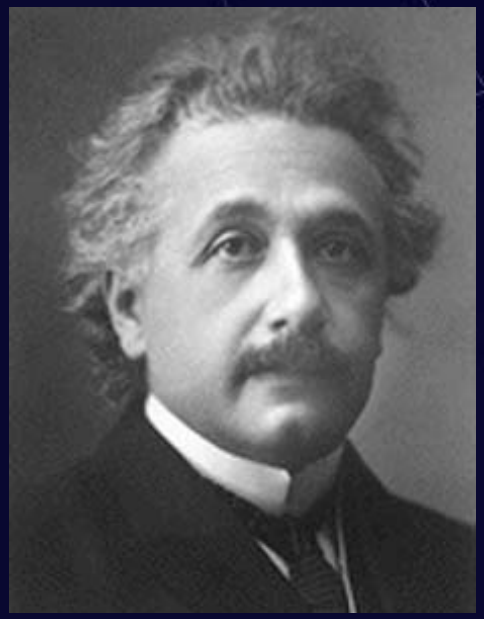
Einstein's Universe

UNIVERSITY of GLASGOW



Dr Martin Hendry

Dept of Physics and Astronomy
University of Glasgow, UK

Einstein's Universe

Course Lecturers:

Dr Martin Hendry — Dept of Physics and Astronomy
University of Glasgow
martin@astro.gla.ac.uk

Plus (provisionally): Matt Pitkin

Fiona Speirits

UNIVERSITY *of* GLASGOW

ASTRONOMY ASTROPHYSICS

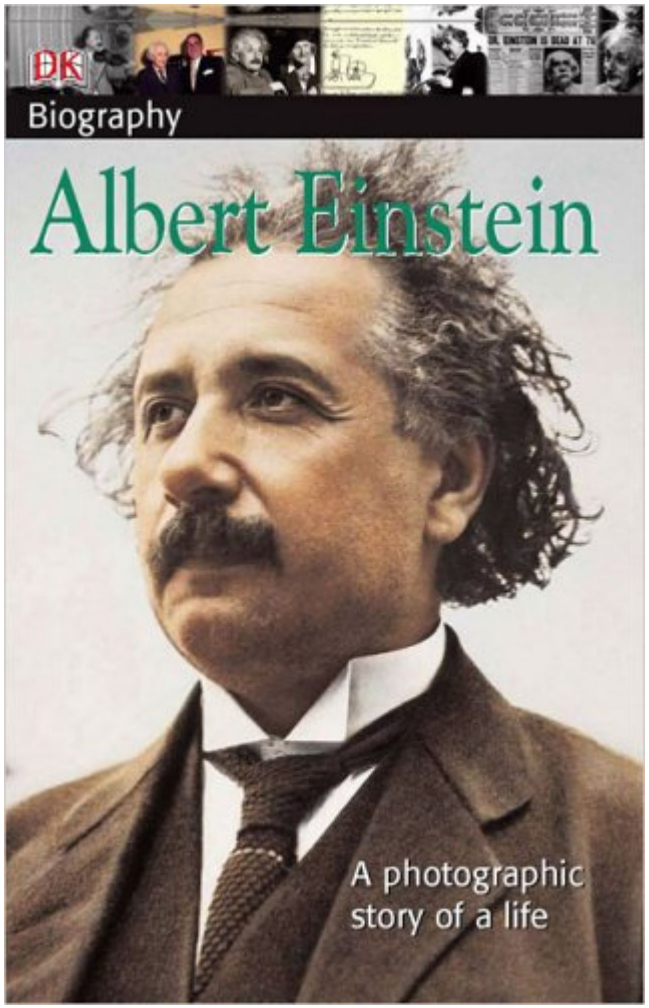
IGR

Course Website:

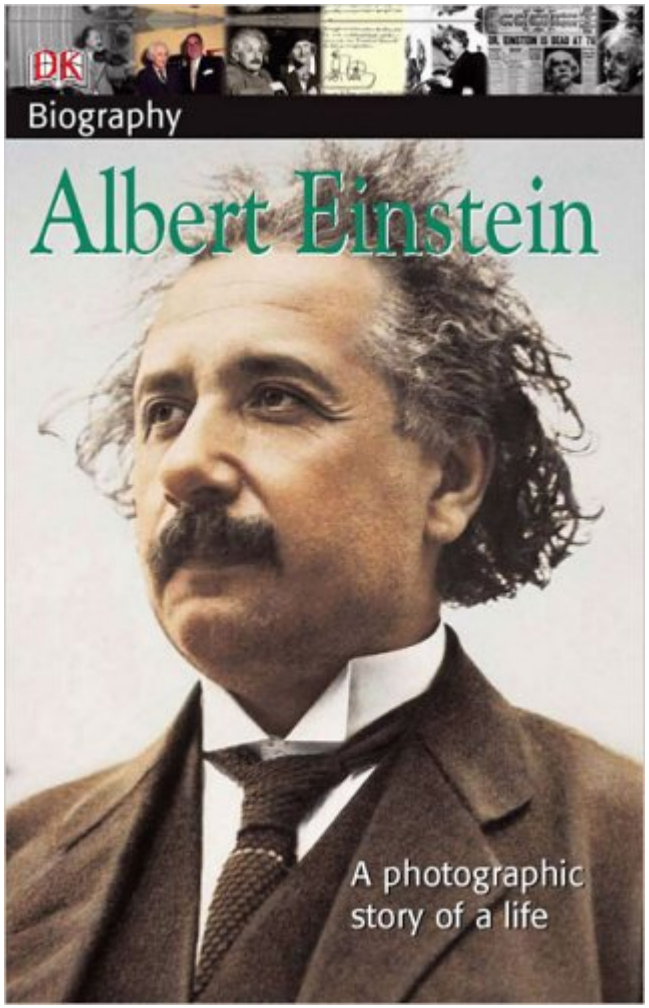
http://www.astro.gla.ac.uk/users/martin/teaching/einstein/

