

3. Zur Elektrodynamik bewegter Körper;
von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhafthen scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Mag-

On the electrodynamics of moving bodies

A. Einstein

Ann. d. Phys. 17 (1905), 891

Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche



PRINCIPES GÉNÉRAUX
DE L'ETAT D'EQUILIBRE DES FLUIDES.
PAR M. EULER.

L



Je me propose ici de développer les principes, sur lesquels toute l'Hydrostatique, ou la Science de l'équilibre des fluides, est fondée. Pour leur donner la plus grande étendue dont ils sont susceptibles, je renfermerai dans mes recherches non seulement les fluides, qui ont partout le même degré de densité, tels que l'eau, & les autres corps liquides, dont on dit, qu'ils ne reçoivent aucune compréssion; mais aussi ceux qui sont composés de particules d'une densité différente.

General principles of fluid equilibrium

L. Euler

Mém. acad. sci. Berlin 11 (1757), 217

trouve expliqués dans les éléments, ne font qu'un cas très particulier de ceux, que je m'en vais établir ici. Car d'un côté on ne regarde communément que la gravité, à l'action de laquelle les particules du fluide sont assujetties; & de l'autre côté on ne confidère que les fluides.

Adm. de l'Acad. Tom. XI

E e des

Zur Quantenmechanik der Stoßvorgänge.

[Vorläufige Mitteilung.]¹⁾

Von Max Born, Göttingen.

(Eingegangen am 25. Juni 1926.)

Durch eine Untersuchung der Stoßvorgänge wird die Auffassung entwickelt, daß die Quantenmechanik in der Schrödinger'schen Form nicht nur die stationären Zustände, sondern auch die Quantensprünge zu beschreiben gestattet.

Die von Heisenberg begründete Quantenmechanik ist bisher ausschließlich angewandt worden zur Berechnung der stationären Zustände und der den Übergängen zugeordneten Schwingungsamplituden (ich vermeide absichtlich das Wort „Übergangswahrscheinlichkeiten“). Dabei scheint sich der inzwischen weit entwickelte Formalismus gut zu bewähren. Aber diese Fragestellung betrifft nur eine Seite der quantentheoretischen Probleme; daneben erhebt sich als ebenso wichtig die Frage nach dem Wesen der „Übergänge“ selbst. Hinsichtlich dieses Punktes scheint die Meinung geteilt zu sein; viele nehmen an, daß das Problem der Übergänge von der Quantenmechanik in der vorliegenden Form nicht erfaßt wird, sondern daß hier neue Begriffsbildungen nötig sein werden. Ich selbst kam durch den Eindruck der Geschlossenheit des logischen Aufbaues der Quantenmechanik zu der Vermutung, daß diese Theorie vollständig sei und das Übergangsproblem mit enthalten müsse. Ich glaube, daß es mir jetzt gelungen ist, dies nachzuweisen.

Schon Bohr hat die Aufmerksamkeit darauf gerichtet, daß alle

On the quantum mechanics of collisions

M. Born

Z. Phys. 37 (1926), 863

könnte aber dort wegen Raumangabe nicht aufgenommen werden. Ich hoffe, daß ihre Veröffentlichung an dieser Stelle nicht überflüssig erscheint.
Zeitschrift für Physik. Bd. XXXVII.

57



Clarendon Press Series



A TREATISE
ON
ELECTRICITY AND MAGNETISM

$$dQ = 0$$

$$dF = 0$$

$$d(\epsilon F) = Q$$

BY

JAMES CLERK MAXWELL, M.A.

LLD. EDIN., F.R.SS. LONDON AND EDINBURGH
HONORARY FELLOW OF TRINITY COLLEGE,
AND PROFESSOR OF EXPERIMENTAL PHYSICS
IN THE UNIVERSITY OF CAMBRIDGE

VOL. I

Oxford

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1873

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VOL. I

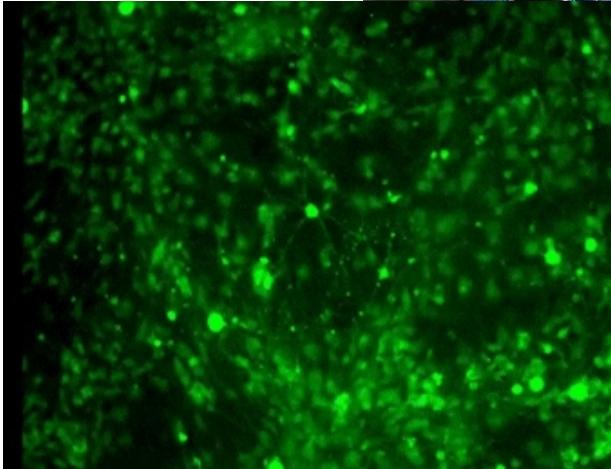
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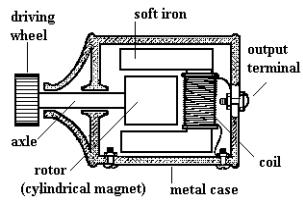
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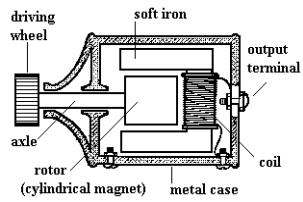
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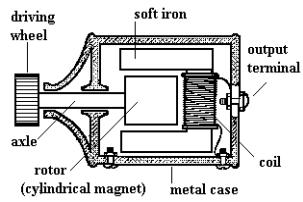
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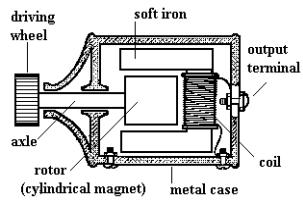
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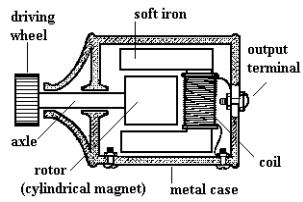














