
The old sage
and
the young turk
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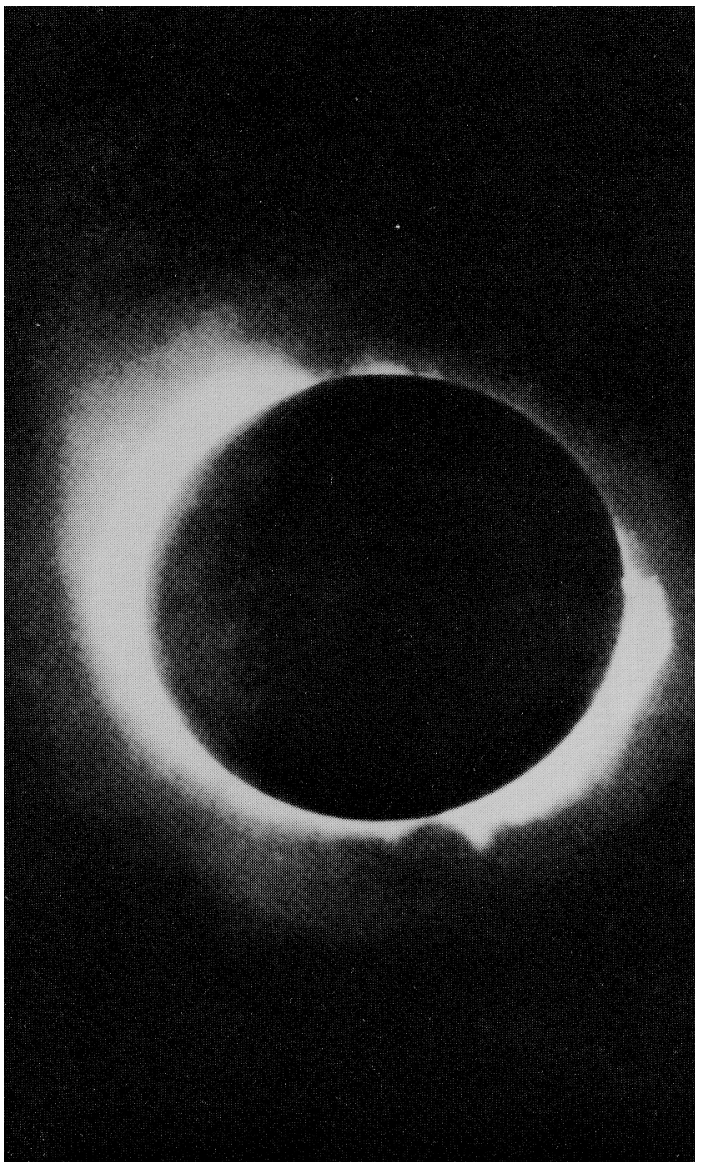
The old sage on scientific methodology

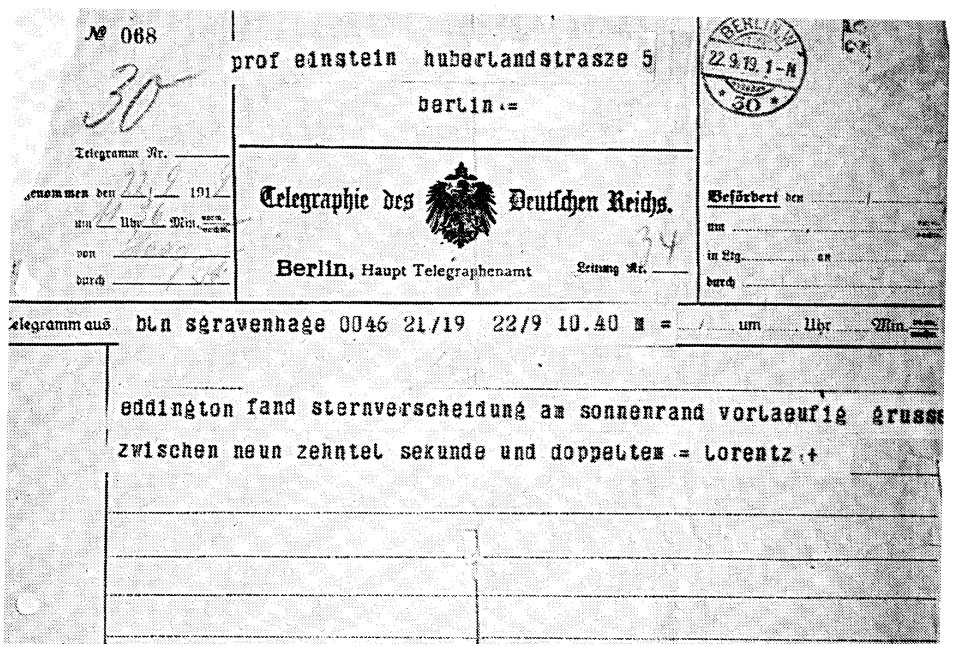
"Our experience hitherto justifies us in believing that nature is the realization of the simplest conceivable mathematical ideas. I am convinced that we can discover by means of purely mathematical constructions the concepts and the laws … which furnish the key to the understanding of natural phenomena … Experience remains, of course, the sole criterion of the physical utility of a mathematical construction. But the creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed"

—Herbert Spencer Lecture, Oxford, June 10, 1933

This picture fits with the myth of Einstein's cavalier attitude toward empirical data



Ilse Rosenthal-Schneider was with Einstein when a telegram with the results of the British eclipse expedition confirming general relativity was delivered.



№ 068

30

prof einstein hubertandstrasze 5

berlin

Telegramm Nr.

Telegraphie des Deutschen Reichs.

Berlin, Haupt Telegraphenamt

Leitung Nr. 34

Telegramm aus bln sgravenhage 0046 21/19 22/9 10.40 m = um Uhr Min.

eddington fand sternverscheidung am sonnenrand vorlaeufig grusse

zwischen neun zehntel sekunde und doppeltem = lorentz +

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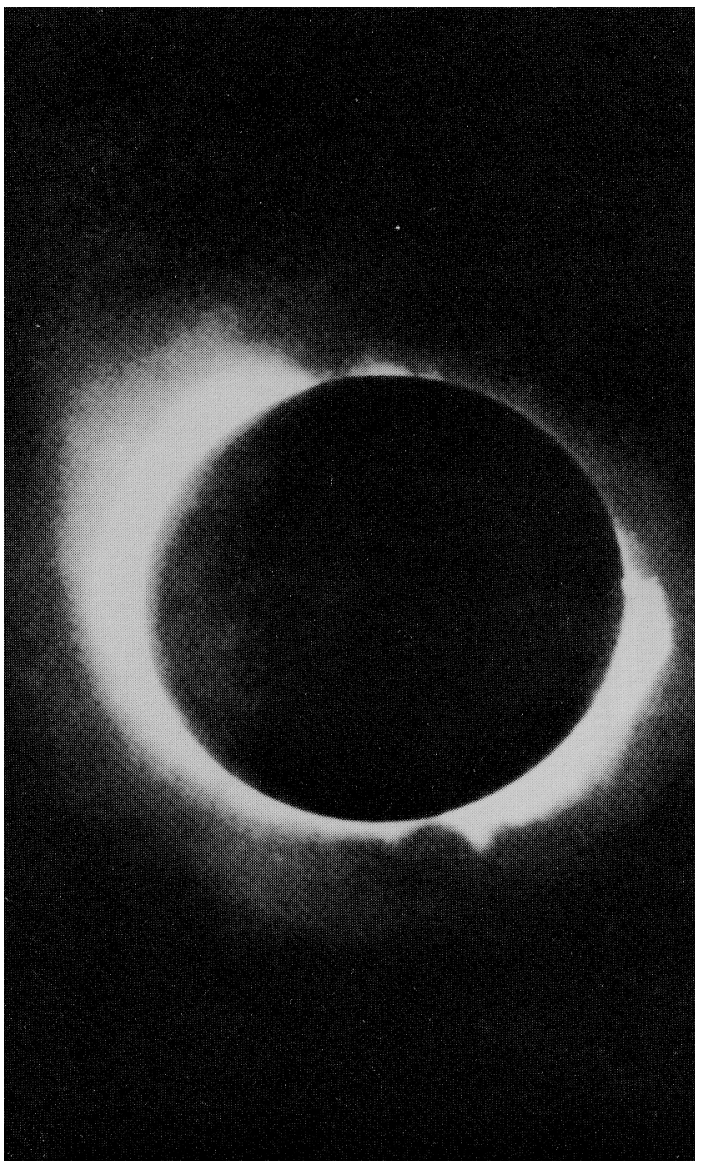

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Rosenthal-Schneider: "… when I asked, what if there had been no confirmation of his prediction, he countered: **'Then I would have been sorry for the dear Lord—the theory is correct.'**"

The old sage on scientific methodology

"If you want to find out anything from the theoretical physicists about the methods they use, I advise you to stick closely to one principle: do not listen to what they say, look at what they do."

—Herbert Spencer Lecture, Oxford, June 10, 1933

More accurate picture of the young turk's attitude toward empirical data

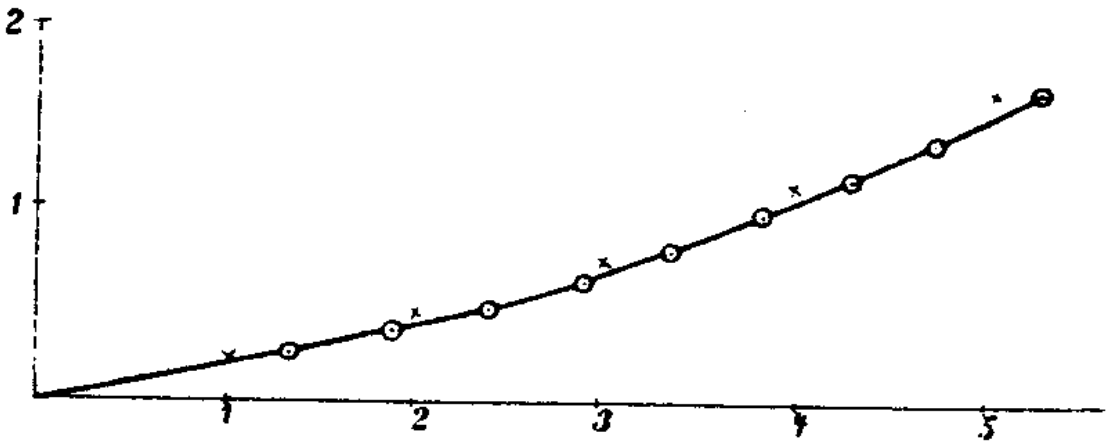
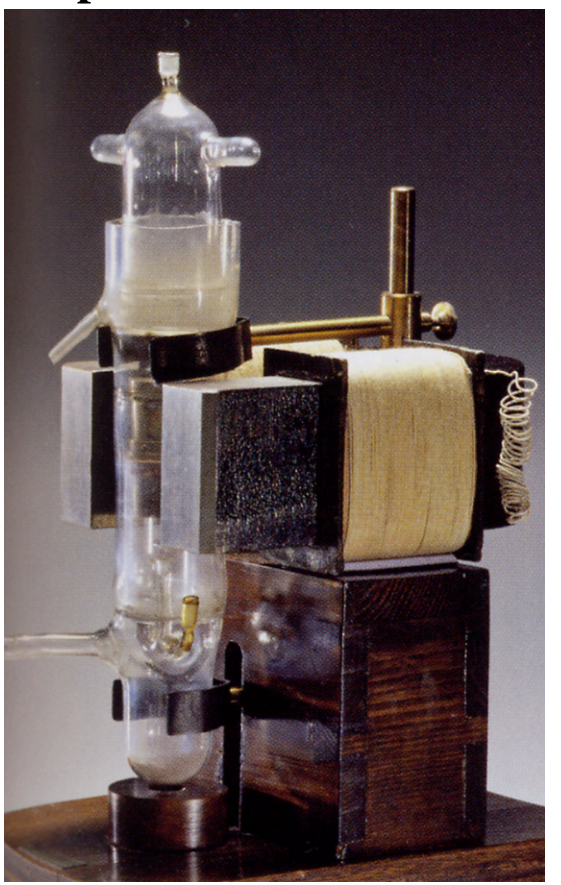


Fig. 2.



