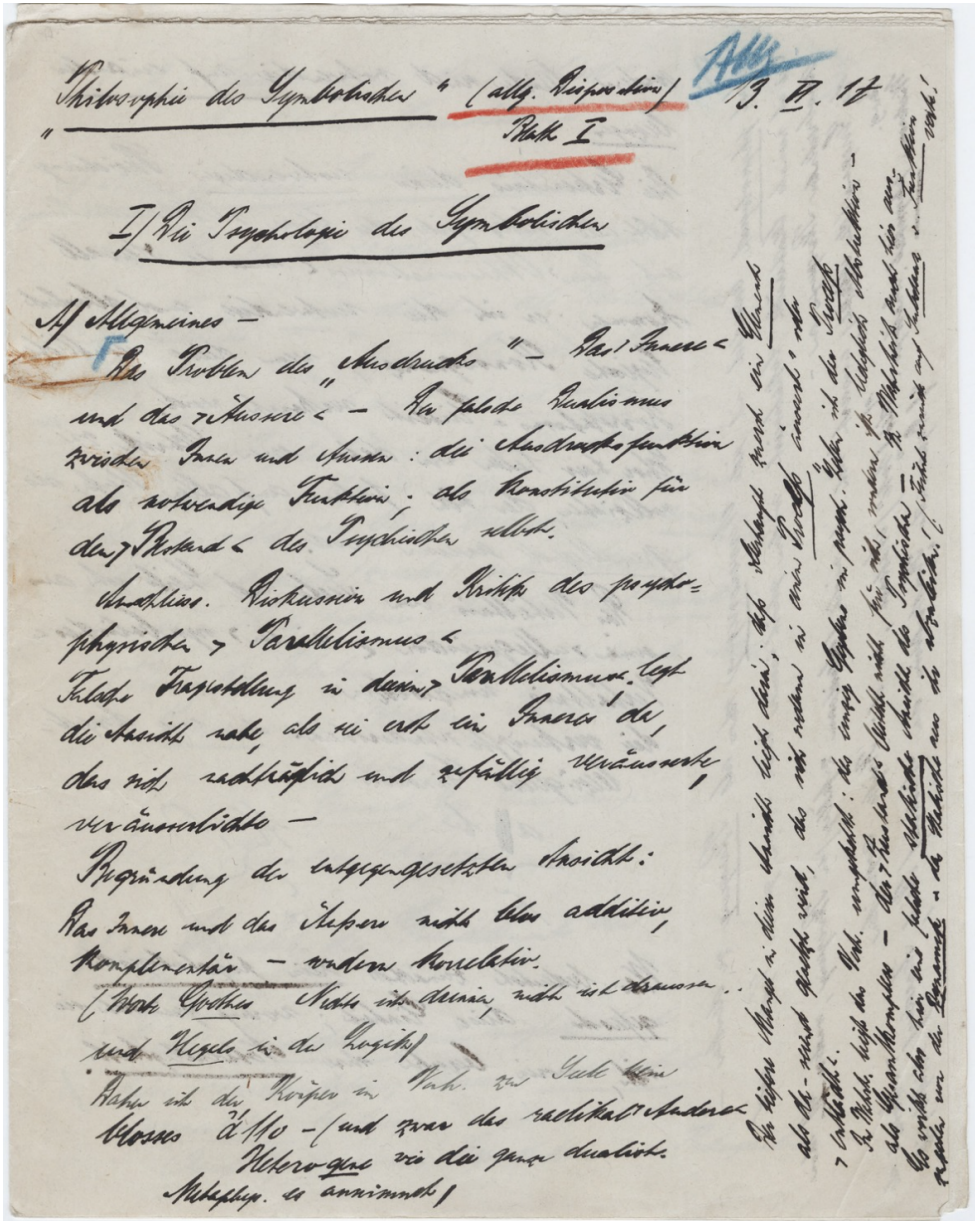
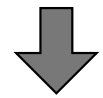
Part II

Substance-Concept vs. Function-Concept



Substanzbegriff und Funktionsbegriff (*Probevorlesung*, July 26, 1907)



> modern *energetics* elevated the question of the general relationship between **substance-concept** and **function-concept** to a new and higher point of view

Substance-Concept vs. Function-Concept: The Lecture

> [According to] Robert **Mayer** [. . .] the actual logical advantage of the energy law [. . .] What is really given to us, for example in the conversion of heat into motion, are in fact only two **qualitatively** different processes, between which we discover a constant **quantitative** relationship of transition and thus a functional *dependency*. Wherever we speak of energy as a **separate being**, we mean nothing other than this **relationship** and this mathematical context. The energy is not an **object** endowed with its own perceivable qualities and characteristics; it is even less an unknown and merely imaginary **carrier** that lies at the basis of the diverse forms of physical events as a permanent and qualityless substrate.

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Substance-Concept vs. Function-Concept: The Lecture

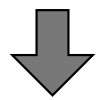
reception **Mayer** within the energetics: movement

- **Helm**: energetics as a ‘pure system of relations’ (Helm, 1898, 20, 362) between the observable parameters which determine the ‘state’ of a material system
- **Ostwald**: energy as ‘a real substance and not just as a mathematical abstraction’ (Ostwald, 1891, 566).