$$dQ = 0$$

$$dF = 0$$

$$d(\epsilon F) = Q$$

different phenomena!



3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

On the electrodynamics of moving bodies

A. Einstein

Annalen der Physik 17 (1905), 891

ON THE ELECTRODYNAMICS OF MOVING BODIES

by A. Einstein

[*Annalen der Physik* 17 (1905): 891-921]

It is well known that Maxwell's electrodynamics—as usually understood at present—when applied to moving bodies, leads to asymmetries that do not seem to attach to the phenomena. Let us recall, for example, the electrodynamic interaction between a magnet and a conductor. The observable phenomenon depends here only on the relative motion of conductor and magnet, while according to the customary conception the two cases, in which, respectively, either the one or the other of the two bodies is the one in motion, are to be strictly differentiated from each other.

Examples of a similar kind, and the failure of attempts to detect a motion of the earth relative to the "light medium", lead to the conjecture that not only in mechanics, but in electrodynamics as well, the phenomena do not have any properties corresponding to the concept of absolute rest, but that in all coordinate systems in which the mechanical equations are valid, also the same electrodynamic and optical laws are valid, as has already been shown for quantities of the first order. We shall raise this conjecture (whose content will be called "the principle of relativity" hereafter) to the status of a postulate and shall introduce, in addition, the postulate, only seemingly incompatible with the former one, that in empty space light is always propagated with a definite velocity v which is independent of the state of motion of the emitting body. These two postulates suffice for arriving at a simple and consistent electrodynamics of moving bodies on the basis of Maxwell's theory for bodies at rest. The introduction of a "light ether" will prove superfluous, inasmuch as in accordance with the concept to be developed here, no "space at absolute rest" endowed with special properties will be introduced, nor will a velocity vector be assigned to a point of empty space at which electromagnetic processes are taking place.

Like every other electrodynamics, the theory to be developed is based on the kinematics of the rigid body, since assertions of each and any theory concern the relations between rigid bodies (coordinate systems), clocks, and electromagnetic processes. Insufficient regard for this circumstance is at the root of the difficulties with which the electrodynamics of moving bodies must presently grapple.

§1. Definition of simultaneity

If we want to describe the *motion* of a material point, we give the values of its coordinates as a function of time. However, we should keep in mind that for such a mathematical description to have physical meaning, we first have to clarify what is to be understood here by "time." We have to bear in mind that all our propositions involving time are always propositions about *simultaneous events*. If, for example, I say that "the train arrives here at 7 o'clock," that means, more or less, "the pointing of the small hand of my clock to 7 and the arrival of the train are simultaneous events."¹

If there is a clock at point *A* of space, then an observer located at *A* can evaluate the time of the events in the immediate vicinity of *A* by finding the clock-hand positions that are simultaneous with these events. If there is also a clock at point *B*—we should add, "a clock of exactly the same constitution as that at *A*"—then the time of the events in the immediate vicinity of *B* can likewise be evaluated by an observer located at *B*. But it is not possible to compare the time of an event at *A* with one at *B* without a further stipulation; thus far we have only defined an "*A*-time" and a "*B*-time" but not a "time" common to *A* and *B*. The latter can now be determined by establishing by definition that the "time" needed for the light to travel from *A* to *B* is equal to the "time" it needs to travel from *B* to *A*. For, suppose a ray of light leaves from *A* toward *B* at "*A*-time" t_A' , is reflected from *B* toward *A* at "*B*-time" t_B' , and arrives back at *A* at "*A*-time" t_A'' . The two clocks are synchronous by definition if

$$t_B - t_A = t_A'' - t_B'$$

we have thus laid

down what is to be understood by synchronous clocks at rest that are situated at different places, and have obviously obtained thereby a definition of "synchronous" and of "time."

What was new in Einstein's paper?

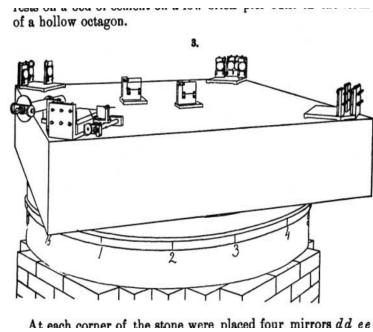
What was new in Einstein's paper?