Einstein's reaction (1907) to Kaufmann's alleged refutation of special relativity:

"Abraham's and Bucherer's theories […] yield curves that are significantly closer to the observed curve than […] the theory of relativity. However, the probability that their theories are correct is rather small, in my opinion, because their **basic assumptions** […] **are not suggested by theoretical systems that encompass larger complexes of phenomena.**"

More accurate picture of the young turk's attitude toward empirical data

Inaugural lecture, Berlin, July 2, 1914:

"The theorist's method involves […] general postulates or "principles" from which he can deduce conclusions … The scientist has to extract these general principles from nature by **perceiving in comprehensive complexes of empirical facts certain general features which permit of precise formulation**."

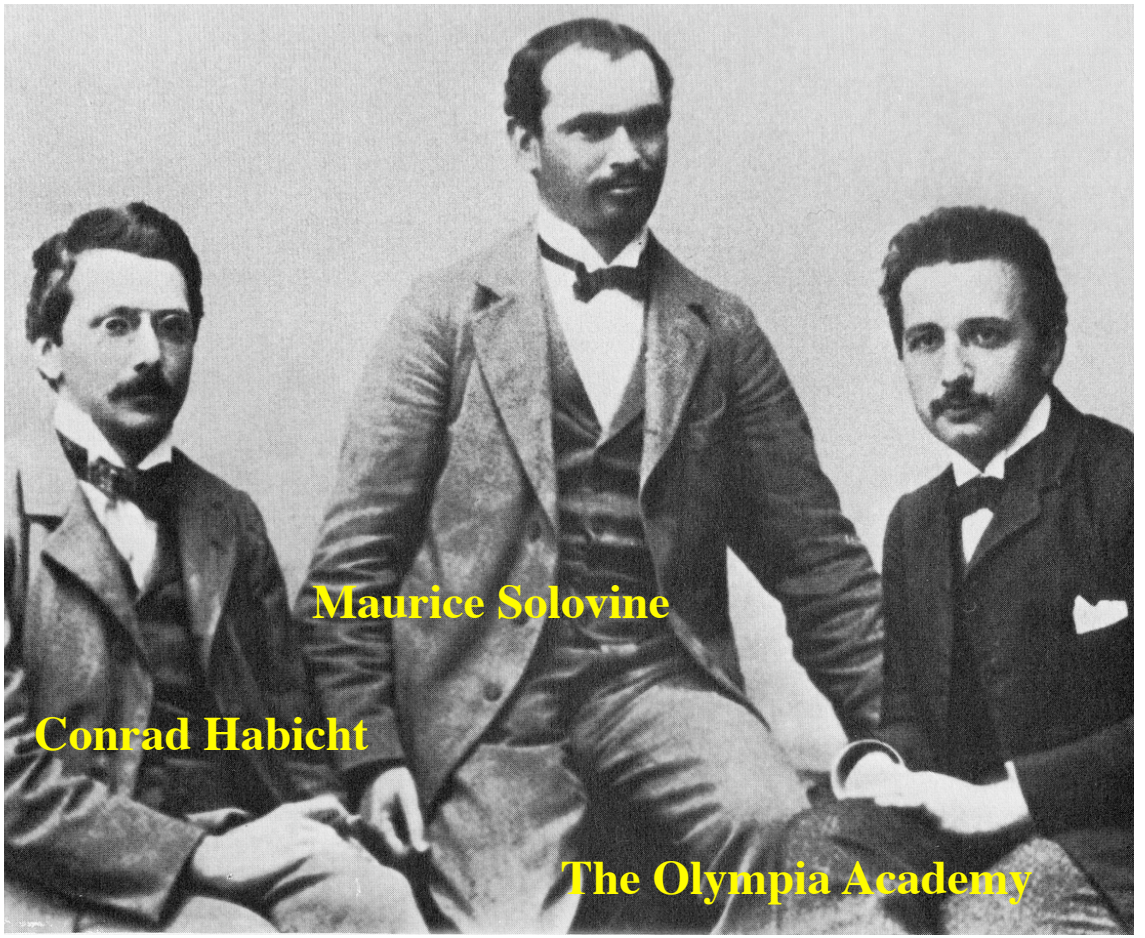
How did the young turk find his principles?

- **Humdrum way: inductive generalization.**
  Example: every attempt so far to detect ether drift has failed, so probably all attempts will fail.

- **Magic Wand I**: **'Fixed point approach'**
  (= **Decide which elements of existing knowledge you can trust: bet the house on those elements and let the chips fall where they may).**
  Examples: early work in quantum theory, special relativity.

- **Magic Wand II**: **exploit explanatory defiencies in existing theories**
  (= ask embarrassing why-questions).
  Examples: special and general relativity.

1905: *annus mirabilis* [miracle year] (3 Papers in Vol. 17 of *Annalen der Physik*)



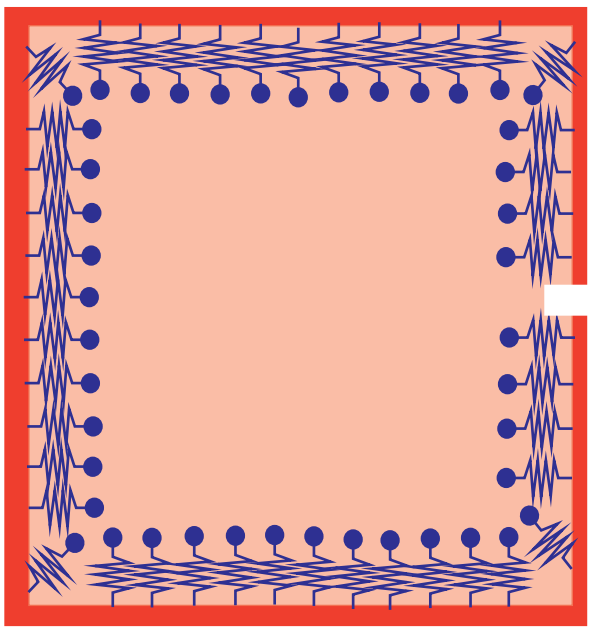
<u>Completed/Published</u>
March/June Light Quantum
May/July Brownian Motion
June/September Relativity

Einstein to Conrad Habicht, May 1905: "I can promise you four works, the **first** of which … deals with radiation and the energy characteristics of light **[→ ligh quanta]** and is **very revolutionary**

[2nd & 3rd: dissertation & paper on Brownian motion]

The **fourth** … is an electrodynamics of moving bodies by the use of a modification of the theory of space and time. The purely kinematical part of this work will undoubtedly interest you **[→ special relativity]**"

Magic Wand I ('fixed point approach'): early work in quantum theory.



1905 light quantum paper ("On a Heuristic Point of View Concerning the Production and Transformation of Light")

Argument in the introduction: **trust**

- Equipartition: average energy for every degree of freedom is $\frac{1}{2}kT$.
- Relation between resonator energy distribution and radiation energy distribution in black body radiation: $E_{\mathrm{rad}}(\nu, T) \propto \nu^2 E_{\mathrm{res}}(\nu, T)_{\mathrm{res}}$.

Gives black-body radiation law: $E_{\mathrm{rad}}(\nu, T) \propto \nu^2 kT$
(Rayleigh-Jeans law, ultraviolet catastrophe)

Problem: combination of discrete matter (atoms) and continuous fields (light waves) leads to ultraviolet catastrophe

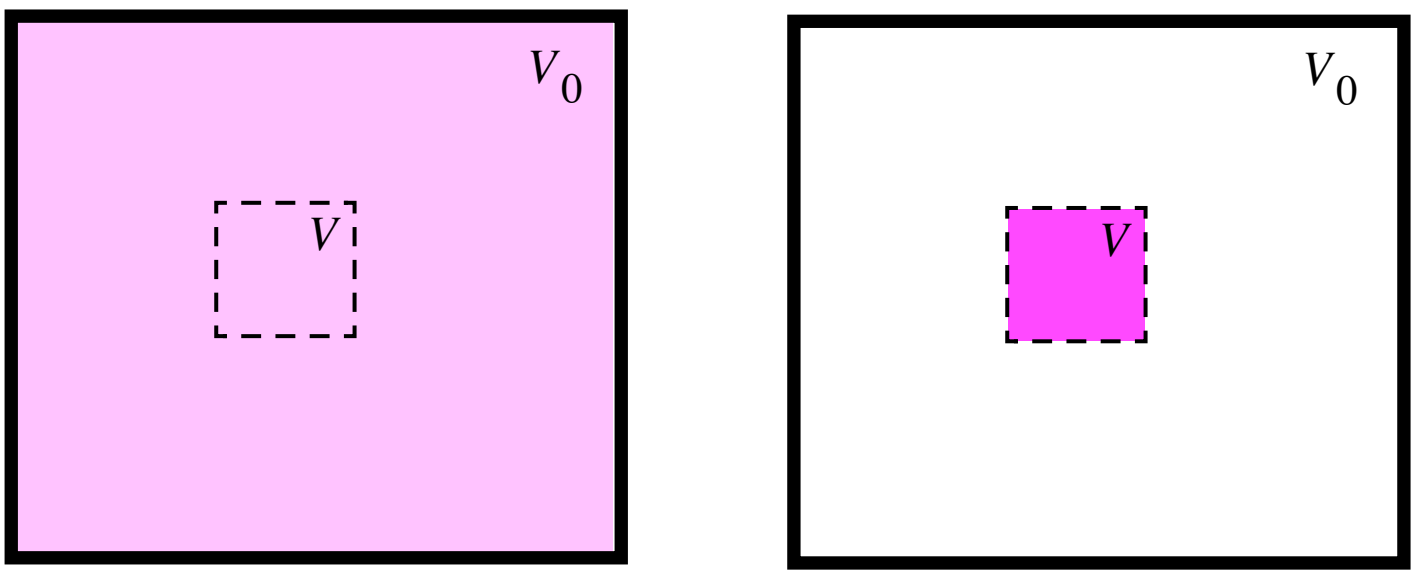
Solution: make radiation discrete as well → Light quanta

Magic Wand I ('fixed point approach') [cont'd]. Einstein's fluctuation arguments.

Trust: (a) Planck law for black-body radiation (which for high frequencies reduces to Wien law); (b) Boltzmann's principle relating entropy and probability $S = k \ln \Omega$.

Derive formula for entropy of black-body radiation in Wien regime as a function of volume.