Space-Concepts and Number-Concepts

epistemological mistake:

- **energeticists**: phenomenological vs. mechanisicists physics, observables vs. models
- **Cassirer**: algebraic vs. geometric methods, number-concepts vs. number-concepts*



energetics: process of **algebraization** of physics

*(Cassirer 1909, 1902).

SUBSTANZBEGRIFF UND FUNKTIONSBEGRIFF

Untersuchungen über die Grundfragen
der Erkenntniskritik

von

ERNST CASSIRER

VERLAG VON BRUNO CASSIRER
BERLIN 1910

Substance-Concept vs. Function-Concept

> The fundamental thought [*of energetics*] from an epistemological point of view, does not go back primarily to the **concept of space**, but to the **concept of number**

Cassirer 1910, 189

- **abstraction** of common identical properties of the actually given
- **construction** of series of possible different values of parameters

Substance-Concept vs. Function-Concept

> “The insertion of the sensible manifold into a **series** of purely mathematical structure remains inadequate, as long as these series are separated from each other a constant numerical relation governing the **transition** from one series [*Reihe*] to the others [. . .] From this point, the general meaning of the conception of **energetics** can be surveyed. The structure of mathematical physics is in principle complete when we have arranged the members of the individual series according to an **exact numerical scale**, and when we discover a **constant numerical relation** governing the transition from one series to the others. Only when this is done is the way determined from one member to any other, and prescribed by **fixed rules** of deduction, no matter what the series.”

Cassirer 1910, 252

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Cassirer 1910, 252

Substance-Concept vs. Function-Concept

- process: $A, B, C, \ldots$ (mechanical, electrical, thermal, etc.)
- states: $A_1, A_2, A_3, \ldots A_n, B_1, B_2, B_3 \ldots B_n, C_1, C_2, C_3, \ldots C_n$
- parameters: $a_1, a_2, a_3, \ldots a_n, b_1, b_2, b_3 \ldots b_n, c_1, c_2, c_3, \ldots c_n$ (height, velocity, temperature, etc..)

equal changes in state parameters of certain processes ($\Delta a, \Delta b, \ldots$) $\equiv$ equal changes in height of a standard object (ΔW)

coordinate to each momentary state a unique value (*eindeutiger Wert*) (in work units) to the momentary state of a given physical system with respect to an arbitrarily chosen zero state $\Longrightarrow$ **energy**

Substance-Concept vs. Function-Concept

> The law of energy directs us to **coordinate** every member of a manifold with one and only one member of any other manifold, in so far as to any *quantum* of motion, there corresponds one *quantum* of heat, to any *quantum* of electricity, one *quantum* of chemical attraction, and so on. In **'work' as a measure-concept** [*Maßbegriff der Arbeit*], all these determinations of magnitude are related to a common denominator [*Nenner*]. If such a connection is once established, then every numerical difference that we find within one series can be completely expressed and **reproduced** in the appropriate values of any other series. [. . .] In this postulate, the essential content of the principle of **conservation** is already exhausted, for any quantity of work which arose from nothing would violate the principle of the mutual univocal **coordination** [*wechselseitig eindeutigen Zuordnung*] of all series

Cassirer, 1910, 253f.

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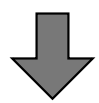
Substance-Concept vs. Function-Concept

principle of coordination vs. principle of conservation

- energy as a **substance** is a *quid* that is common to motion, heat, magnetism and electricity, without being reducible to any of these.
- energy as a functional **relation** is nothing more than a rule according to which changes in disparate phenomena can be compared along a common measurement scale.



the **choice of units** (work units, heat units, etc..) is arbitrary, but the **ratio of units** is an natural constant

Substance-Concept vs. Function-Concept

energetics vs. **mechanism**

- **mechanism**: reduction of qualitatively different phenomena to one class (local motion);
- **energetics** establish the minimum of conditions for the ‘measurability’ of different classes of phenomena in general without thereby extinguishing their individual qualitative features.

energy principle as **invariant** of experience
$\Longrightarrow$ provisional candidate for a constitutive *a priori*

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Part III

Measure-Concept vs. Thing-Concept

ZUR
EINSTEIN'SCHEN RELATIVITÄTSTHEORIE

ERKENNTNISTHEORETISCHE BETRACHTUNGEN

VON

ERNST CASSIRER

BERLIN 1921
BRUNO CASSIRER VERLAG

Measure-Concept vs. Thing-Concept

young Planck's definition of energy (1887)

- **energy concept**: the energy E of a physical system as the amount of external effects, measured in work units, necessary for a system to pass in whatever way from its current state S' to an arbitrary chosen zero state S.
- **energy principle**: The amount, calculated in mechanical work units, of all the effects that a material system produces in the external environment when it passes arbitrarily from a given state S' to an arbitrarily chosen zero state S, has a precise value, independent of the way in which passage is effected

path independence: energy has a "univocal value [*einen eindeutigen Wert*] [E]" no matter which process one uses to transform S' back into S.