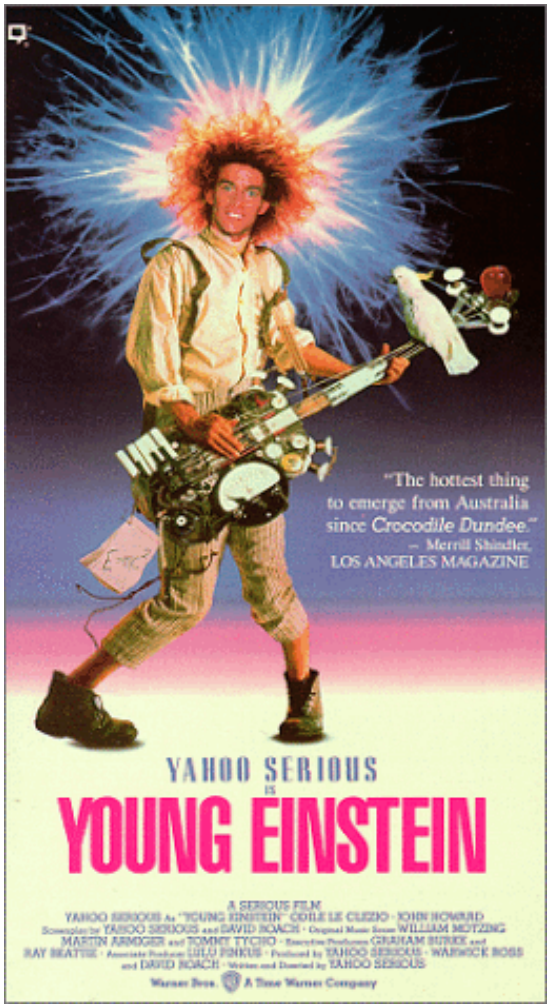
username: einstein password: einstein

Young Einstein



Young Einstein

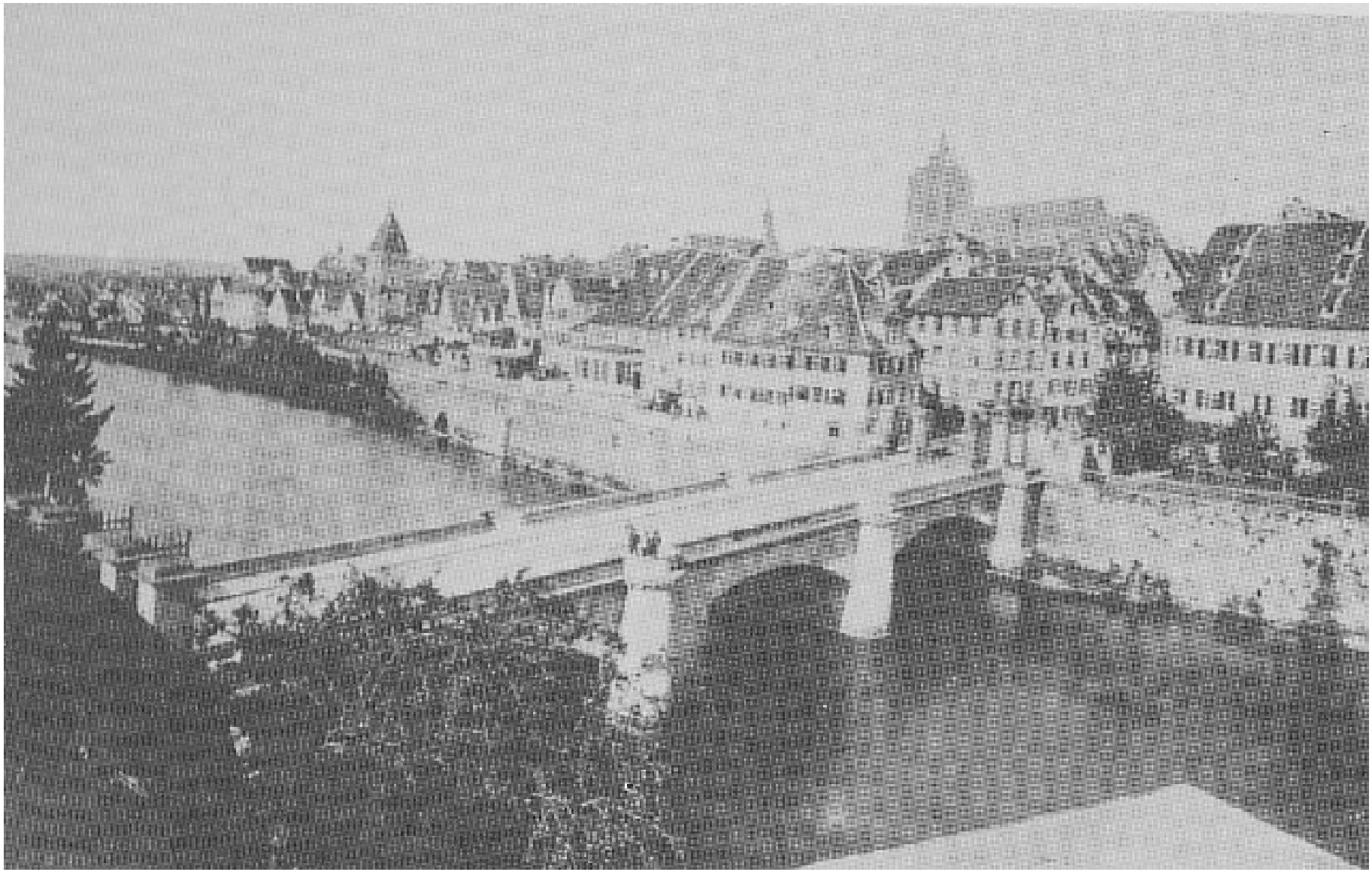




Hermann Einstein

Pauline Koch

Married in Ulm, Germany, August 8th 1876



Ulm, photographed in 1870

Hermann Einstein

Pauline Koch

Married in Ulm, Germany, August 8th 1876

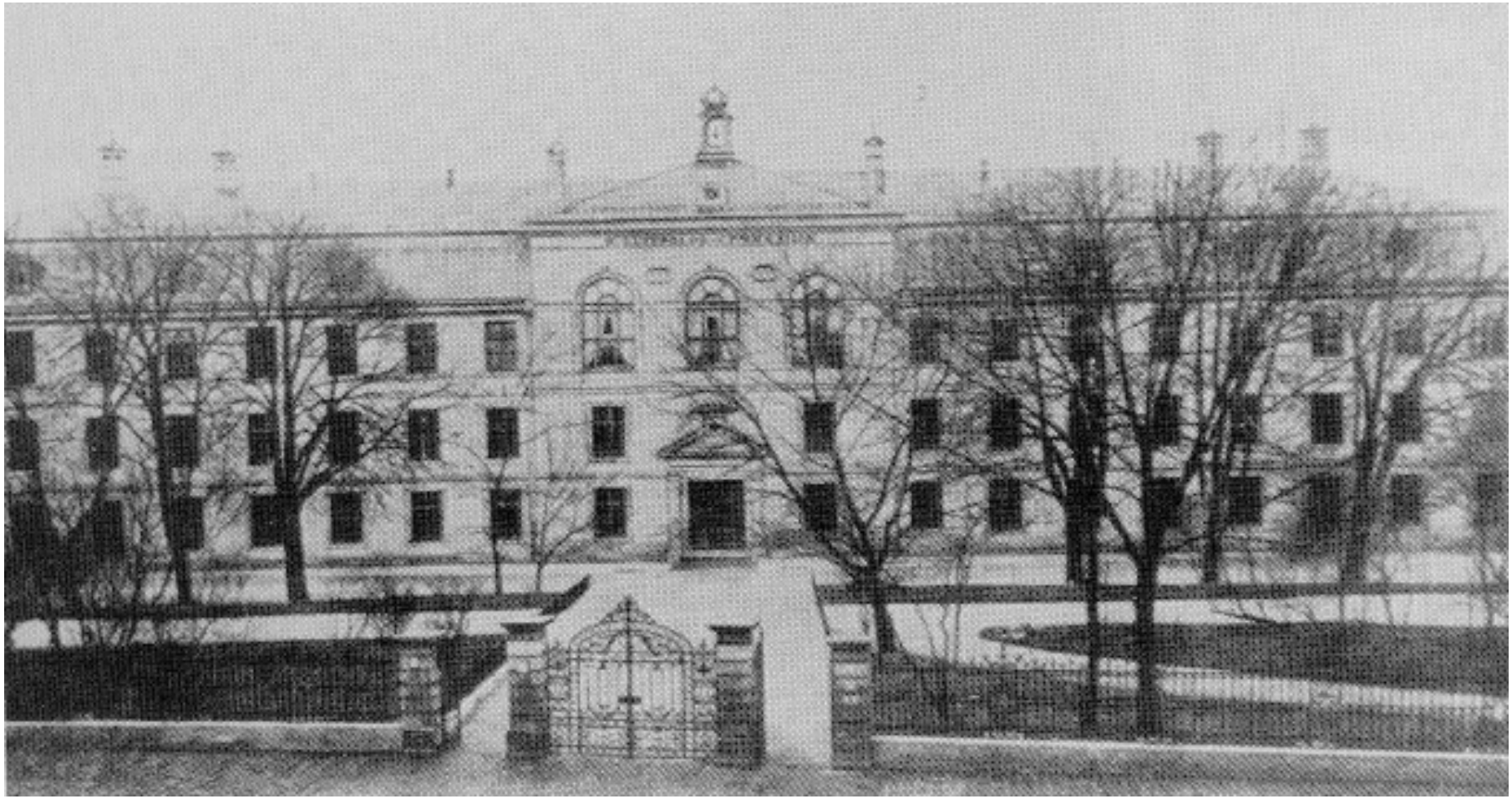
Albert Einstein, born here March 14th 1879