$V \ll V_0$

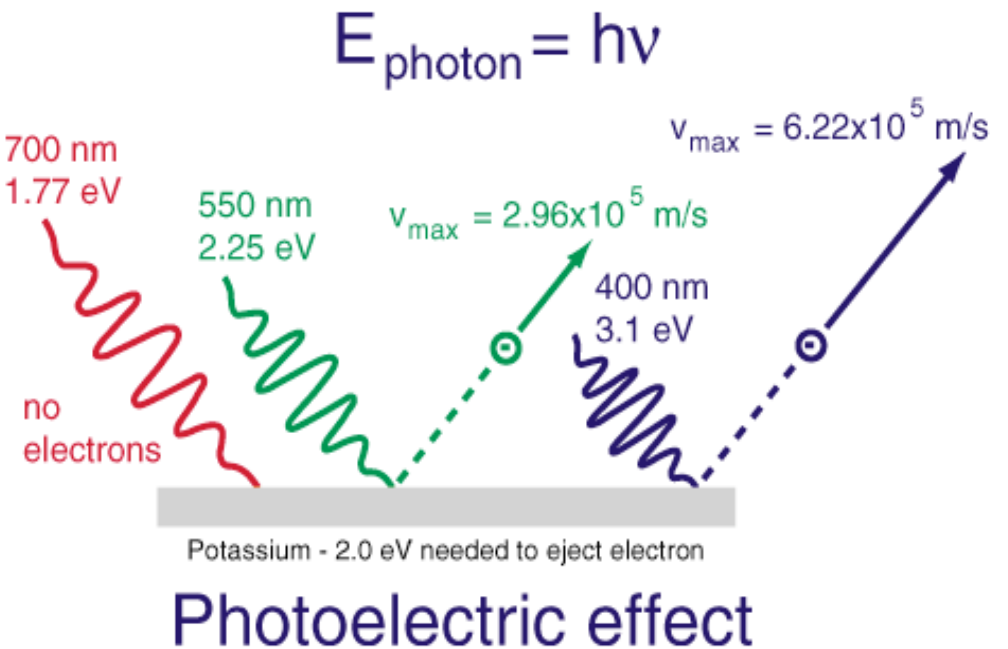


- Probability of finding all black-body radiation in V_0 in subvolume V: $(V/V_0)^{E/h\nu}$
- Probability of finding all N molecules of ideal gas in V_0 in subvolume V: $(V/V_0)^N$
- Einstein's conclusion: "radiation ... behaves ... as if it consisted of [N] mutually independent energy quanta of magnitude [$h\nu$]."

How serious should we take the analogy between radiation in a box and an ideal gas in a box? Einstein took it very seriously. The rest of the physics community did not.

Examples of "production and transformation of light": photoelectric effect

Heinrich Hertz (1857–1894)

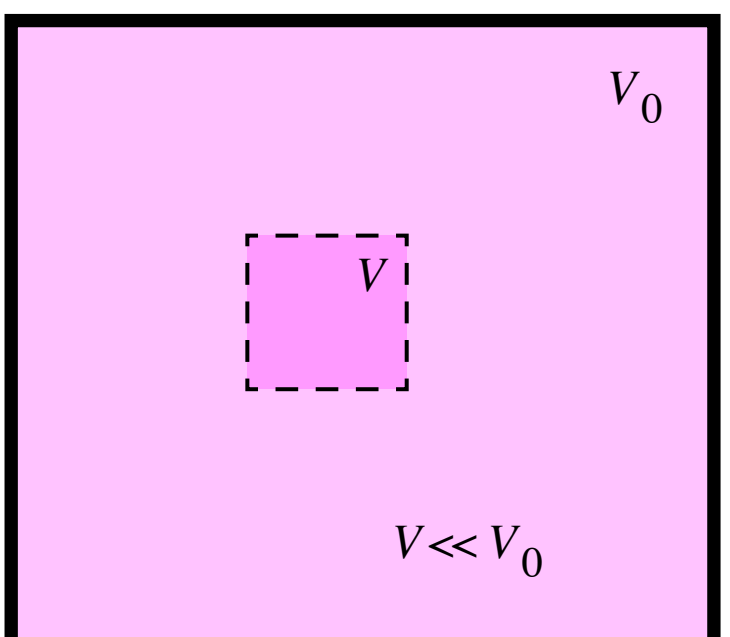


- Discovered by Hertz in 1887
- Puzzling fact for wave theory: energy of electrons depends on **frequency** of the light, not on the **intensity**.
- Readily explained by light quantum hypothesis

Magic Wand I ('fixed point approach') [cont'd]. Einstein's fluctuation arguments.

Salzburg lecture 1909: the wave-particle duality of light

Einstein on what I called the 'fixed point approach': "proceed in the opposite direction of the one taken by Planck … We consider Planck's radiation formula as correct and ask ourselves whether some conclusion about the constitution of radiation can be inferred from it."



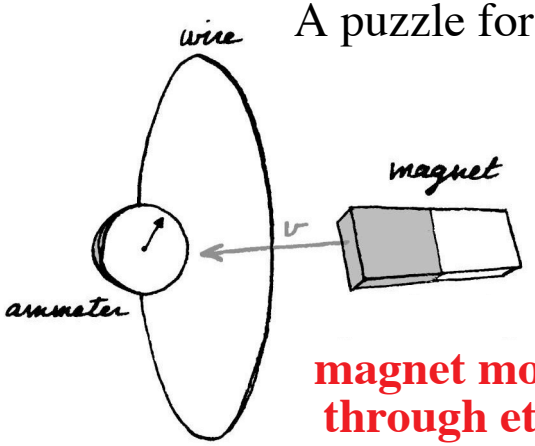
Calculate energy and momentum fluctuations in black-body radiation on the basis of Planck's law.

Result: two terms, one characteristic of particles, the other characteristic of waves.

Einstein's conclusion: first statement of wave-particle duality: "It is my opinion, therefore, that the next phase of the development of theoretical physics will bring us a theory of light that can be interpreted as a kind of fusion of the wave and emission theories."

Magic wand II (explanatory defiencies): relativity. Example 1: magnet & conductor

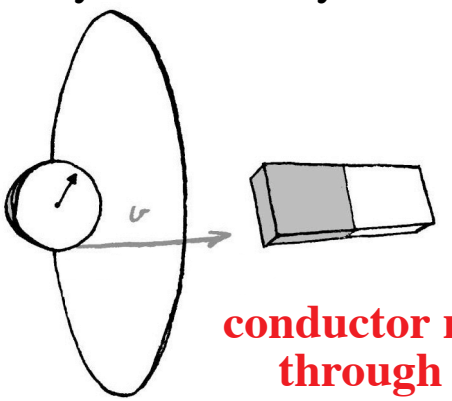
A puzzle for Lorentz's ether-based theory of electrodynamics



magnet moving through ether

moving magnet induces **electric field** in the wire (Faraday's induction law)

electric field makes electrons go round the wire



conductor moving through ether

electrons in the wire move in **magnetic field**

Lorentz force coming from **magnetic field** makes electrons go round the wire

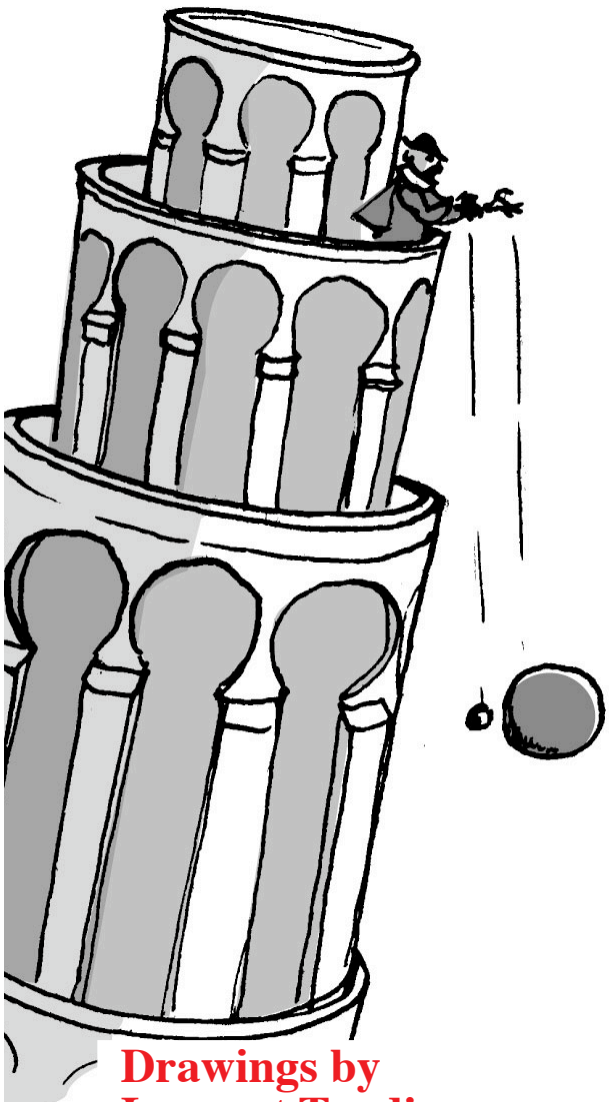
Embarrassing why-question for Lorentz: why is the current the same in the two cases?

Einstein's answer: same situation looked at from different points of view

→ There is no ether

→ There are no separate electric and magnetic fields but only one electromagnetic field that splits differently into electric and magnetic components for different observers.

Magic wand II (explanatory defiencies): relativity. Example 2: equivalence principle



Drawings by Laurent Taudin

Galileo's principle (early 1600s): (as long as air resistance can be neglected) all objects fall with the same acceleration (**uniqueness of free fall**)

Galileo's principle in Newton's theory (1687)

law of motion

$$F = m_i a$$

m_i = **inertial mass** = resistance to acceleration

law of gravity

$$F = m_g g$$

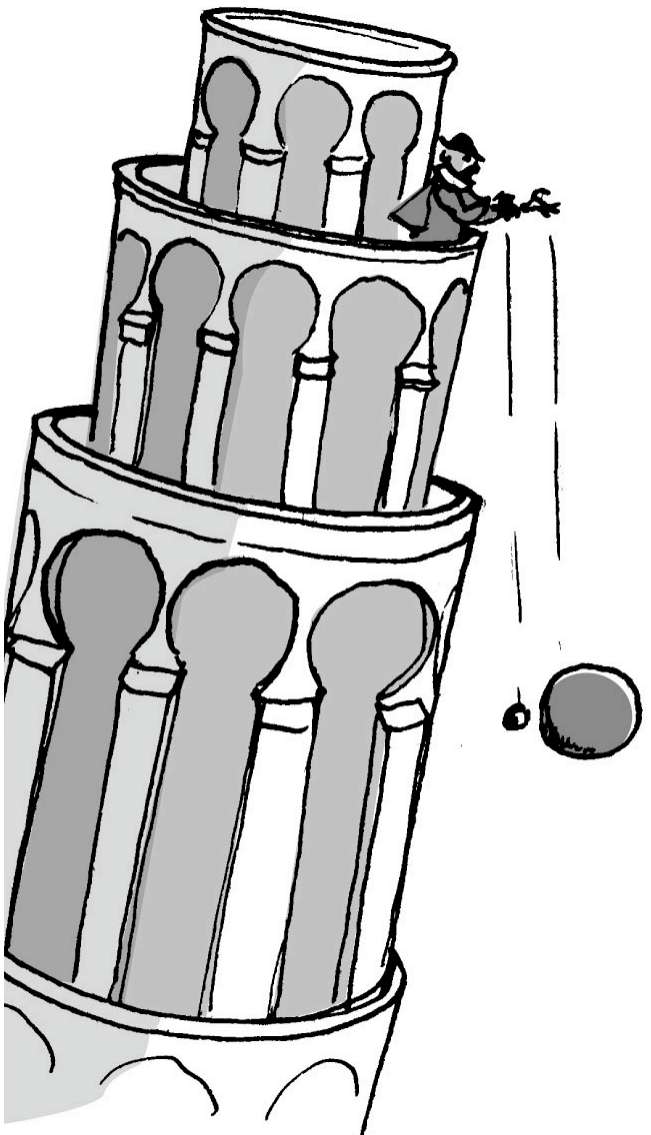
m_g = **gravitational mass** = susceptibility to gravity