~~Experiment~~

Michelson-Morley experiment, 1887

THE
AMERICAN JOURNAL OF SCIENCE.
1887.
[THIRD SERIES.]

ART. XXXVI.—*On the Relative Motion of the Earth and the Luminiferous Ether*; by ALBERT A. MICHELSON and EDWARD W. MORLEY.*



What was new in Einstein's paper?

~~Maths~~

Lorentz transformations: Lorentz, 1899

Physics. — “*Simplified Theory of Electrical and Optical Phenomena in Moving Systems*”. By Prof. H. A. LORENTZ.

§ 4. Now, in order to simplify the equations, the following quantities may be taken as independent variables

$$x' = \frac{V}{\sqrt{V^2 - p_x^2}} x, \quad y' = y, \quad z' = z, \quad t' = t - \frac{p_x}{V^2 - p_x^2} x \quad . \quad (1)$$

energy's inertia: Poincaré, 1900

LA THÉORIE DE LORENTZ

er

LE PRINCIPE DE RÉACTION

Recueil de Travaux offerts par les Auteurs à H. A. Lorentz, professeur de Physique à l'Université de Leiden à l'occasion du 25^e anniversaire de son Doctorat, le 11 décembre 1900.

Le recul réel est $\frac{J}{V}$; dans le mouvement apparent, il faut remplacer J par $J(1 - \frac{\varphi}{V})$ de sorte que le recul apparent est

$$\frac{J}{V} - \frac{J\varphi}{V^2}.$$

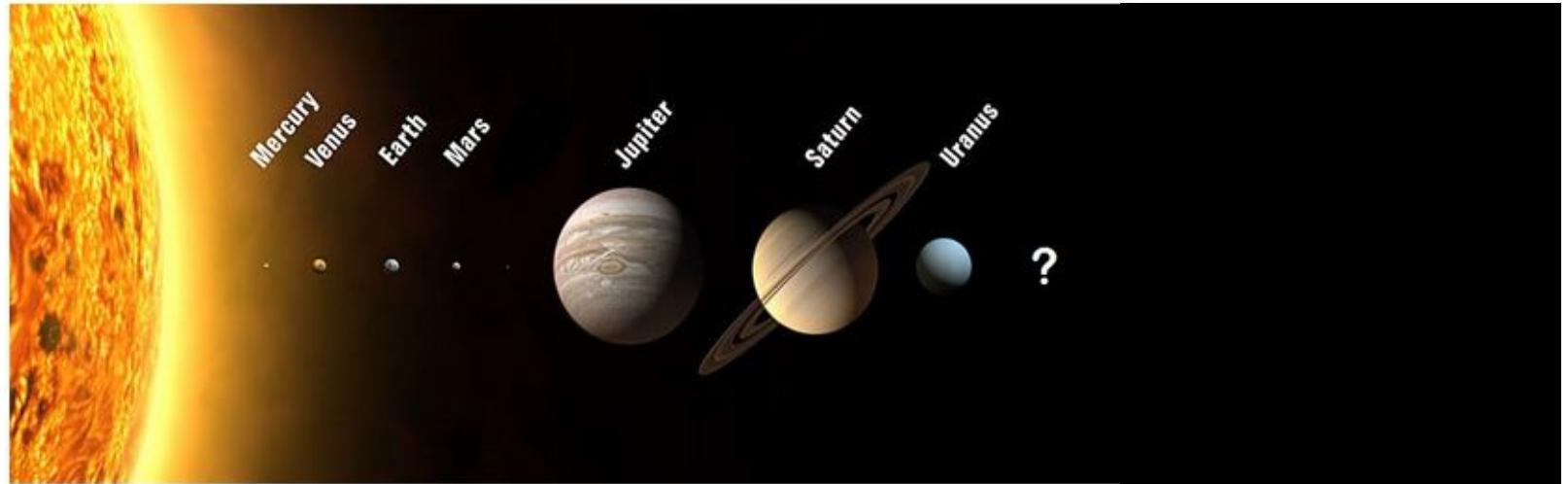
Il faut donc pour compléter le recul réel, ajouter au recul apparent une force complémentaire apparente $\frac{J\varphi}{V^2}$ (je mets le signe — parce que le recul, comme l'indique son nom, a lieu dans le sens négatif).

What was new in Einstein's paper?

Logical/semantic analysis

However, we should keep in mind that for such a mathematical description to have physical meaning, we first have to clarify what is to be understood here by "time."

what is to be understood by synchronous clocks at rest that are situated at different places, and have obviously obtained thereby a definition of "synchronous" and of "time."







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THE LOGIC OF MODERN PHYSICS

BY

P. W. BRIDGMAN

HOLLIS PROFESSOR OF MATHEMATICS AND NATURAL HISTORY
IN HARVARD UNIVERSITY



New York
THE MACMILLAN COMPANY
1958

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THE OPERATIONAL CHARACTER OF CONCEPTS *Einstein's Contribution in Changing Our Attitude Toward Concepts*

We should now make it our business to understand so thoroughly the character of our permanent mental relations to nature that another change in our attitude, such as that due to Einstein, shall be forever impossible. It was perhaps excusable that a revolution in mental attitude should occur once, because after all physics is a young science, and physicists have been very busy, but it would certainly be a reproach if such a revolution should ever prove necessary again.