Albert, aged 4

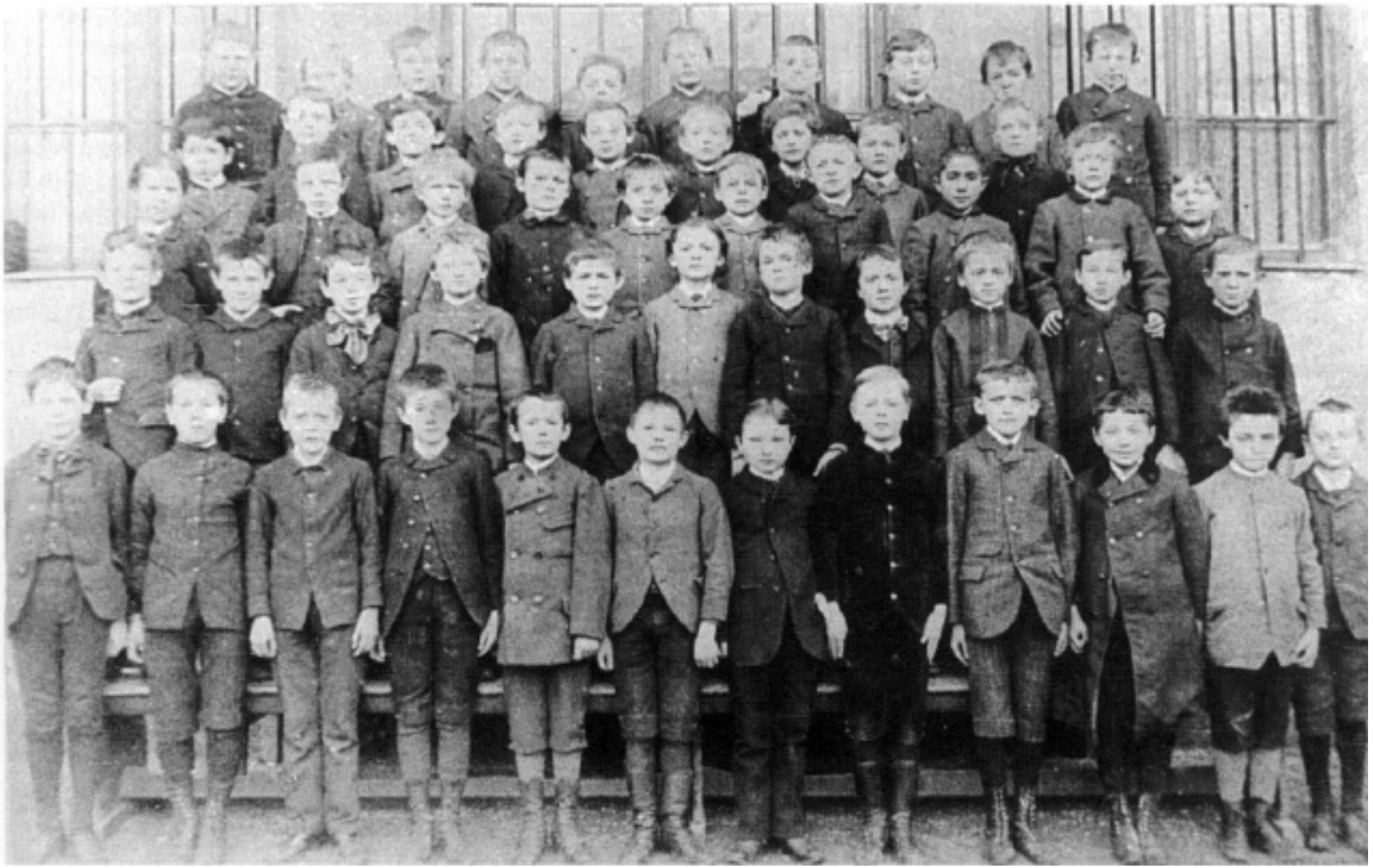
Albert and his sister
Maja, born 1881


S E
E
W
N
N

"I encountered a wonder of such a kind…when my father showed me a compass. That this needle behaved in such a determined way did not fit into the way of incidents at all which could find a place in the unconscious vocabulary of concepts (action connected with “touch”). I still remember – or I think I do – that this incident has left with me a deep impression. There must have been something behind things that was deeply hidden."