Cannon balls falling from the Leaning Tower of Pisa

$$m_i a = m_g g \quad \rightarrow \quad a = (m_g / m_i) g$$

Uniqueness of free fall requires that inertial mass is equal to gravitational mass: $m_i = m_g$

Magic wand II (explanatory defiencies): relativity. Example 2: equivalence principle



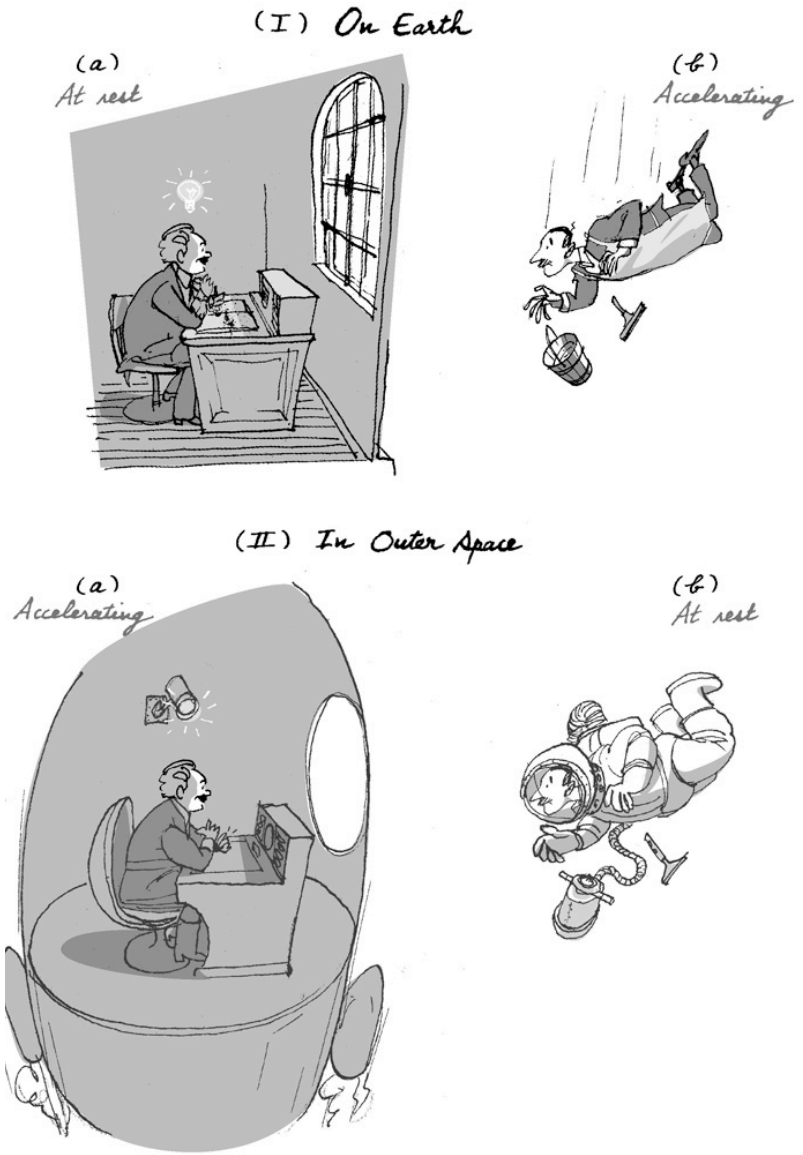
Fast forward two and a half centuries …

Embarrassing why-question for Newton: why are inertial and gravitational mass equal to one another?

Einstein's answer: inertia and gravity are connected to each other (like electricity and magnetism are)

Einstein (reminiscing about 1907 in 1933): "the equality of inertial and gravitational mass was now brought home to me in all its significance. I was in the highest degree amazed … and guessed that in it must lie the key to a deeper understanding of inertia and gravitation."

Magic wand II (explanatory defiencies): relativity. Example 2: equivalence principle



Einstein (reminiscing about 1907 in 1919):

"Then came to me the happiest thought of my life in the following form. In an example worth considering the gravitational field only has a relative existence in a manner similar to the electric field generated by electro-magnetic induction. *Because for an observer in free-fall from the roof of a house, there is during the fall*—at least in his immediate vicinity—*no gravitational field*. Namely, if the observer lets go of any bodies, they remain, relative to him, in a state of rest or uniform motion, independent of their special chemical or physical nature. The observer, therefore, is justified in interpreting his state as being "at rest" … a powerful argument in favor of expanding the postulate of relativity to coordinate systems moving non-uniformly relative to each other."

Why switch from facts-first (young turk) to math-first (old sage)?


David Hilbert
(1862–1943)

Two parts of the answer:

- In 1915, The mathematician Hilbert almost beats him to the punch in putting the finishing touches on general relativity by paying attention only to mathematical elegance and not worrying about what the math means physically.

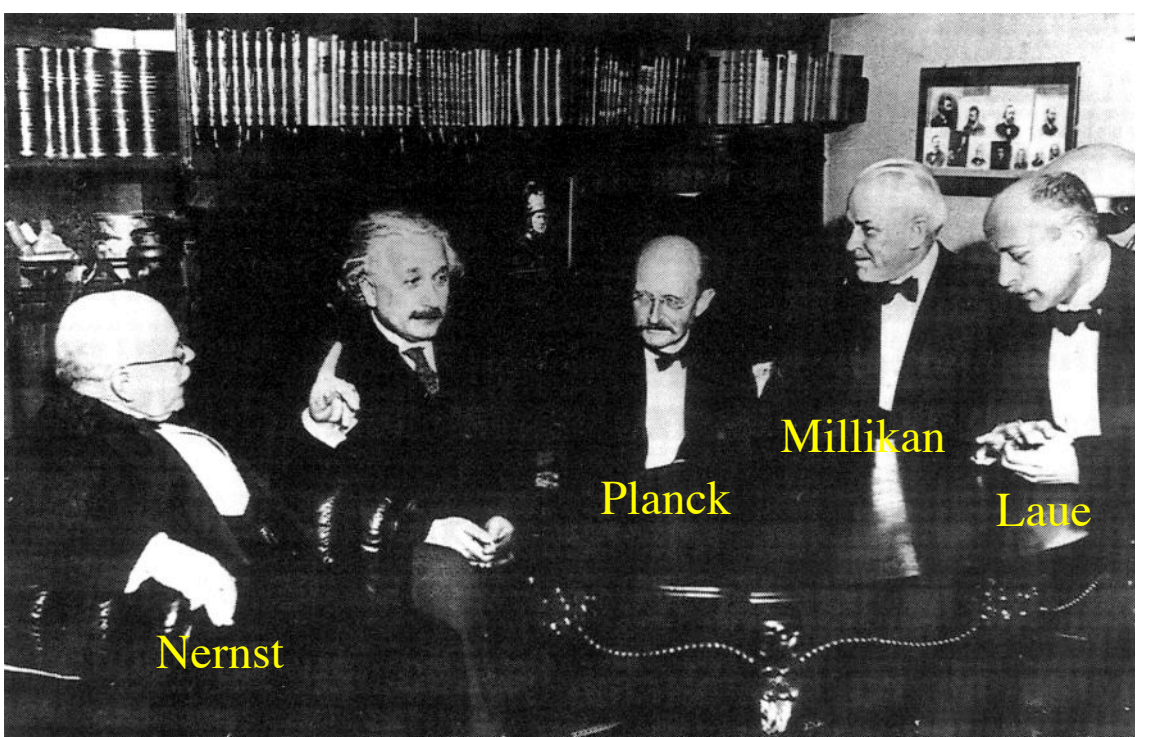
- **After his midlife crisis in 1917–1918 (when he's pushing 40), Einstein starts using physics as his way of escaping from the dreariness of everyday life—of "getting beyond the merely personal" [rest of my talk]**

Physics as a way of "getting beyond the merely personal"

Kafka editor Max Brod

"The tranquility with which [Kepler] applied himself to his labors … was to Tycho almost superhuman. There was something incomprehensible in its absence of emotion, like a breath from a distant region of ice … He had no heart and therefore had nothing to fear from the world. He was not capable of emotion or love."

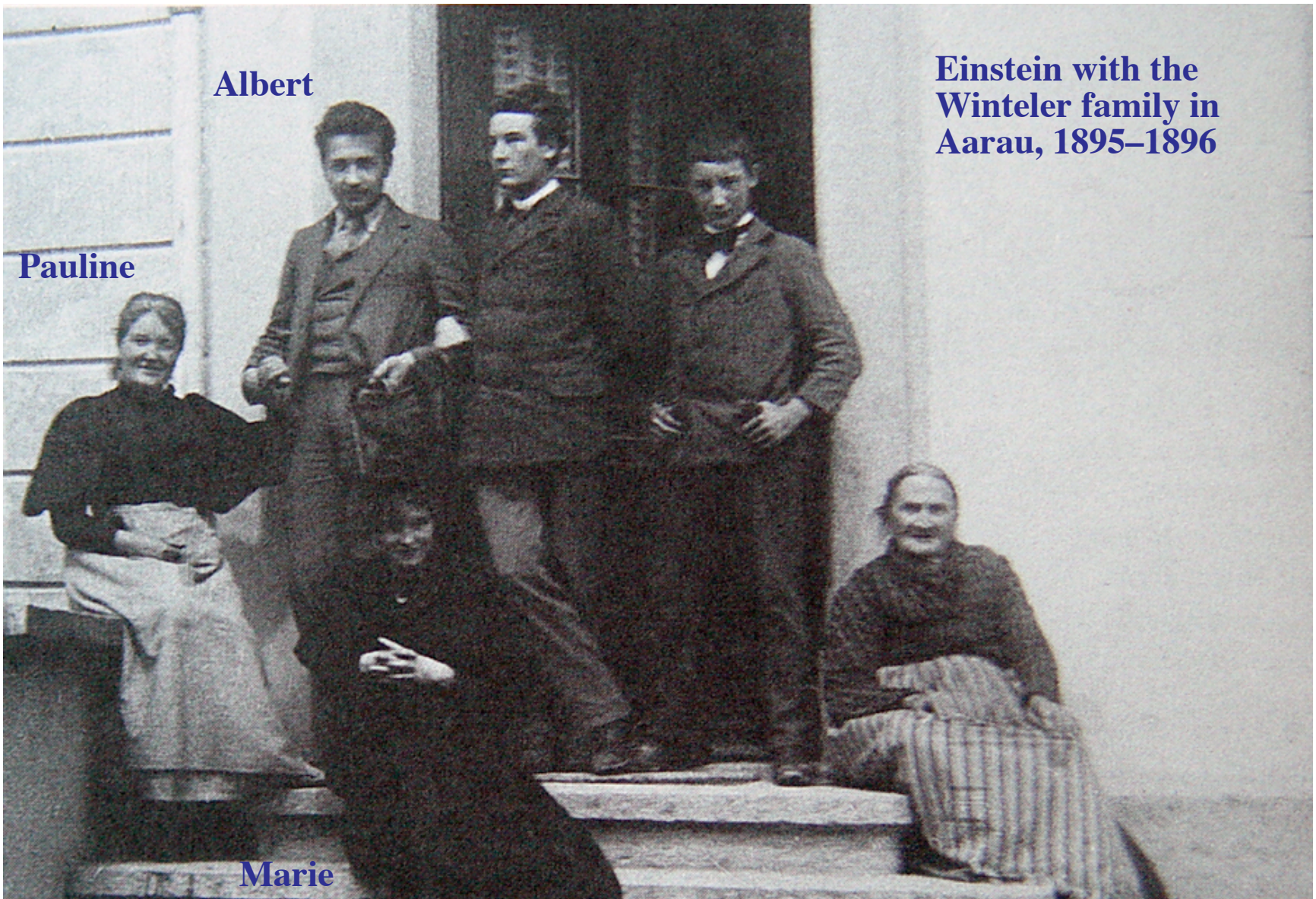
—Max Brod, *The Redemption of Tycho Brahe*



Walther Nernst (1864–1941) to Einstein:

"You are this man Kepler!"