It was a great shock to discover that classical concepts, accepted unquestioningly, were inadequate to meet the actual situation, and the shock of this discovery has resulted in a critical attitude toward our whole conceptual structure which must at least in part be permanent. Reflection on the situation after the event shows that it should not have needed the new experimental facts which led to relativity to convince us of the inadequacy of our previous concepts, but that a sufficiently shrewd analysis should have prepared us for at least the possibility of what Einstein did.

New York
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not only experiment

not only mathematics

not only experiment

not only mathematics

equally important: *logical/semantic* analysis

not only experiment

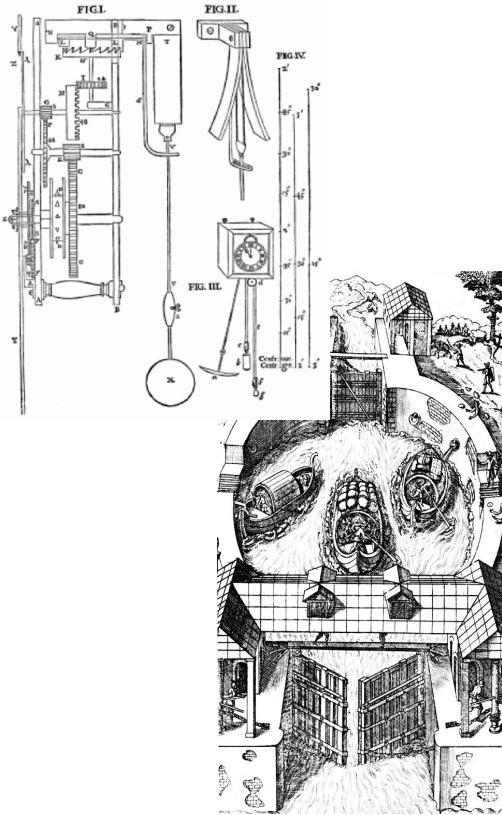
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equally important: *logical/semantic* analysis

...of very innocent-looking words!

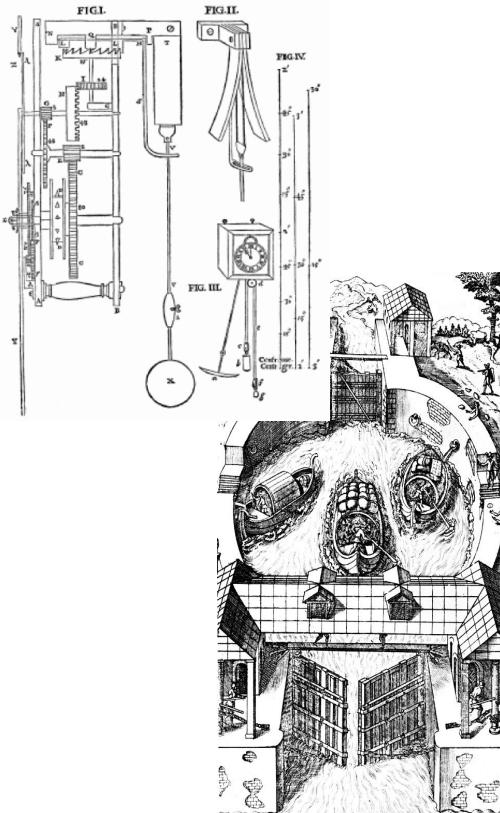


Huygens, 1673
Horologium oscillatorium



Vittorio Zonca, 1607
Novo teatro di machine et edificii per varie et sicure operationi

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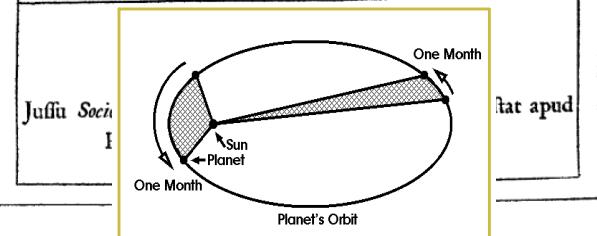


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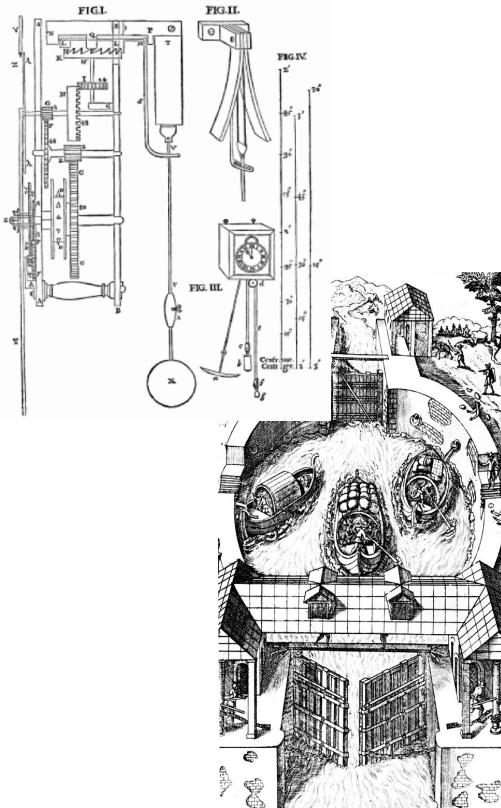
PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA.