Luitpold Gymnasium elementary school, Munich



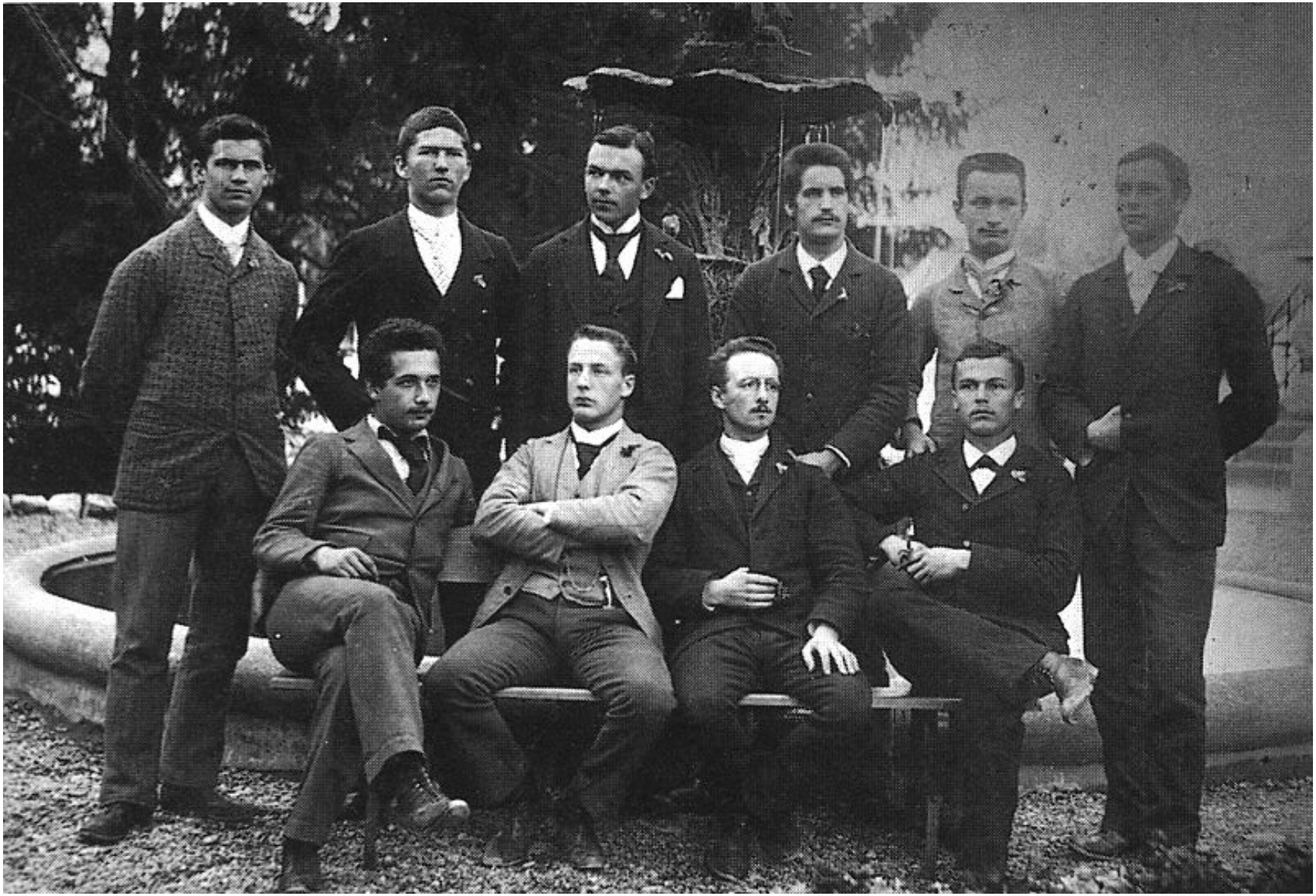
The class of 1889

Max Talmud

Albert, as a teenager

Albert, and his sister Maja

ETH, Zurich: Swiss Federal Polytechnic Institute



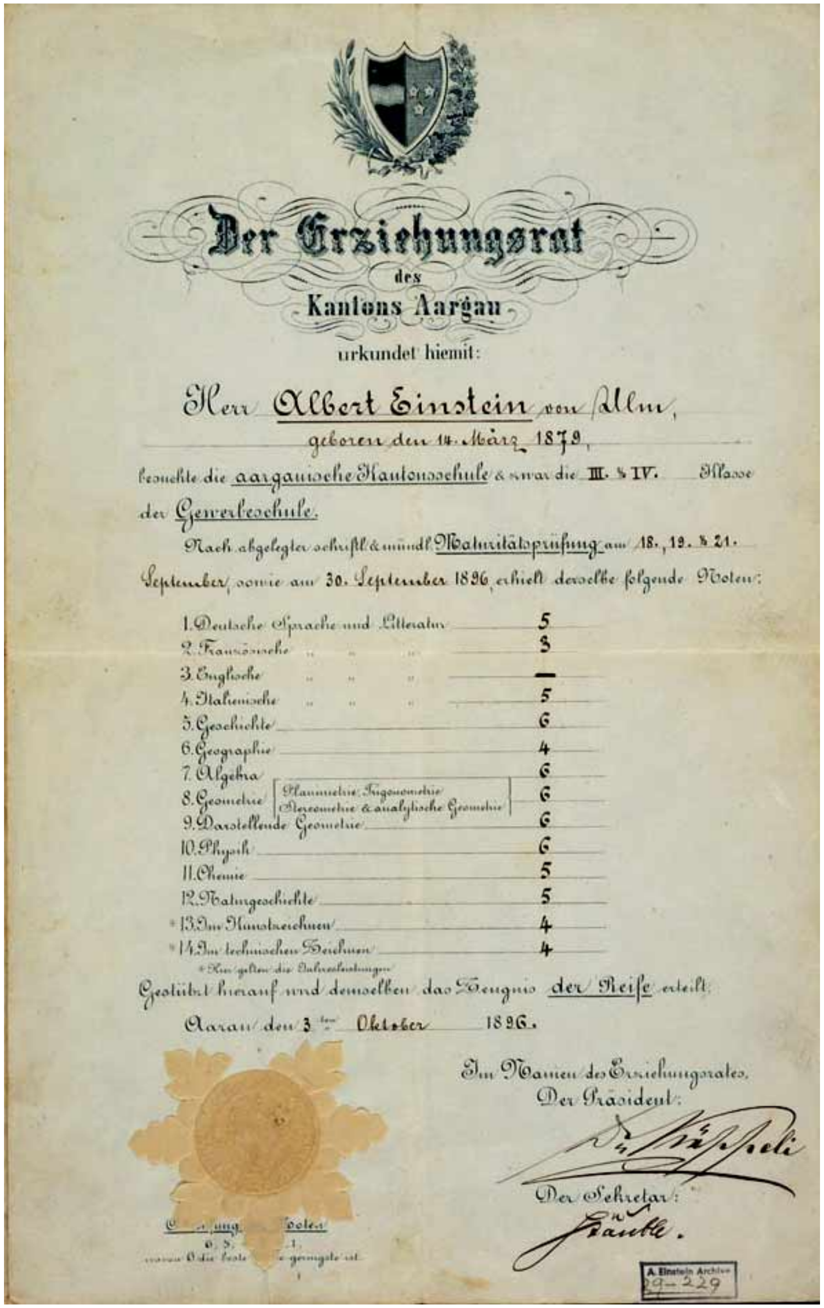
Einstein’s class at Aarau High School, 1896

Voici les raisons qui m'ont
~~choses~~ ~~causes~~ porté à me décider pour ce projet. Il est surtout la disposition
individuelle pour les pensées abstraites et
mathématiques, le manque de ~~talent~~ plastique
et du talent pratique. Ce sont aussi mes
désirs qui ~~me poussent la même but~~,
m'ont inspiré
me conduisaient à la même résolution.
C'est tout naturel, on aime toujours faire
les
~~ces~~ choses, pour lesquelles on a du talent.
Puis c'est aussi une certaine indépendance
de la profession qui scientifique qui me
plaît beaucoup.

3—4.

Voici les raisons qui m'ont
~~choses~~ ~~causes~~ porté à me décider pour ce projet. Il est surtout la disposition
individuelle pour les pensées abstraites et
mathématiques, le manque de ~~phantaisie~~
et du talent pratique. Ce sont aussi mes
désirs qui ~~me persuadent la même chose~~,
m'ont inspiré
me conduisaient à la même résolution.
C'est tout naturel, on aime toujours faire
les choses, pour lesquelles on a du talent.
Puis c'est aussi une certaine indépendance
de la profession qui scientifique qui me
plaît beaucoup.

3—4.



Der Erziehungsrat
des
Kantons Aargau
urkundet hiemit:

Herr Albert Einstein von Ulm,
geboren den 14. März 1879,
besuchte die aargauische Kantonsschule & zwar die III. & IV. Klasse
der Gewerbeschule.

Nach abgelegter schriftl. & mündl. Maturitätsprüfung am 18., 19. & 21. September, sowie am 30. September 1896 erhielt derselbe folgende Noten:

1. Deutsche Sprache und Litteratur	5
2. Französische " " "	3
3. Englische " " "	—
4. Italienische " " "	5
5. Geschichte	6
6. Geographie	4
7. Algebra	6
8. Geometrie (Planimetrie, Trigonometrie, Stereometrie & analytische Geometrie)	6
9. Darstellende Geometrie	6
10. Physik	6
11. Chemie	5
12. Naturgeschichte	5
* 13. Im Kunstzeichnen	4
* 14. Im technischen Zeichnen	4

* Hier gelten die Jahresleistungen

Gestützt hierauf wird demselben das Zeugnis der Reife erteilt.

Aarau, den 3ten Oktober 1896.

Im Namen des Erziehungsrates,
Der Präsident:
Der Sekretär:

A. Einstein Archive
29-229

1. Deutsche Sprache und Litteratur	5
2. Französische " " "	3
3. Englische " " "	—
4. Italienische " " "	5
5. Geschichte	6
6. Geographie	4
7. Algebra	6
8. Geometrie (Planimetrie, Trigonometrie, Stereometrie & analytische Geometrie)	6
9. Darstellende Geometrie	6
10. Physik	6
11. Chemie	5
12. Naturgeschichte	5
* 13. Im Kunstzeichnen	4
* 14. Im technischen Zeichnen	4