Physics as a way of "getting beyond the merely personal"



Physics as a way of "getting beyond the merely personal"

Einstein to PaulineWinteler, May 1897:

"Dear mommy … I cannot come to visit you at Whitsuntide … I have already caused much too much [pain] to [Marie] … It fills me with a peculiar kind of satisfaction that now I myself have to taste some of the pain that I brought upon the dear girl … Strenuous intellectual work and looking at God's Nature are the reconciling, fortifying, yet relentlessly strict angels that shall lead me through all of life's troubles … And yet, what a peculiar way this is to weather the storms of life—in many a lucid moment I appear to myself as an ostrich … One creates a small little world for oneself, and as lamentably insignificant it may be in comparison with the perpetually changing size of real existence, one feels miraculously great and important, like a mole in his self-dug hole."

Physics as a way of "getting beyond the merely personal"

Mileva Maric (1875–1948)

Einstein to Mileva, December 17, 1897: "It is really a screamingly funny life that I am living here, completely in Schopenhauer's sense … To think of all the obstacles that these old philistines put in the way"

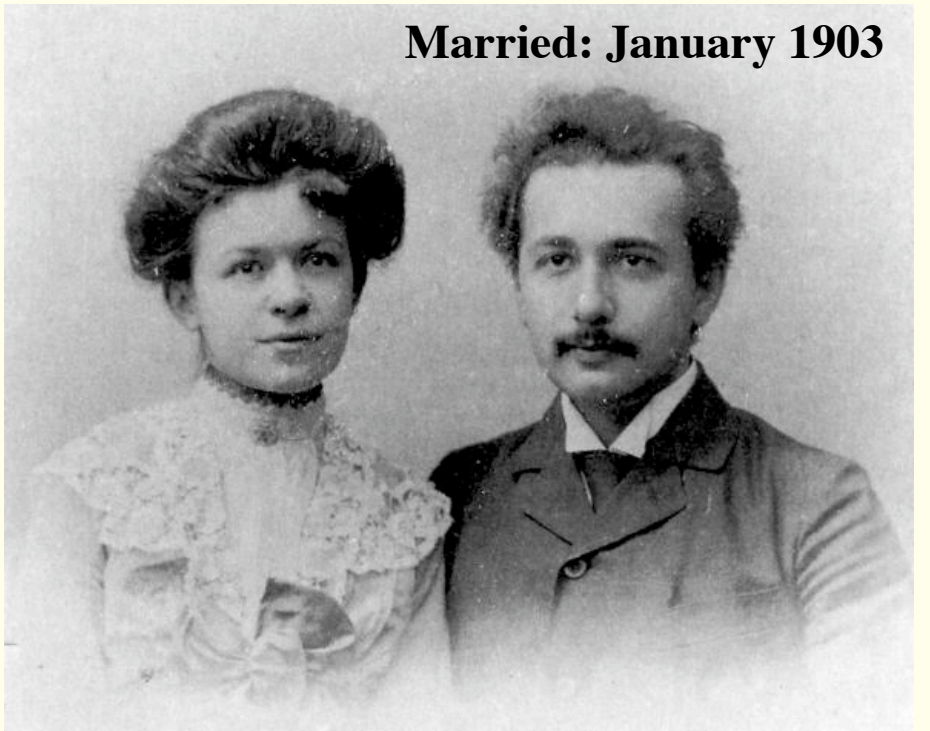
Einstein to Mileva, October 3, 1900: "You too don't like the philistine life any longer, don't you? He who tasted freedom cannot stand the chains any longer. How lucky I am to have found in you a creature who is my equal, who is as strong and independent as I am myself."

Einstein and Mileva: Happy together? May 5, 1901 → January 27, 1902

Einstein and Mileva: Happy together?

Lieserl (1902–?)

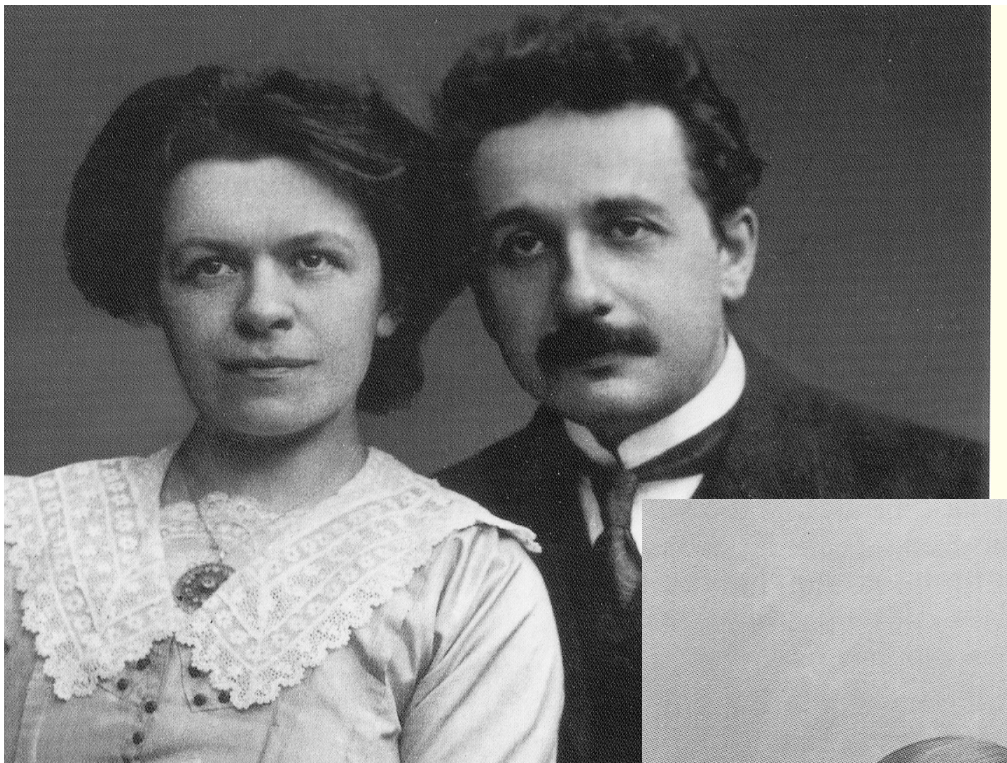
Married: January 1903



Berne 1904

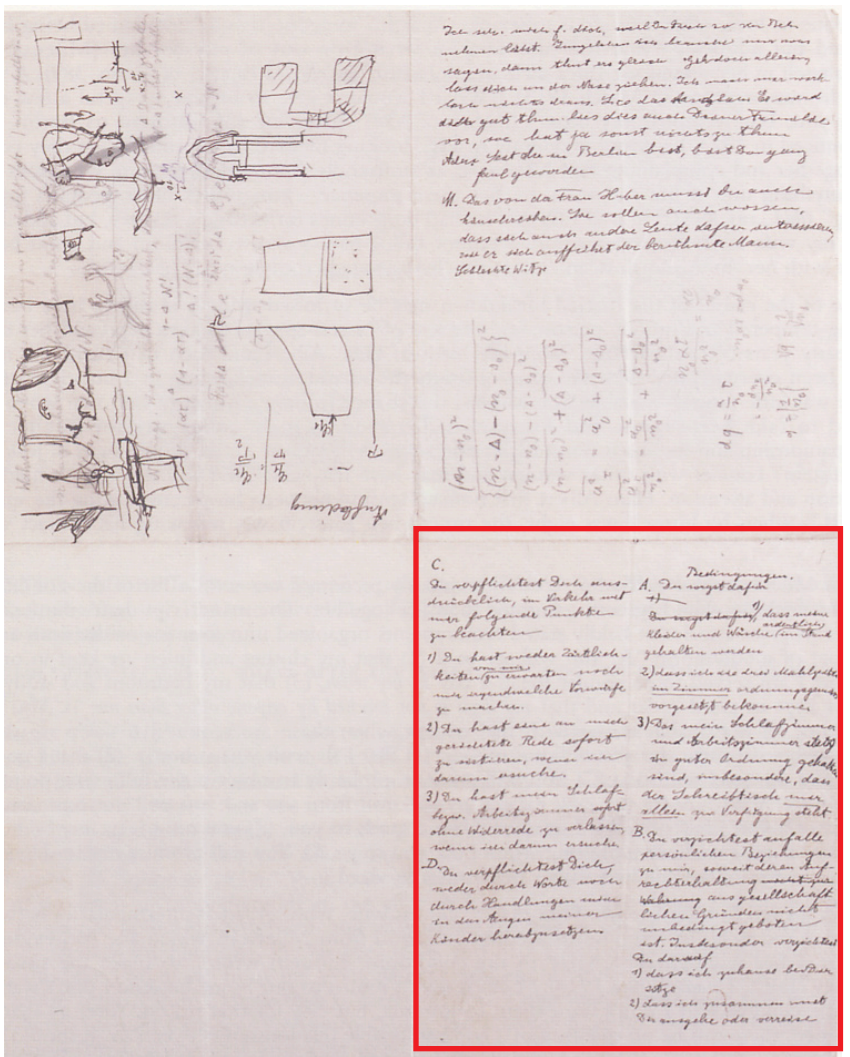
Hans Albert ('Adu')
(1904–1973)

Einstein and Mileva: Happy together?



Zurich 1914

Einstein and Mileva: Happy together?



C.

Du verpflichtest Dich ausdrücklich, im Verkehr mit mir folgende Punkte zu beachten

1) Du hast weder Zärtlichkeiten von mir zu erwarten noch mir irgendwelche Vorwürfe zu machen.

2) Du hast meine an mich gerichtete Rede sofort zu sistieren, wenn ich darum ersuche.

3) Du hast mein Schlaf- bezw. Arbeitszimmer sofort ohne Widerrede zu verlassen, wenn ich darum ersuche.

D. Du verpflichtest Dich, weder durch Worte noch durch Handlungen meine in den Augen meiner Kinder herabzusetzen

Bedingungen.

A. Du sorgst dafür

+) Du sorgst dafür, dass meine Kleider und Wäsche in gutem Stand gehalten werden

2) dass ich die drei Mahlzeiten in meinem Zimmer ordnungsgemäss vorgesetzt bekomme.

3) Das mein Schlafzimmer und Arbeitszimmer stets in guter Ordnung gehalten sind, insbesondere, dass der Schreibtisch mir allein zur Verfügung steht

B. Du verzichtest auf alle persönlichen Beziehungen zu mir, soweit deren Aufrechterhaltung nicht zur Wahrung des gesellschaftlichen Anstandes aus gesellschaftlichen Gründen unbedingt geboten ist. Insbesondere verzichtest Du darauf

1) dass ich zuhause bei Tische sitze

2) dass ich zusammen mit Dir ausgehe oder verreise

Conditions under which Einstein is prepared to stay married to Mileva, July 1914

A. You make sure:
1. that my clothes and laundry are kept in good order and repair.
2. that I receive my three meals regularly in my room.