Measure-Concept vs. Thing-Concept

measure-concept (*Maßbegriff*) vs. **measure-principle** (*Maßprinzip*)

- if path independence would not hold no univocal value of energy
- path independence a physical fact, no *perpetuum mobile*

measure-concept (*Maßbegriff*)) vs. **thing-concept** (*Dingbegriff*)

- the energy of a system is a single-valued function of the parameters that determine its instantaneous state.
- energy thus resembles a substance that can be ‘stored’, ‘transferred’, ‘consumed’, etc. (Planck)

univocality of measurement [*Eindeutigkeit der Maßbestimmung*] $\Longrightarrow$ **univocality of the object** [*Eindeutigkeit der Objektbestimmung*] (Cassirer 1921, 47)

Measure-Concept vs. Thing-Concept

> In the strict sense, I would actually only accept the idea of [. . .] the '**univocality of the coordination**' [*Eindeutigkeit der Zuordnung*] as '*a priori*' in the strict sense. How this idea is specified into particular **principles and requirements** emerges only in the progress of scientific experience [. . .] However, in my view the principle of univocality [*Eindeutigkeit*] itself is more than a mere 'convention' or as an 'inductive generalization': it is an expression for me of '**reason**', of the *logos* itself.

Cassirer to Schlick, 23-10-1920

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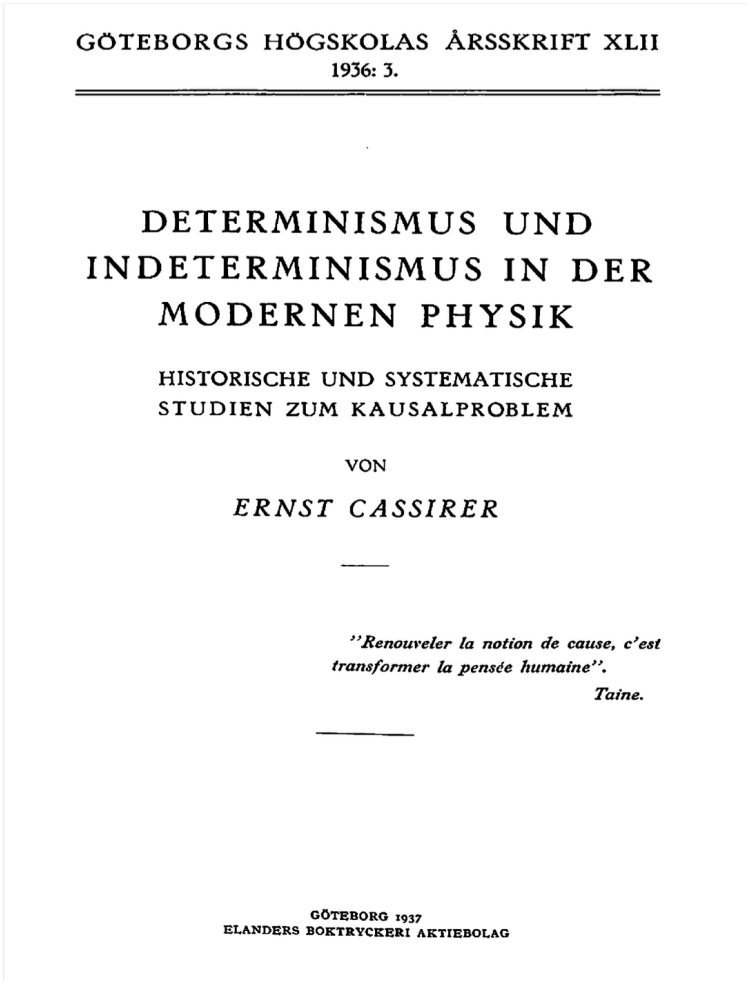


GÖTEBORGS HÖGSKOLAS ÅRSSKRIFT XLII
1936: 3.

DETERMINISMUS UND INDETERMINISMUS IN DER MODERNEN PHYSIK

HISTORISCHE UND SYSTEMATISCHE STUDIEN ZUM KAUSALPROBLEM

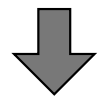
VON

ERNST CASSIRER

''Renouveler la notion de cause, c'est transformer la pensée humaine''.
Taine.

GÖTEBORG 1937
ELANDERS BOKTRYCKERI AKTIEBOLAG

- energy principle as a 'statement of principle': constitutive, but *a posteriori* constraint imposed on the structure of the laws of nature:
- the *a priori* motivates and guides the search for the laws of nature, without providing any particular insight into their structure.



motivational Kantianism*

*Giovanelli 2022.

Part IV

Conclusion

Conclusion

Cassirer, the energy principle and the Energetics

history of physics:

- origin of the concept of work in Descartes and Leibniz: contribution of French engineers (Hiebert vs. Kuhn)

philosophy of physics:

- relational conception of energy: localization of energy (Planck vs. Hertz)
- conception of the *a priori*: constitutive vs. regulative (Cassirer vs. Schlick)

Thanks!

Marco Giovanelli

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