Graduation certificate
September 1896

ETH, Zurich: Swiss Federal Polytechnic Institute

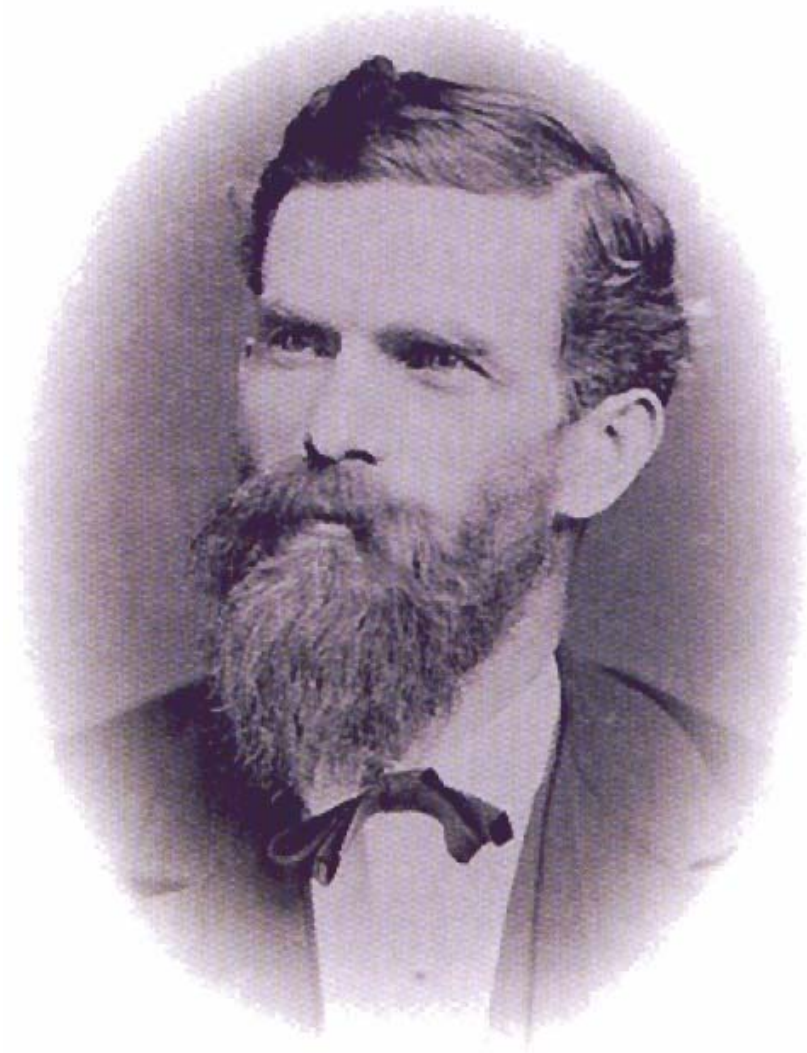
Marcel
Grossman

ETH, October 1896

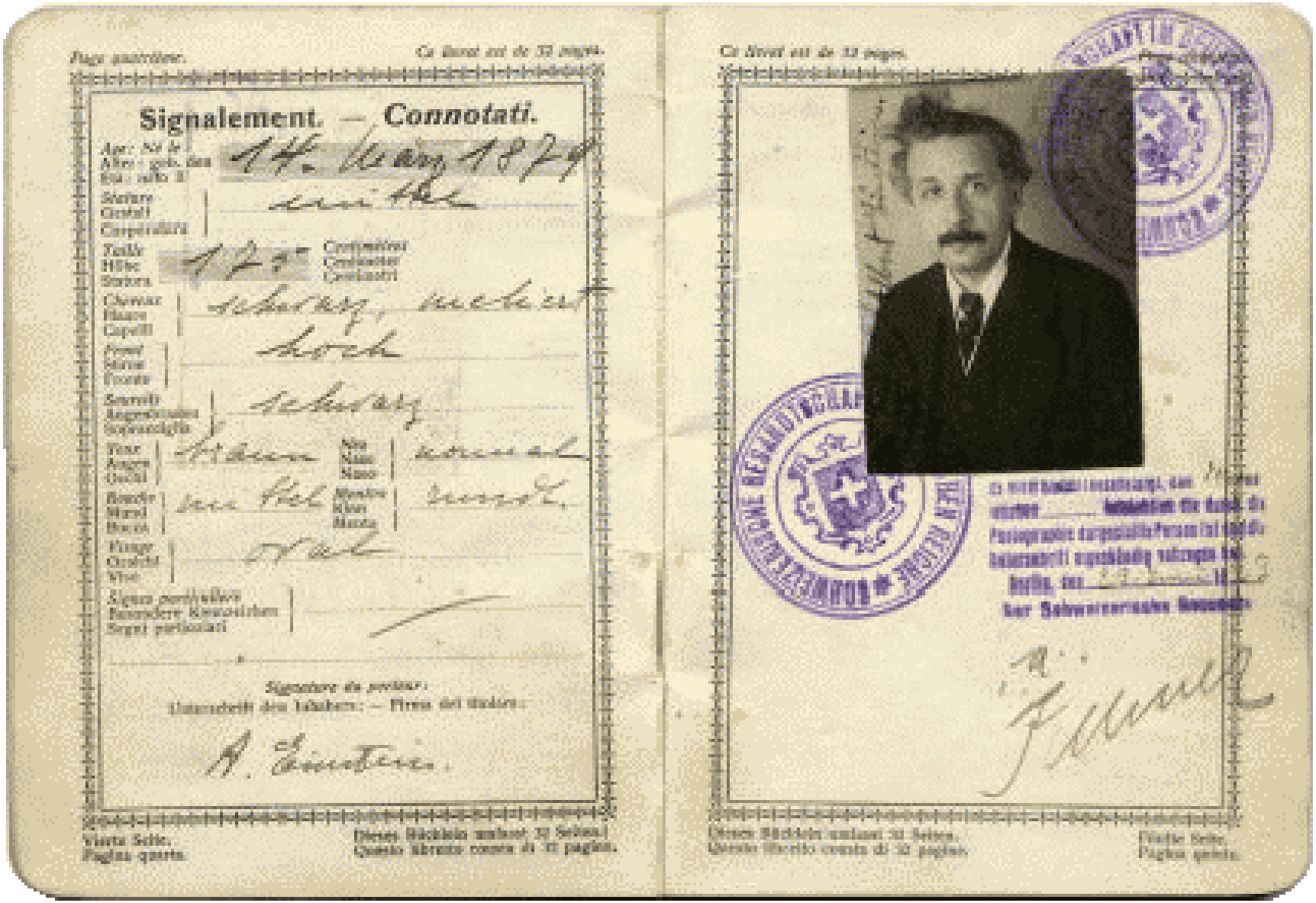
Michele Besso

Mileva Maric

Hermann Minkowski



Heinrich Weber



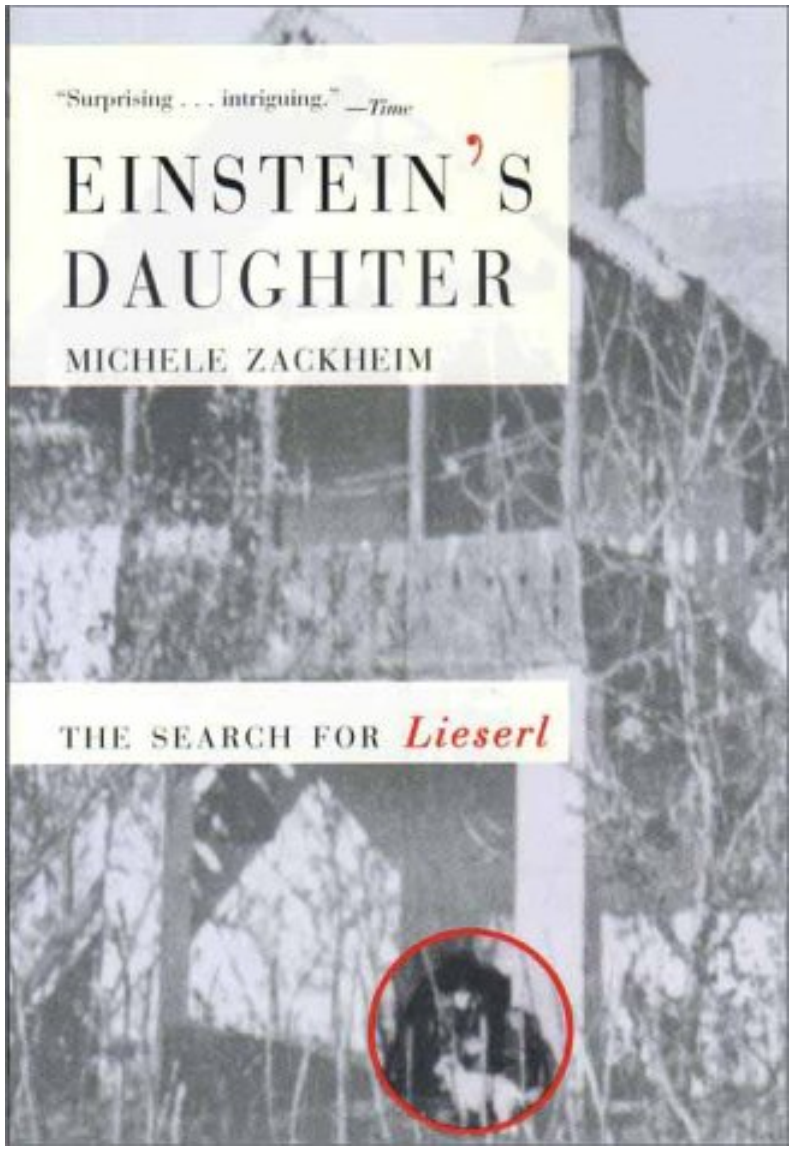
Albert gains Swiss Citizenship, December 1900