B. You abstain from all personal contact with me unless absolutely required for reasons of social decorum.

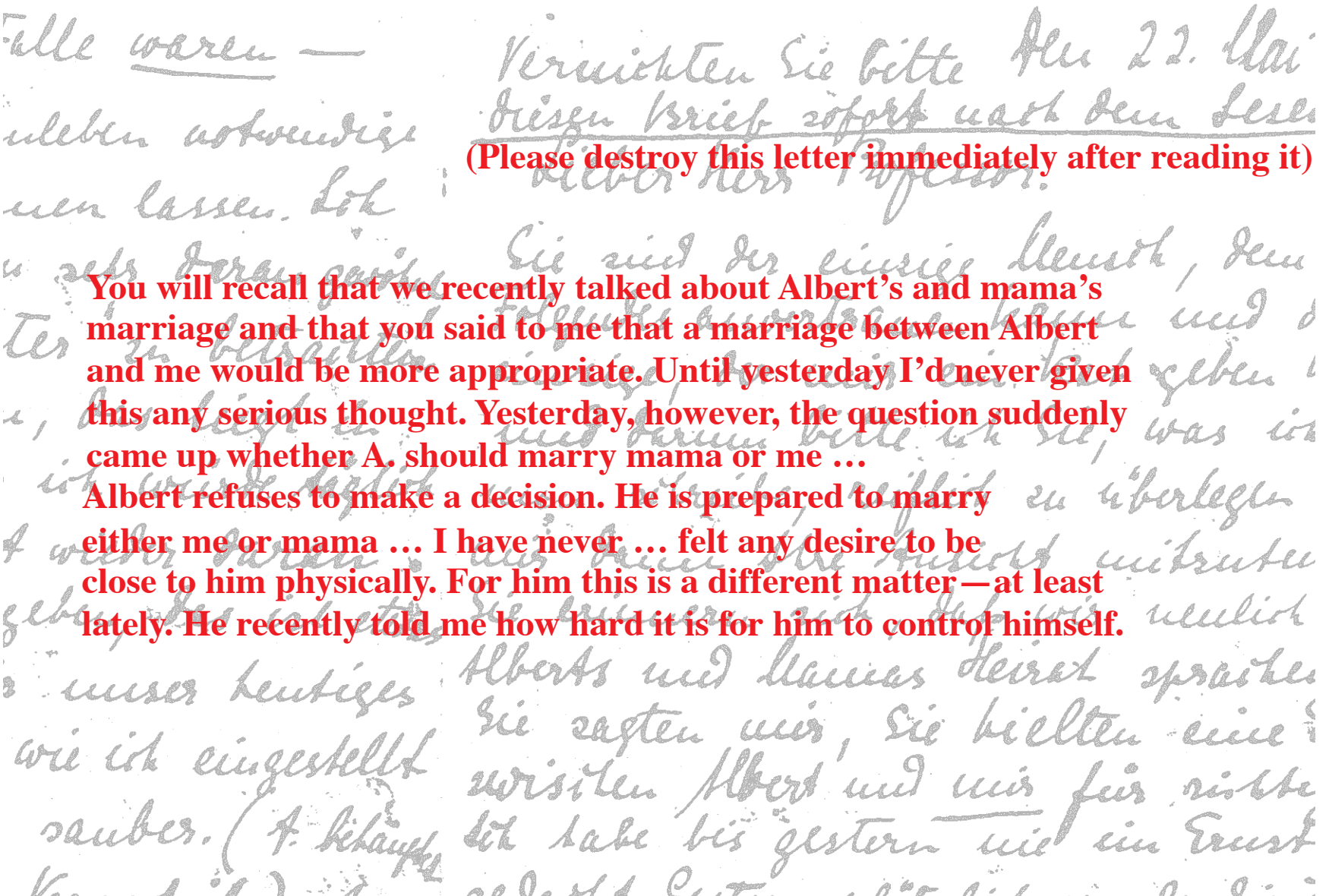
C. You commit yourself to observing the following points in your dealings with me:
1. You are neither to expect intimacy from me nor to reproach me in any way.
2. You are to stop talking to me immediately when I ask you to.
3. You are leave my bedroom as well as my study immediately and without protest when I ask you to.

[Some zingers from Mileva:] Read it to your family as well. They have nothing else to do anyway. You should also write down this thing about Frau Haber. They should know that there are others who are interested in what a spectacle he is making of himself, the famous man. [Einstein's comment:] Bad jokes.

Einstein and his 1st+2nd cousin/2nd wife Elsa Einstein-Löwenthal (1876–1936)

Ilse Einstein to Georg Nicolai (1874–1964), May 22, 1918

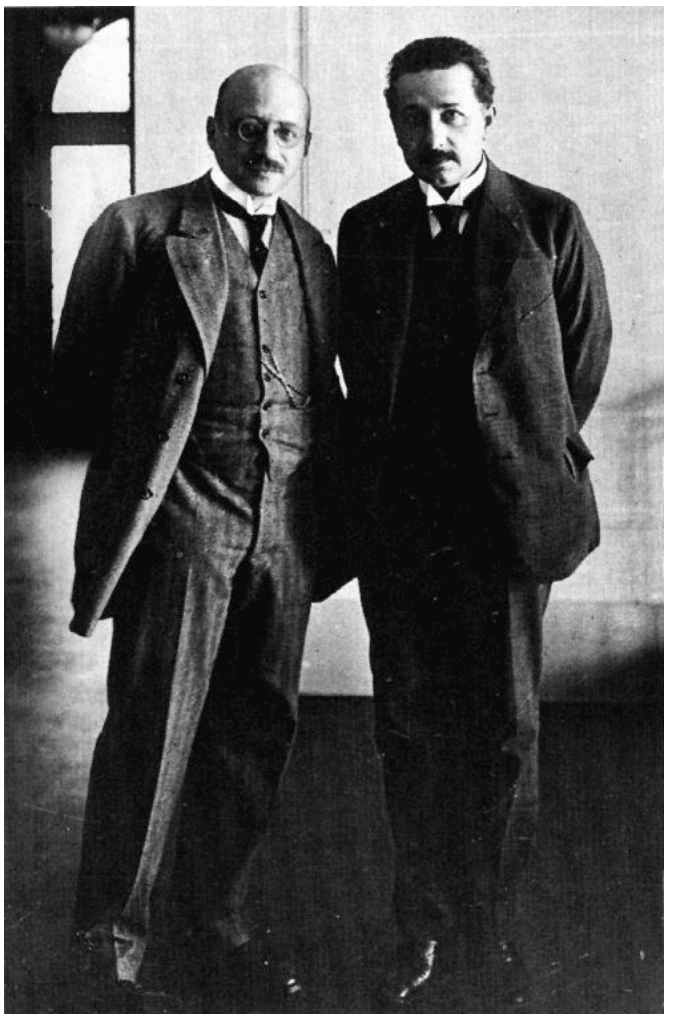
Ilse Einstein to Georg Nicolai (1874–1964), May 22, 1918



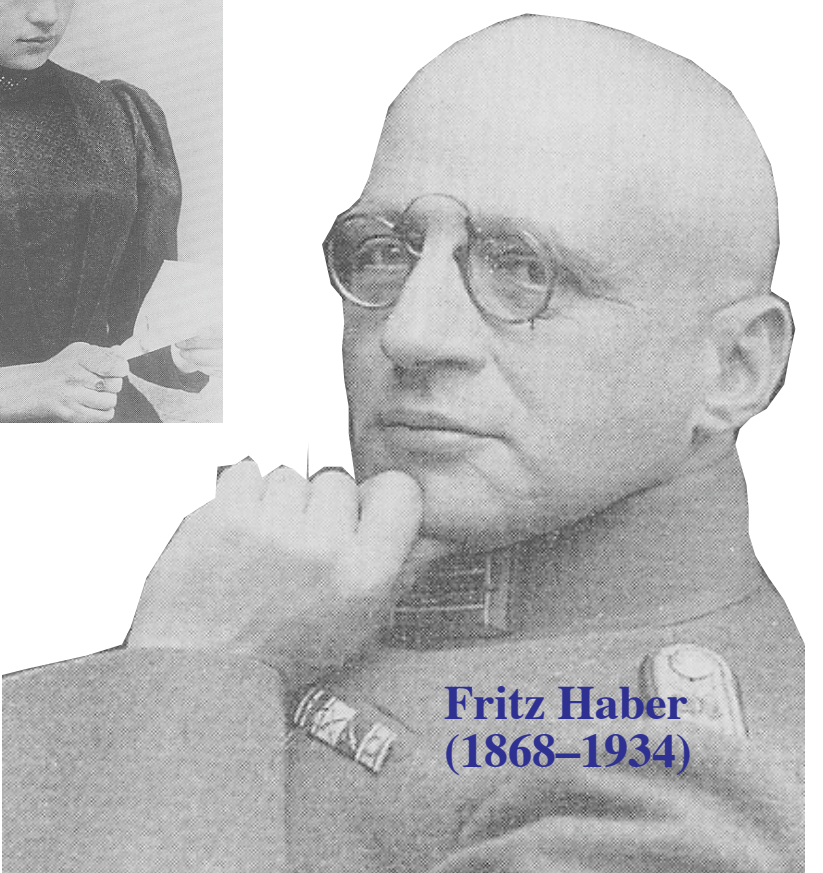
(Please destroy this letter immediately after reading it)

You will recall that we recently talked about Albert's and mama's marriage and that you said to me that a marriage between Albert and me would be more appropriate. Until yesterday I'd never given this any serious thought. Yesterday, however, the question suddenly came up whether A. should marry mama or me …
Albert refuses to make a decision. He is prepared to marry either me or mama … I have never … felt any desire to be close to him physically. For him this is a different matter—at least lately. He recently told me how hard it is for him to control himself.

In addition to personal turmoil: World War I (1914–1918)



Clara Haber
(1870–1915)



Fritz Haber
(1868–1934)

Fritz Haber and gas warfare

Einstein to Mileva, April 1918: "I am curious to see what will last longer, the world war or our divorce proceedings. Both began essentially at the same time. This matter of ours is actually still the prettier of the two."