Autore J. S. NEWTON, Trin. Coll. Cantab. Soc. Mathesios
Professore Lucaiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. P E P Y S, Reg. Soc. PRÆSES.
Julii 5. 1686.



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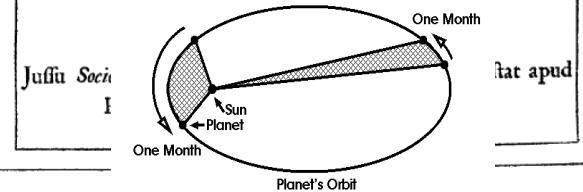
$$F = ma \dots ?$$



PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA.

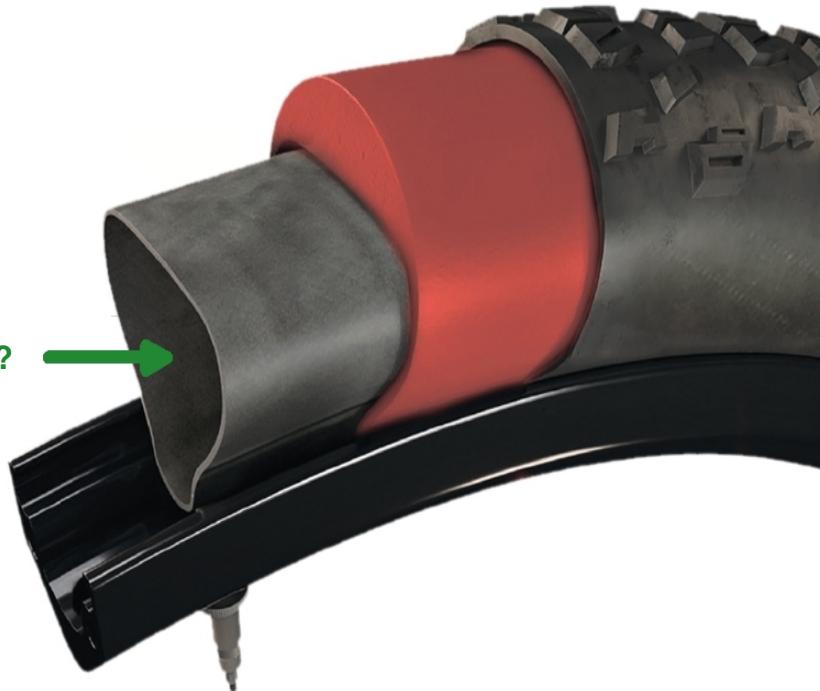
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how much is the pressure here? →

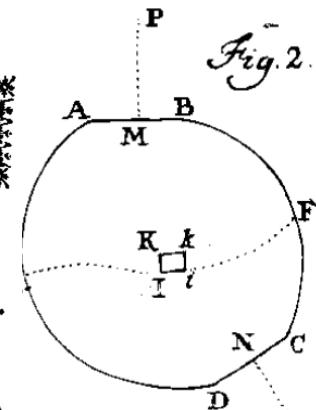




Euler, 1753: what does *pressure* mean?



PRINCIPES GÉNÉRAUX DE L'ETAT D'EQUILIBRE DES FLUIDES. PAR M. EULER.



mens des vaisseaux soutiennent des pressions, qui répondent à la même hauteur p , mais aussi tous les éléments du fluide même se trouveront dans le même état de pression. Qu'on conçoive dans l'intérieur du fluide un diaphragme immatériel $EJiF$, qui retranche de la masse du fluide une portion quelconque $AEBF$; &, puisque cette portion est en équilibre, toutes les particules du diaphragme soutiendront aussi des forces, qui répondent à la même hauteur p . D'où il s'ensuit, que chaque élément de la masse fluide $IKki$ fera de toutes parts pressé par de pareilles forces; ou bien toutes les particules du fluide feront pressées les unes contre les autres par des forces qui répondent toutes à la même hauteur p ; c'est donc l'égalité de toutes ces forces, qui constitue l'état d'équilibre, supposant toujours, qu'il n'y ait point de forces particulières, comme la gravité, qui agissent sur les particules du fluide.