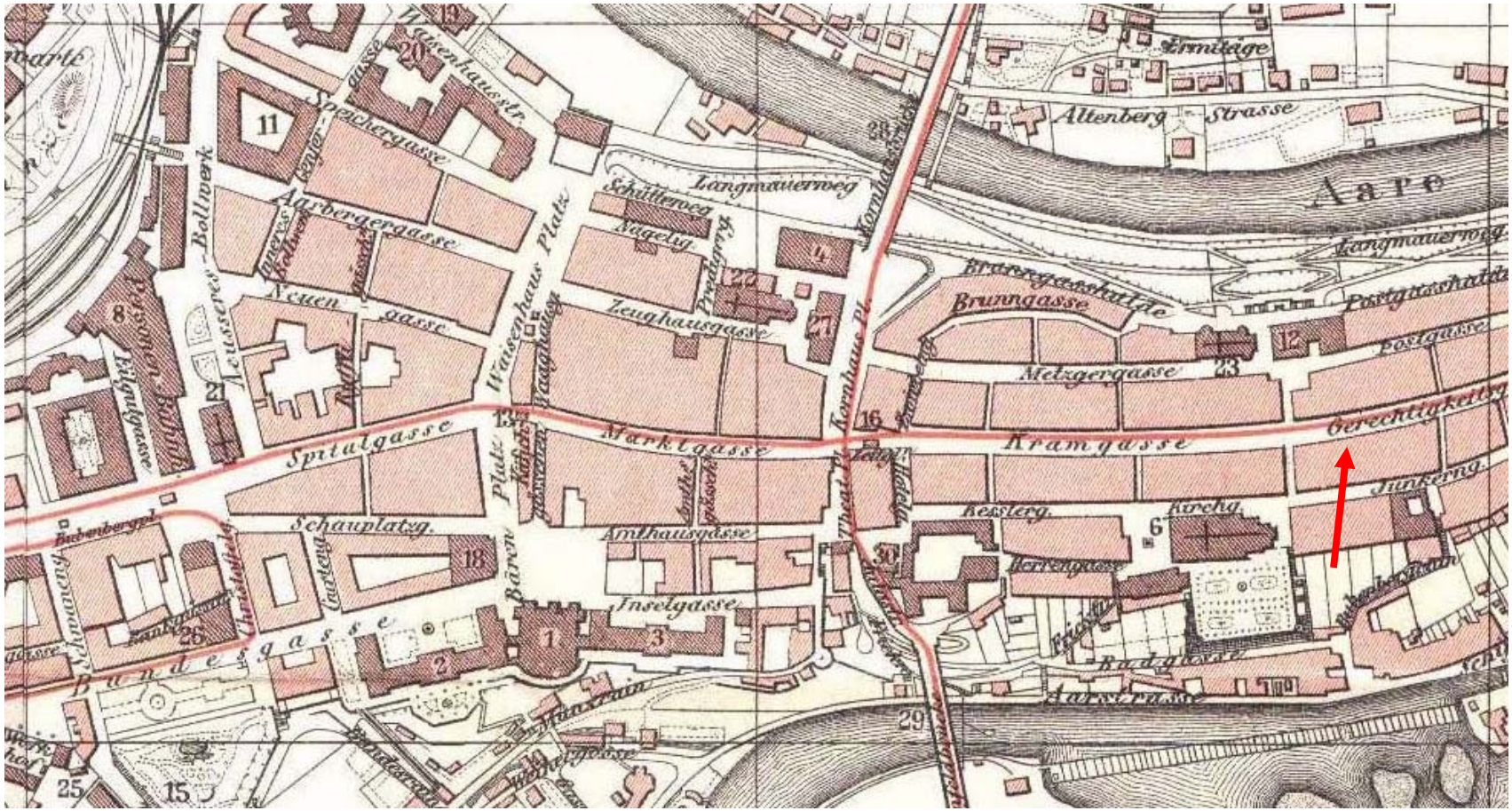
“Science is a wonderful thing, if one does not have to earn one's living at it”

The Swiss Patents Office, Bern
1893 – 1907

Mileva and Albert, 1900

Alfred Kleiner, supervisor of Albert’s PhD thesis

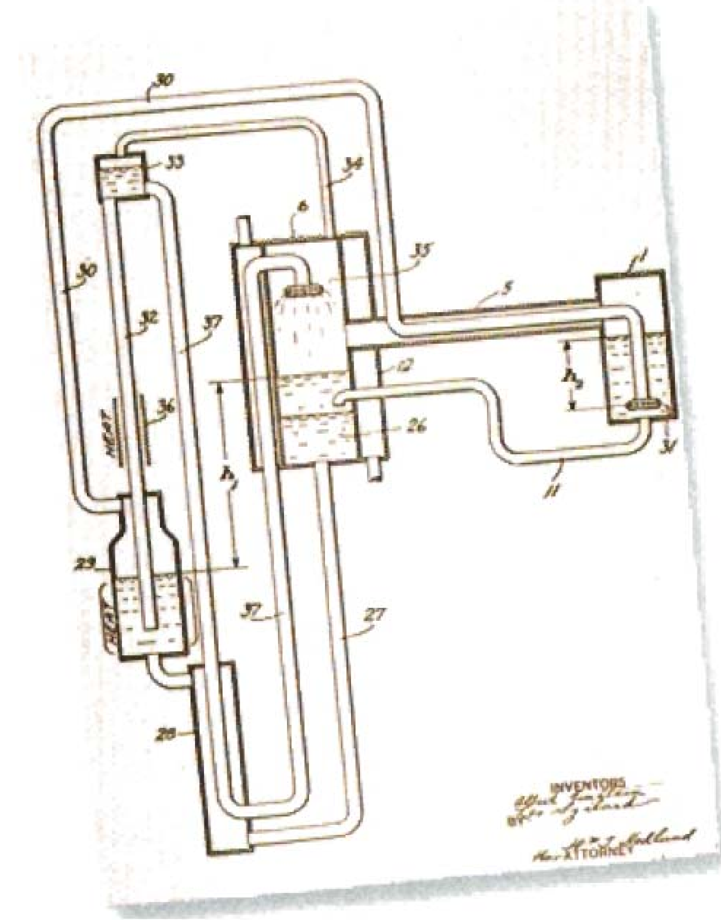

"Surprising . . . intriguing." —Time
EINSTEIN'S DAUGHTER
MICHELE ZACKHEIM
THE SEARCH FOR Lieserl