John Singer Sargent (1856–1935), *Gassed* (1918)

Physics as a way of "getting beyond the merely personal"

Compare inaugural lecture in 1914
(*before* separation, illness, war)
to lecture for Planck's 60th birthday in 1918
(*after* separation, illness, war)

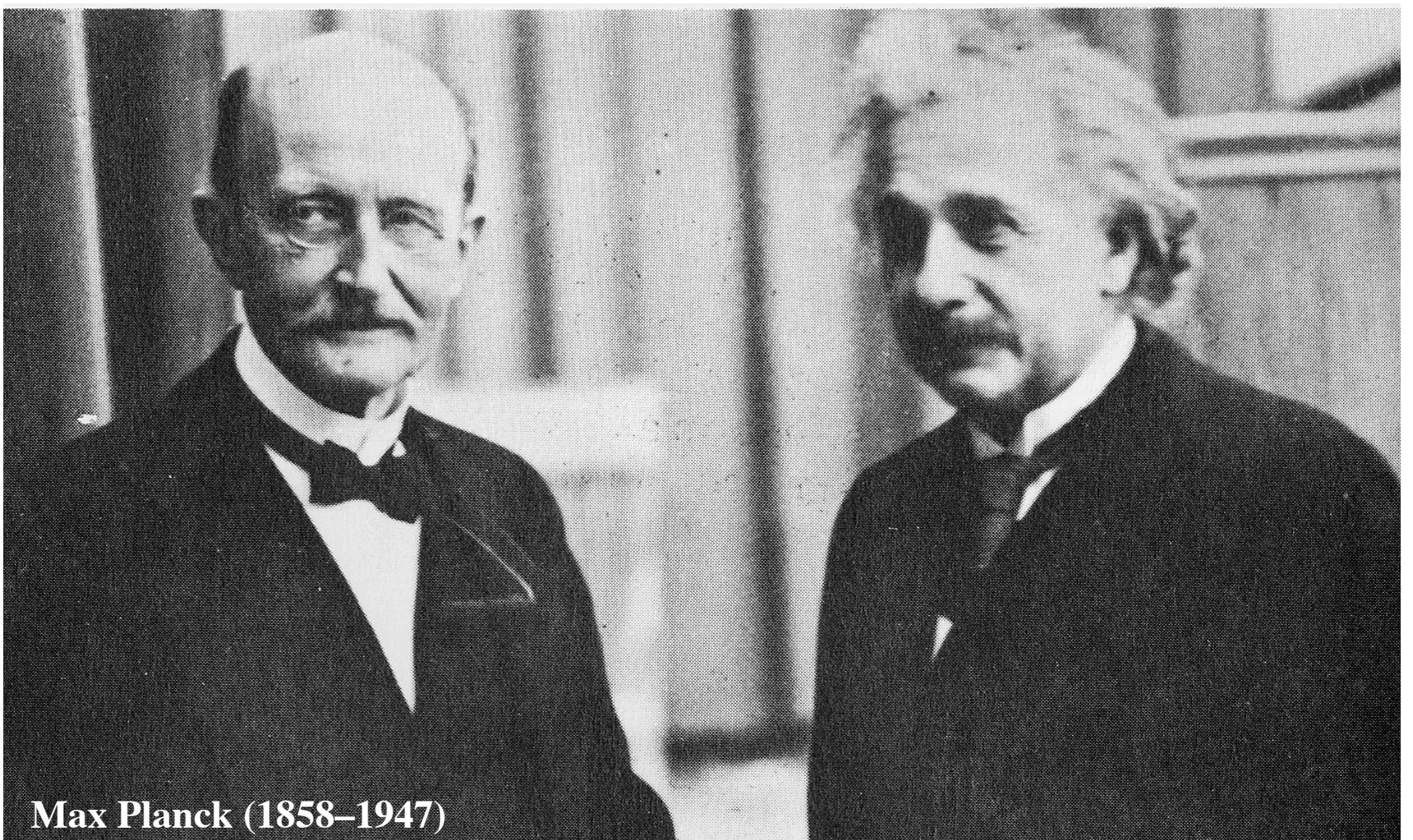
Recall

- **Inaugural lecture, 1914 (facts-first):** "The scientist has to worm … general principles out of nature by perceiving in comprehensive complexes of empirical facts certain general features which permit of precise formulation."

- **Spencer lecture, 1933 (math-first):** "we can discover [the laws of nature] by means of purely mathematical constructions … the creative principle resides in mathematics … pure thought can grasp reality."

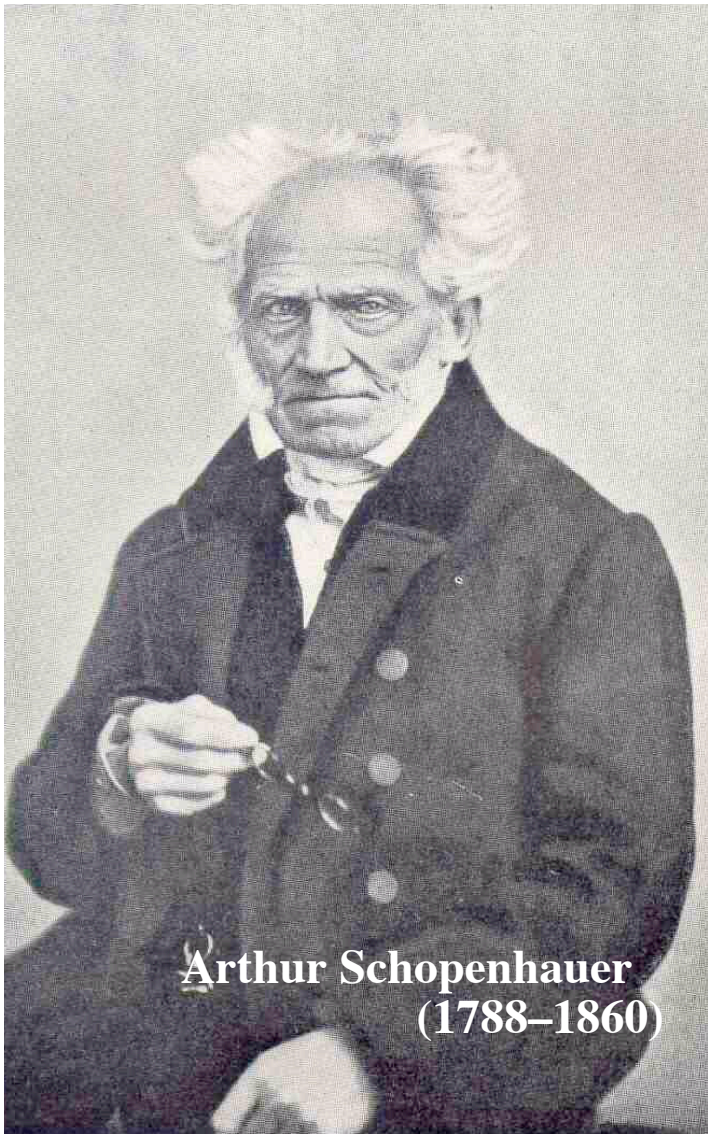
Physics as a way of "getting beyond the merely personal"

"Motivations for doing research" (Lecture in honor of Max Planck's 60th birthday, April 26, 1918)



Max Planck (1858–1947)

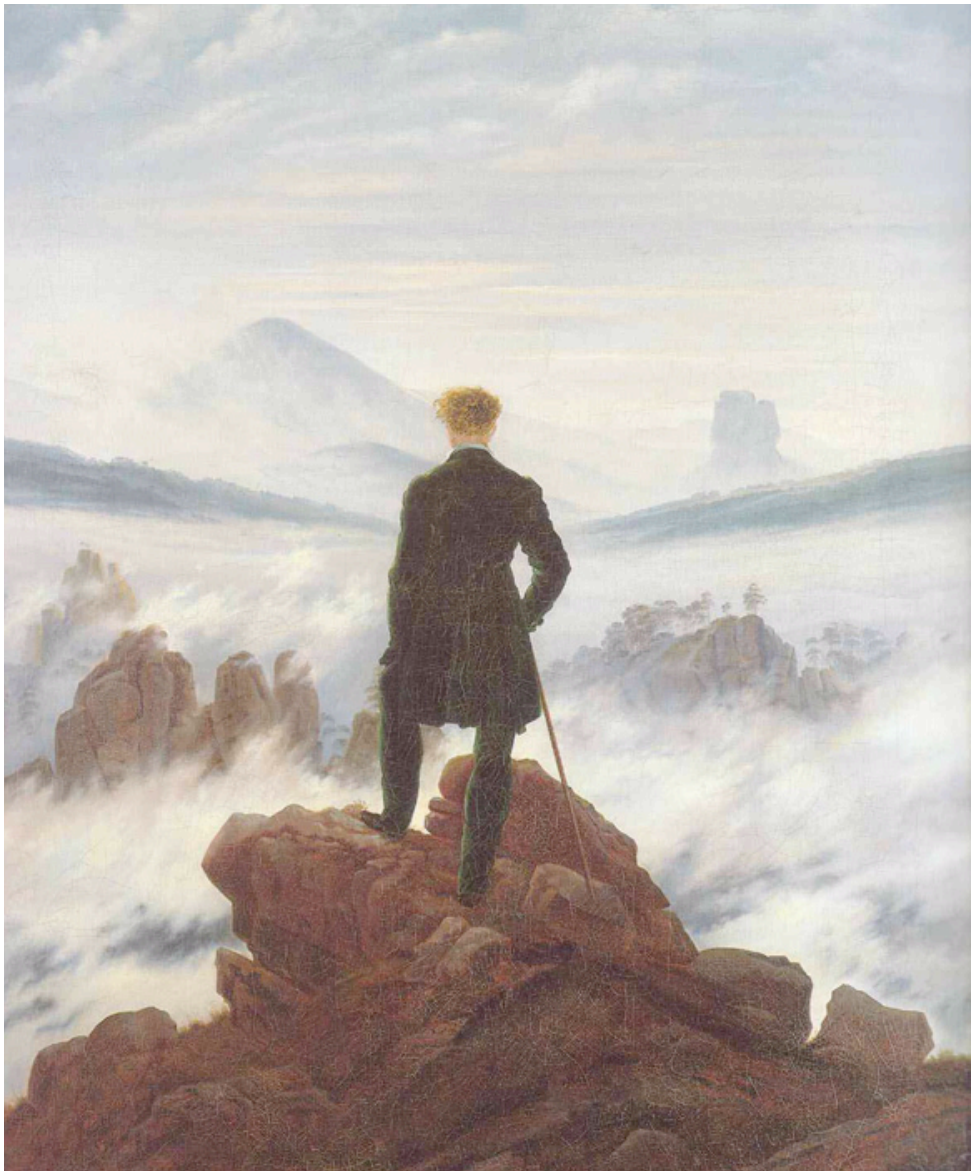
Physics as a way of "getting beyond the merely personal"



"Motivations for doing research" (1918)

"I believe with Schopenhauer that one of the strongest motives that leads men to art and science is escape from every day life with its painful crudity and hopeless dreariness, from the fetters of one's own ever shifting desires. A finely tempered nature longs to escape from personal life into the world of objective perception and thought"

Physics as a way of "getting beyond the merely personal"



"Motivations for doing research" (1918)

"this desire may be compared to the townman's irresistible longing to escape from his noisy, cramped surroundings into the silence of high mountains, where the eye ranges freely through the still, pure air and fondly traces the restful contours apparently built for eternity."

Caspar David Friedrich (1774–1840), *The Wanderer Above The Sea of Mists* (1818)

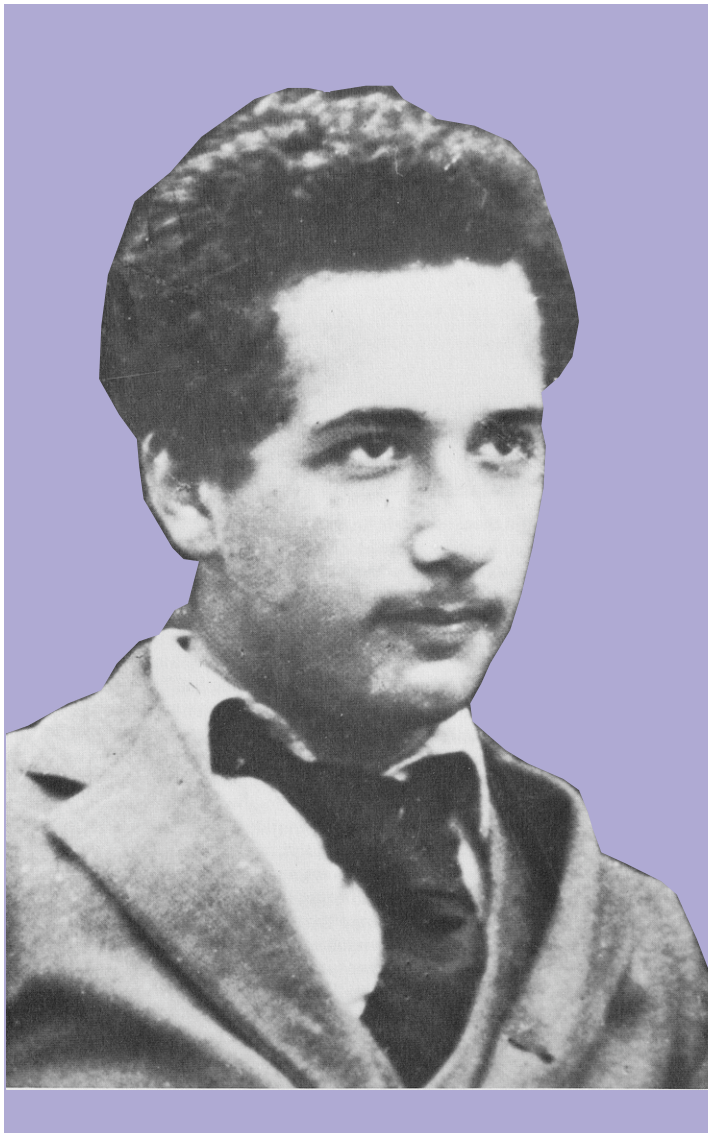
Physics as a way of "getting beyond the merely personal"

Einstein's book plate

"Motivations for doing research" (1918)

"With this negative motive goes a positive one. Man tries to make for himself in the fashion that suits him best a simplified and intelligible picture of the world; he then tries to some extent to substitute this cosmos of his for the world of experience, and thus to overcome it. This is what the painter, the poet, the speculative philosopher, and the natural scientist do, each in his own fashion. Each makes this cosmos and its construction the pivot of his emotional life, in order to find in this way the peace and security which he cannot find in the narrow whirlpool of personal experience."