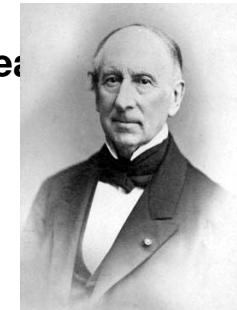
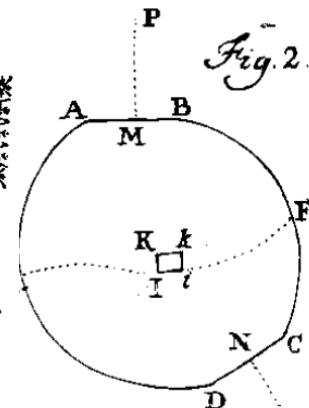


Euler, 1753:
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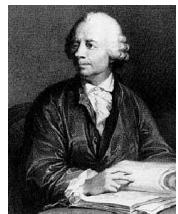


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Cauchy, 1828
SUR LES ÉQUATIONS
QUI EXPIMENT
LES CONDITIONS D'ÉQUILIBRE
de
LES LOIS DU MOUVEMENT INTÉRIEUR
D'UN CORPS SOLIDE, ÉLASTIQUE OU NON ÉLASTIQUE.

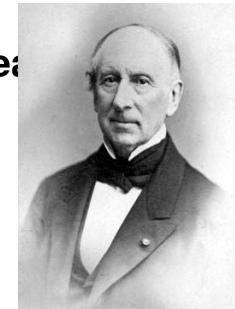
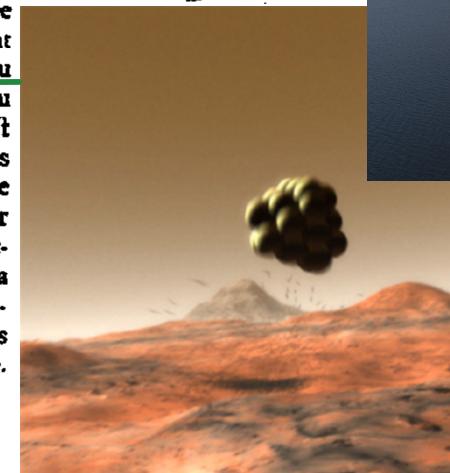
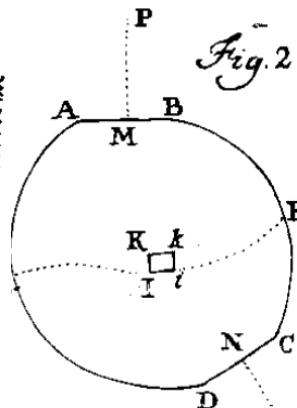


Euler, 1753:
what does pressure measure?



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Cell Mechanotransduction With Piconewton Forces Applied by Optical Tweezers

Fabio Falleroni¹, Vincent Torre^{1,2,*} and Dan Cojoc^{4*}

¹Neuroscience Area, International School for Advanced Studies, Trieste, Italy

²Cixi Institute of Biomedical Engineering, Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Zhejiang, China

³Center of Systems Medicine, Chinese Academy of Medical Sciences, Suzhou Institute of Systems Medicine, Suzhou Industrial Park, Suzhou, China

⁴Institute of Materials, National Research Council of Italy (CNR), Trieste, Italy

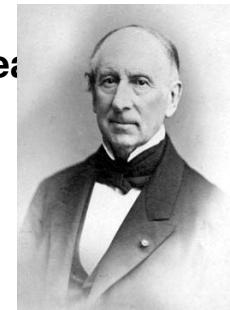
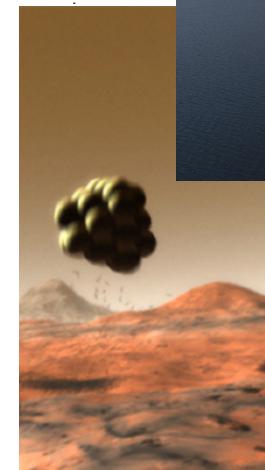
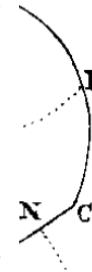
PRIN
DE L'E'TA

mens des vaisseaux hauteur p , mais dans le même é fluidé un diaphrاغne fluidé une portio en équilibre, tou forces, qui rép chaques élément c de pareilles force sées les unes con même hauteur p tué l'état d'équilit particulières, con

Mechanical stresses are always present in the cellular environment and mechanotransduction occurs in all cells. Although many experimental approaches have been developed to investigate mechanotransduction, the physical properties of the mechanical stimulus have yet to be accurately characterized. Here, we propose a mechanical stimulation method employing an oscillatory optical trap to apply piconewton forces perpendicularly to the cell membrane, for short instants. We show that this stimulation produces membrane indentation and induces

753:
sure mea

Fig. 2.