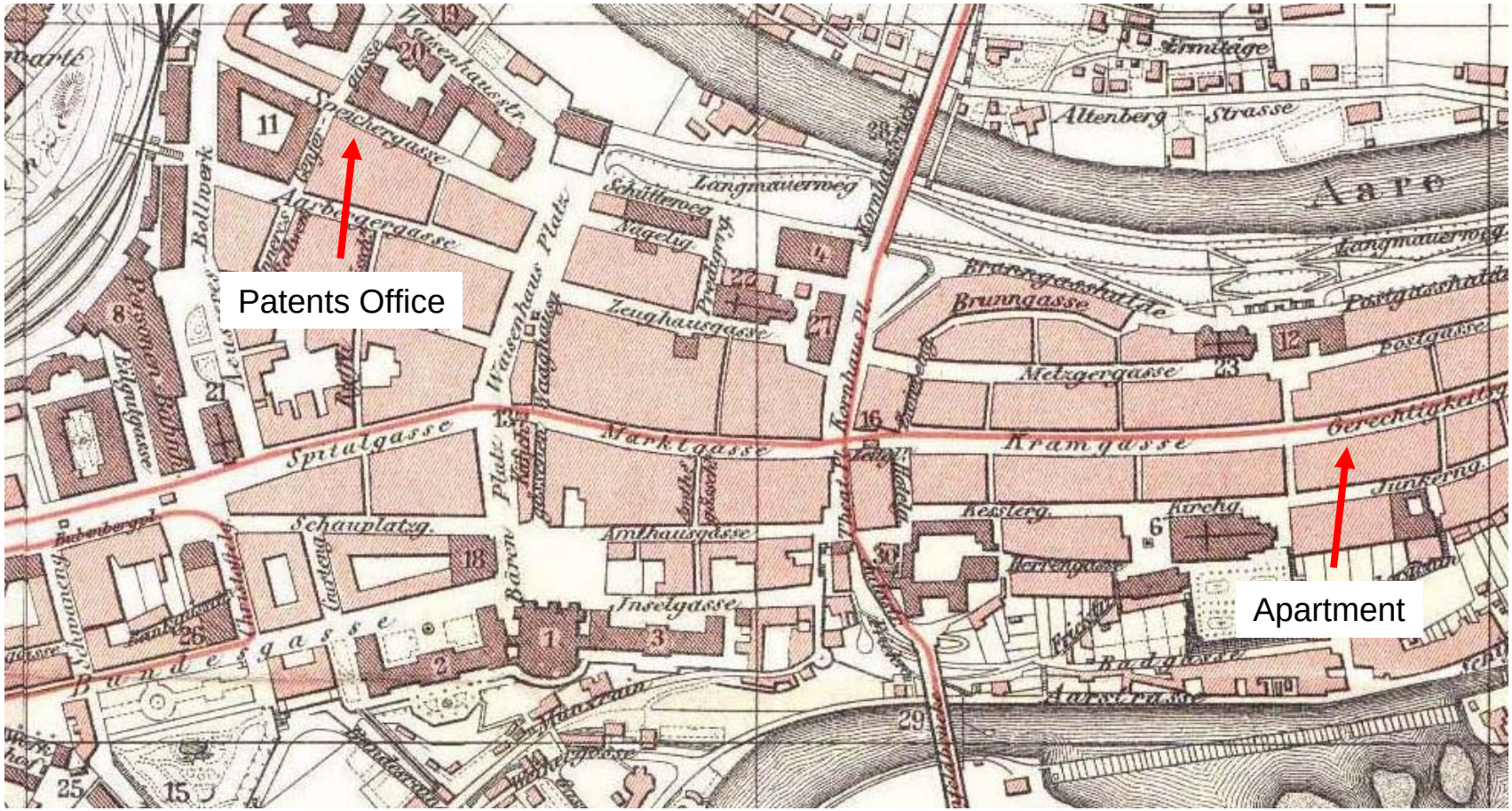


Albert’s one-bedroom apartment in Bern

Maurice Solovine Conrad Habicht

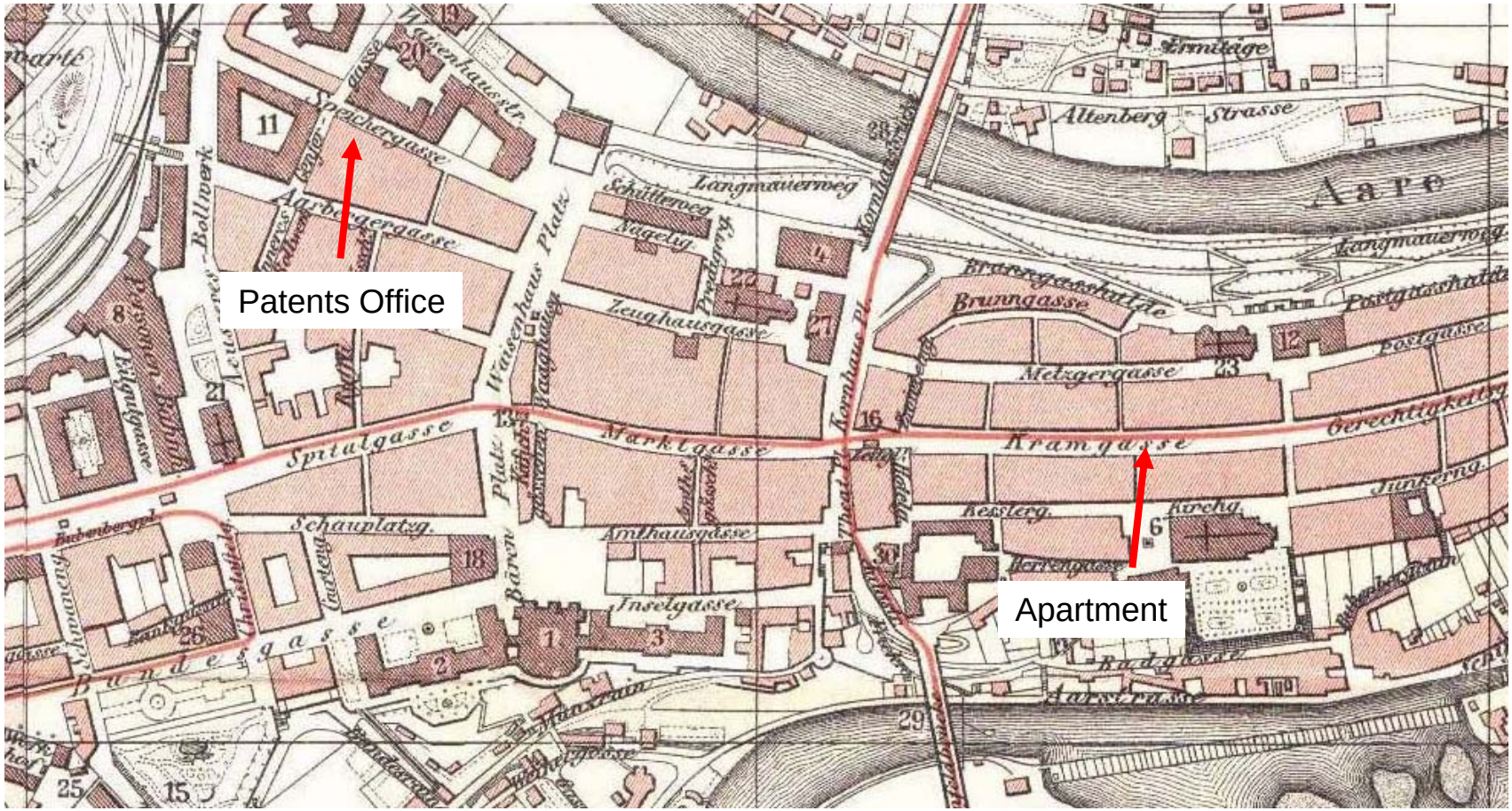
Interior of the Patents Office, Bern


HEAT
INVENTORS
ATTORNEY


Patents Office
Apartment
Aare
Altenberg Strasse
Ermitage
Langmauerweg
Brunngasse
Postgasse
Metzgergasse
Gerechtigkeitsg.
Kramgasse
Marktgasse
Spitalgasse
Schauplatzg.
Amthausgasse
Inselgasse
Bundesgasse
Zeughausgasse
Waisenhaus Platz
Aarbergergasse
Speichergasse
Kesslerg.
Kirchg.
Junkerng.
Radgasse
Aarstrasse