Physics as a way of "getting beyond the merely personal"



"Motivations for doing research" (1918)

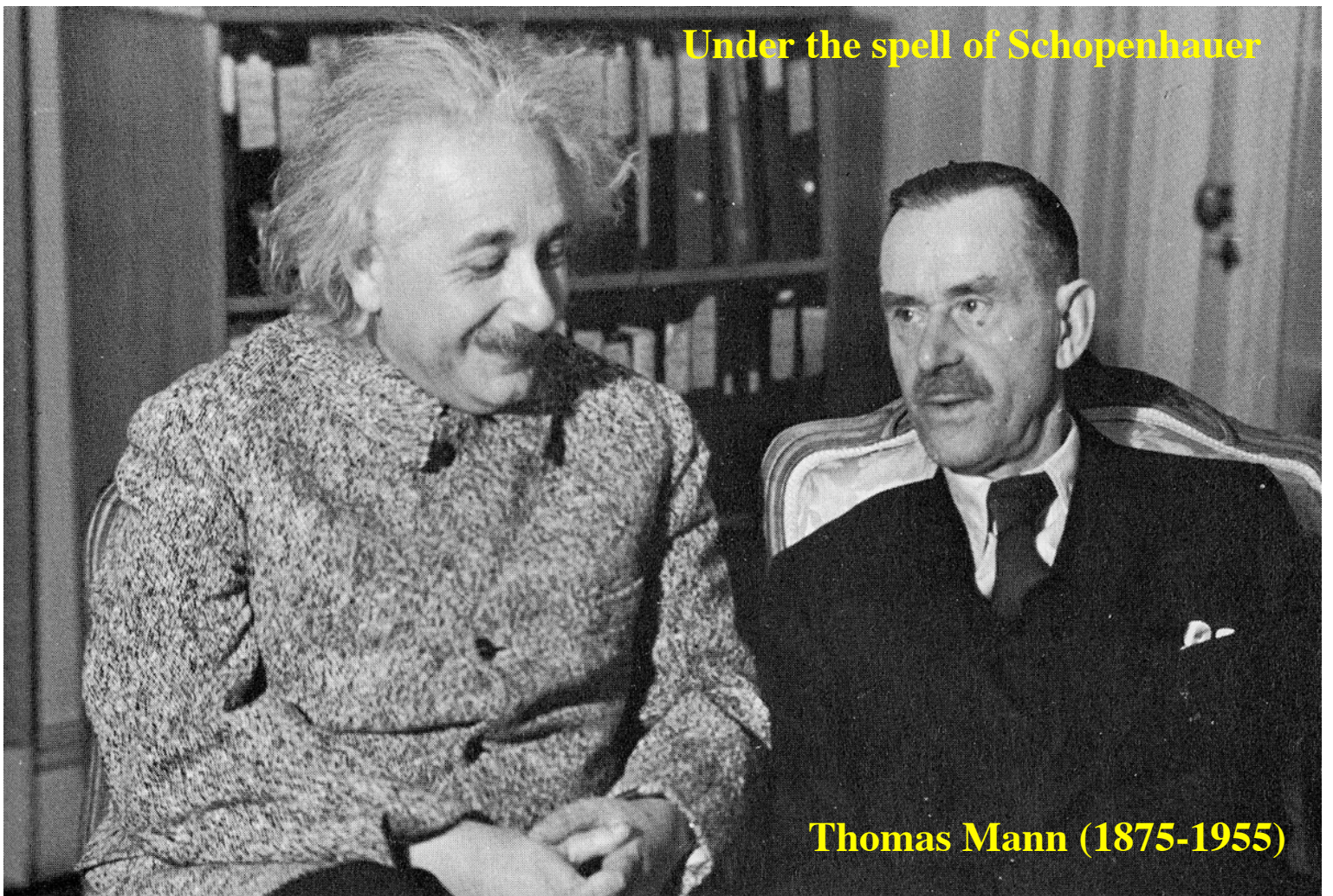
Sounds remarkably similar to Einstein's "dear mommy"-letter 21 years earlier!

"One creates a small little world for oneself, and as lamentably insignificant it may be in comparison with the perpetually changing size of real existence, one feels miraculously great and important, like a mole in his self-dug hole."

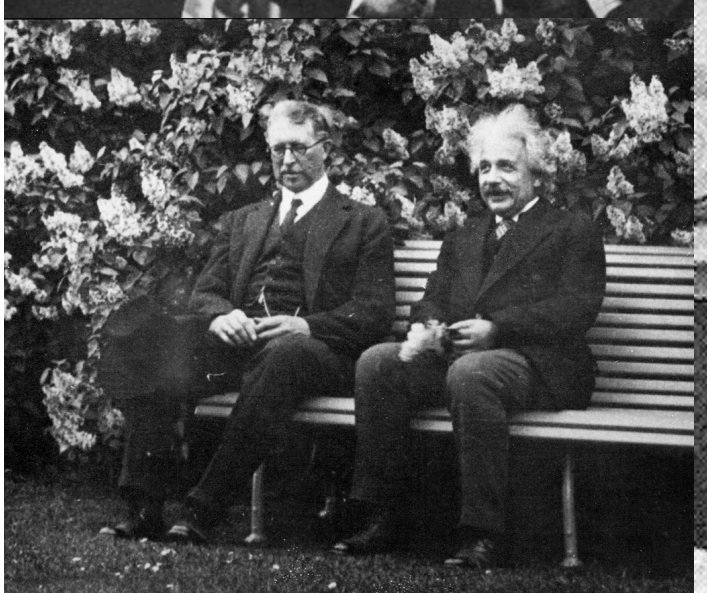
Schopenhauer cult. Described for instance in Thomas Mann, *Buddenbrooks* (1901) [Nobel prize, 1929]. Cool in 1897, not so cool anymore in 1918.

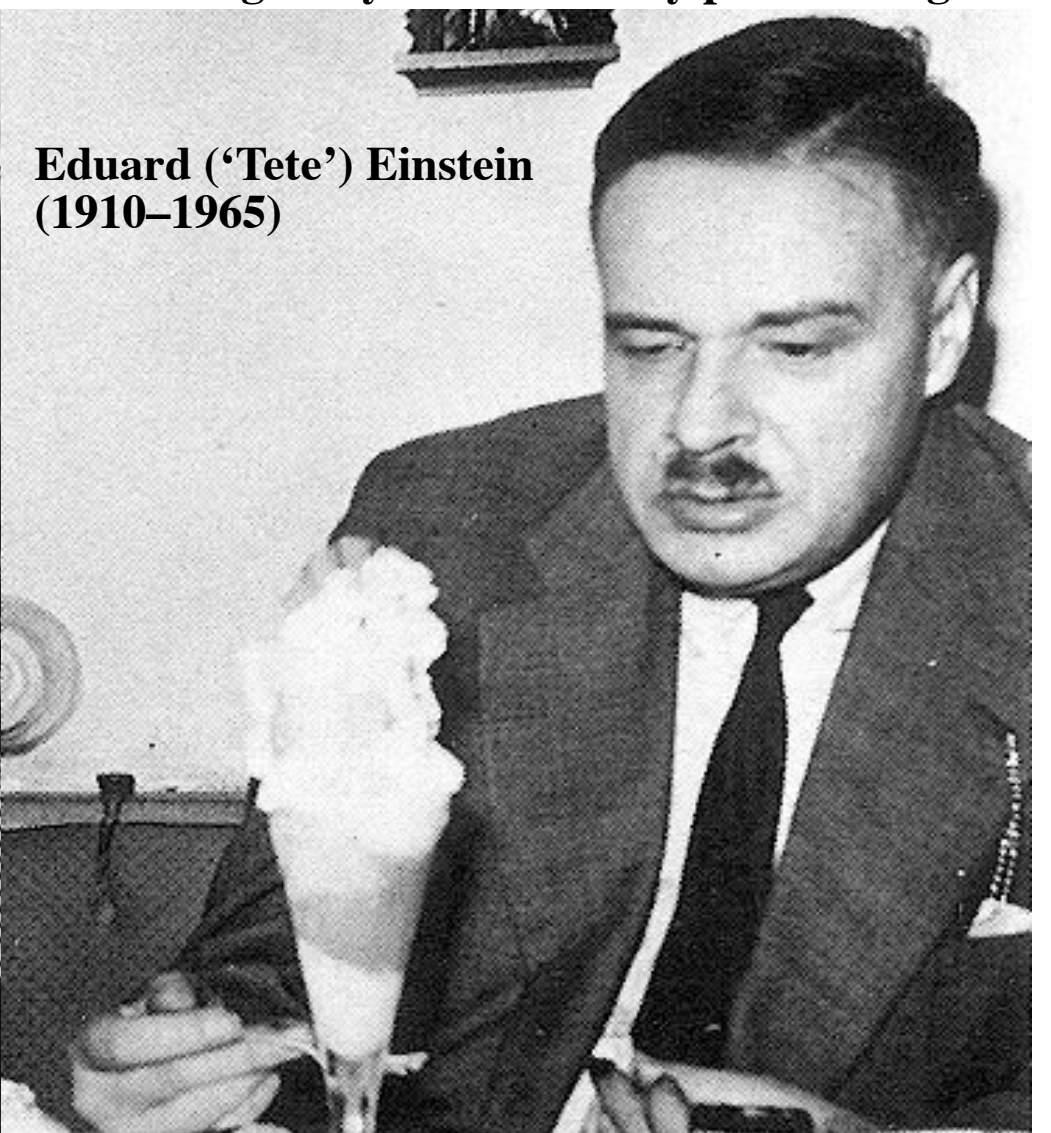
Thomas Mann (1875-1955)

My suggestion: Einstein's reading of Schopenhauer played a not unimportant role in changing Einstein's approach to physics from the empiricism (*putting the facts)* of the young turk to the extreme rationalism (*putting the math first*) of the old sage.



Or … does the old sage's 1933 Spencer lecture reflect just a temporary lapse of judgment as yet another crisis made him want to 'get beyond the merely personal' again?





Eduard ('Tete') Einstein (1910–1965)