Cauchy, 1828

SUR LES ÉQUATIONS

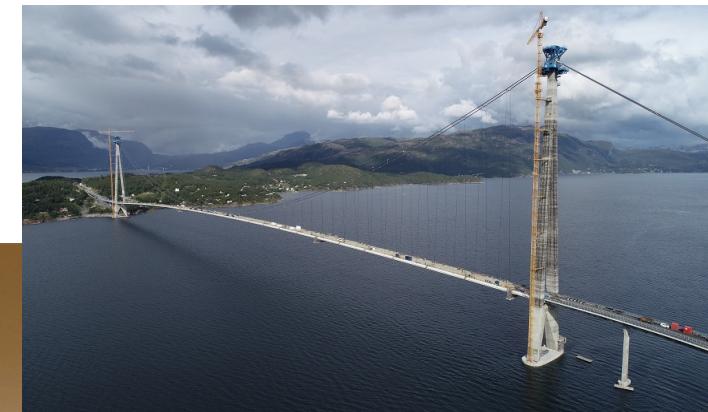
QUI EXPIMENT

LES CONDITIONS D'ÉQUILIBRE

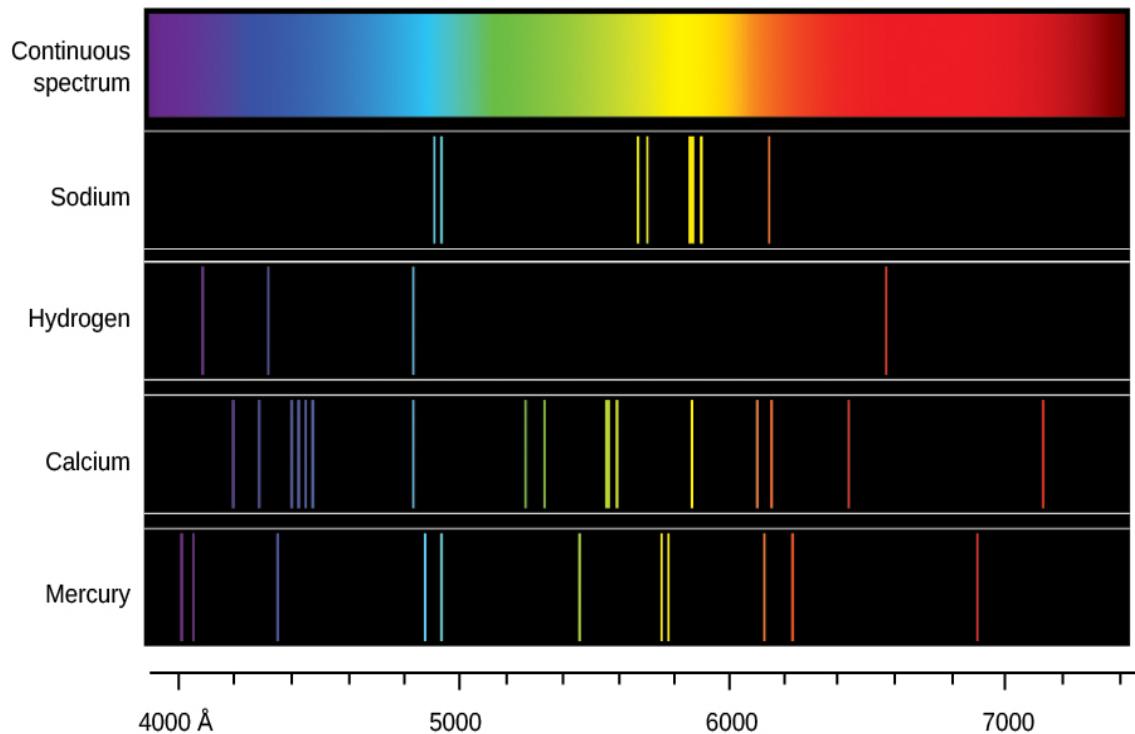
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LES LOIS DU MOUVEMENT INTÉRIEUR

D'UN CORPS SOLIDE, ÉLASTIQUE OU NON ÉLASTIQUE.







Second Series

December, 1926

Vol. 28, No. 6

THE
PHYSICAL REVIEW

AN UNDULATORY THEORY OF THE MECHANICS
OF ATOMS AND MOLECULES

BY E. SCHRÖDINGER

nd so an equation be formed that must hold in any case, whatever be
the dependence of the wave-function ψ on time:

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by the following hypothesis: the charge of the electron is not concentrated in a point, but is spread out through the whole space, proportional to the quantity $\psi \bar{\psi}$.

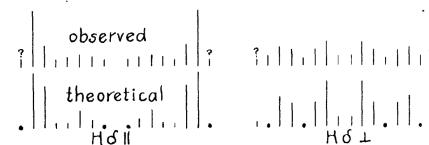
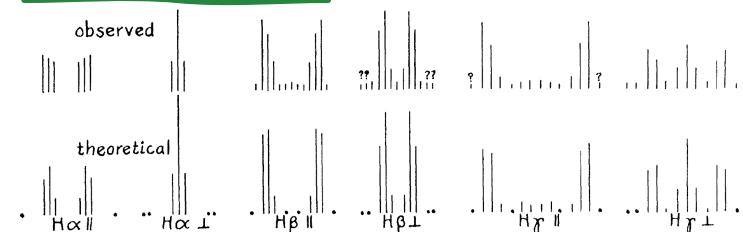


FIG. 1

Zur Quantenmechanik der Stoßvorgänge.

[Vorläufige Mitteilung.¹⁾]

Von **Max Born**, Göttingen.

(Eingegangen am 25. Juni 1926.)

I.2 ON THE QUANTUM MECHANICS OF COLLISIONS

[Preliminary communication][†]

MAX BORN

If one translates this result into terms of particles, only one interpretation is possible. $\Phi_{n,m}(\alpha, \beta, \gamma)$ gives the probability* for the electron, arriving from the z-

* Addition in proof: More careful consideration shows that the probability is proportional to the square of the quantity $\Phi_{n,m}$.



not only experiment

not only mathematics

equally important: *logical/semantic* analysis

of very innocent and familiar words!

“ it would certainly be a
reproach if such a revolution should ever prove nec-
essary again.

Neuroscience:

A circular arrangement of neuroscience terms, each rotated clockwise relative to the next, forming a ring. The terms are:

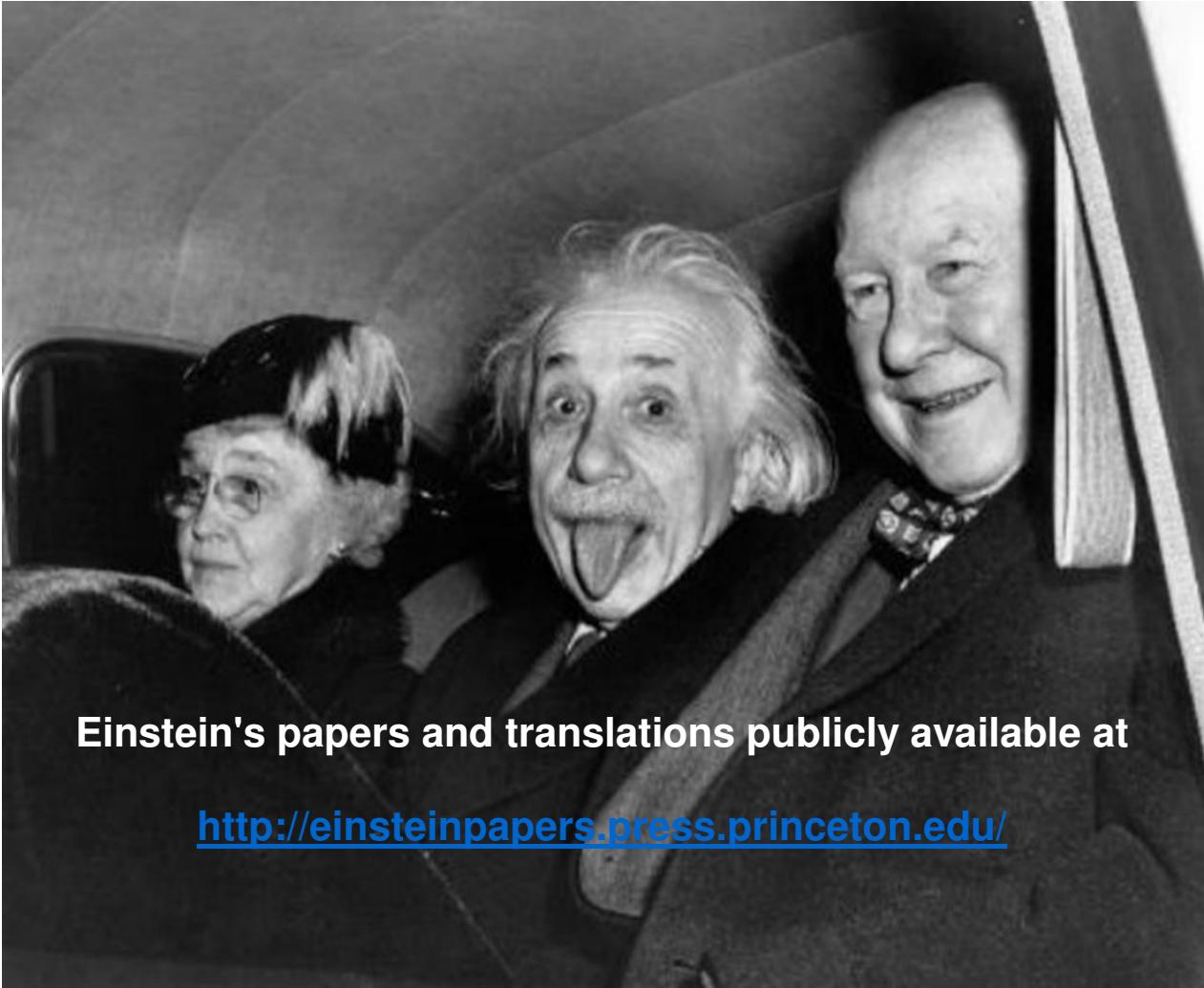
- cooperativity
- noise
- tuning
- processing
- information
- model
- functional
- Code

Neuroscience:

A circular arrangement of neuroscience concepts in various colors, including cooperativity, noise, processing, information, functional, model, coding, tuning, and code.

cooperativity
noise
processing
information
functional
model
coding
tuning
code

*do they have logical loops?
must their meanings be extended?
must their meanings be changed?*



Einstein's papers and translations publicly available at

<http://einsteinpapers.press.princeton.edu/>

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