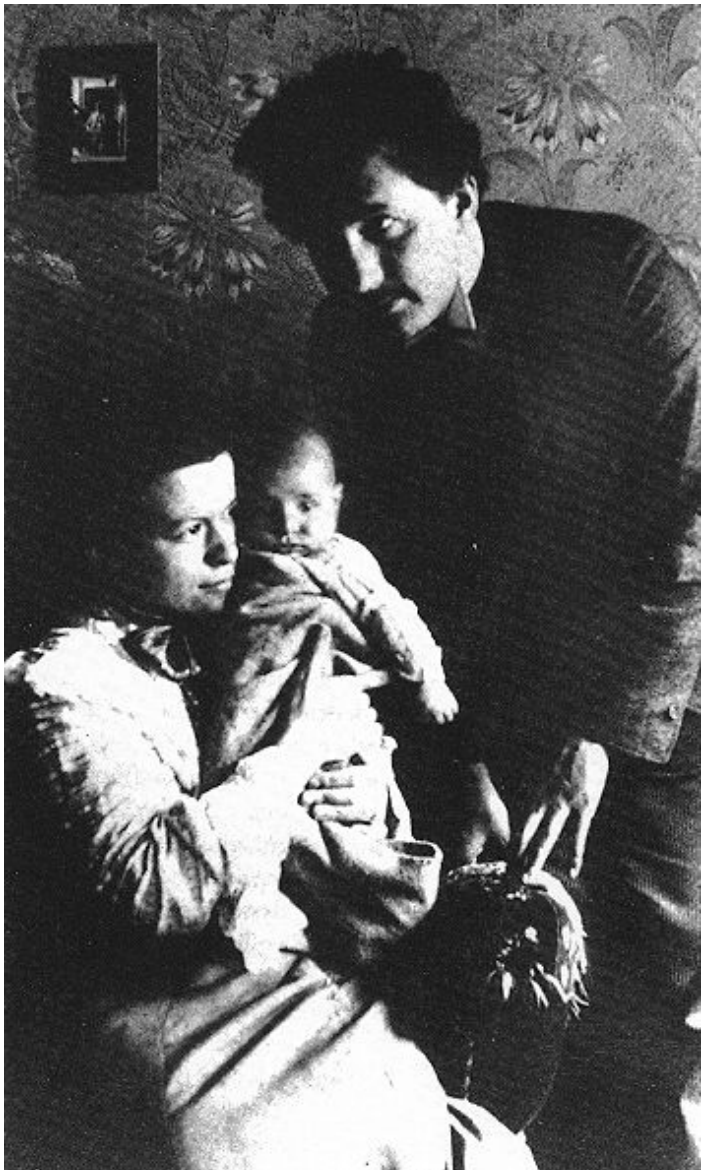
Founding members of the “Olympia Academy”

Wedding day, January 6th 1903 in Bern


Patents Office
Apartment
Aare
Altenberg Strasse
Ermitage
Langmauerweg
Brunngasse
Postgasse
Metzgergasse
Gerechtigkeitsg.
Kramgasse
Marktgasse
Spitalgasse
Schauplatzg.
Amthausgasse
Inselgasse
Bundesgasse
Zeughausgasse
Waisenhaus Platz
Aarbergergasse
Speichergasse
Schützenweg
Predigerg.
Kesslerg.
Kirchg.
Junkerng.
Radgasse
Aarstrasse
Bollwerk
Münstrain

Mileva Maric and Albert Einstein lived at 49 Kramgasse (second apartment from the left) in Berne. Switzerland. At the end of the street is Berne's famous clock tower.


EINSTEIN
HAUS
BERN



Hans Albert, born May 14th 1904

1905: Einstein’s “Annus Mirabilis”

1905 – Theory of Special Relativity

"You can't tell if you're moving"

Physics before Einstein:
"All the World's A Stage"

- Newton's physics assumes absolute space and time, for all observers.

Physics before Einstein:
"All the World's A Stage"

- Newton's physics assumes absolute space and time, for all observers.

Physics before Einstein:

"All the World's A Stage"

- Newton's physics assumes absolute space and time.
- We work out how things look to different observers using simple rules

Physics before Einstein:

"All the World's A Stage"

- Newton's physics assumes absolute space and time.
- We work out how things look to different observers using simple rules

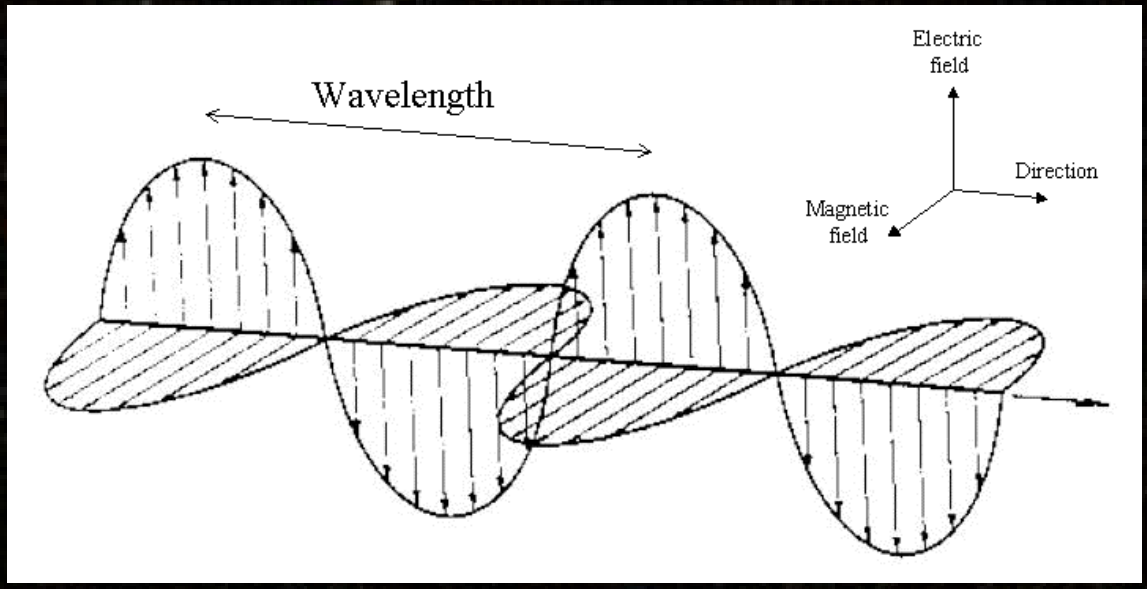
1905 – Theory of Special Relativity

"The laws of physics should be the same for *any* observer"

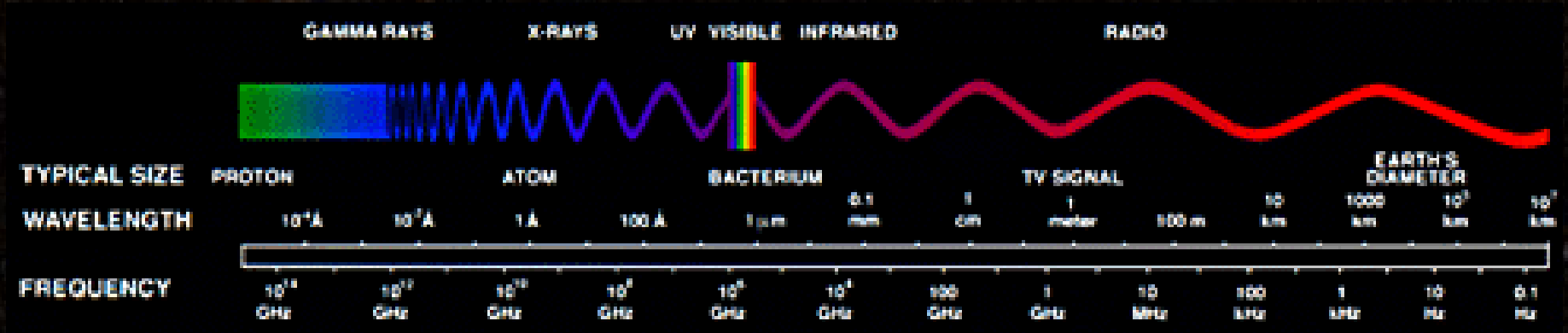
Classical Physics:

James Clerk Maxwell's theory of light

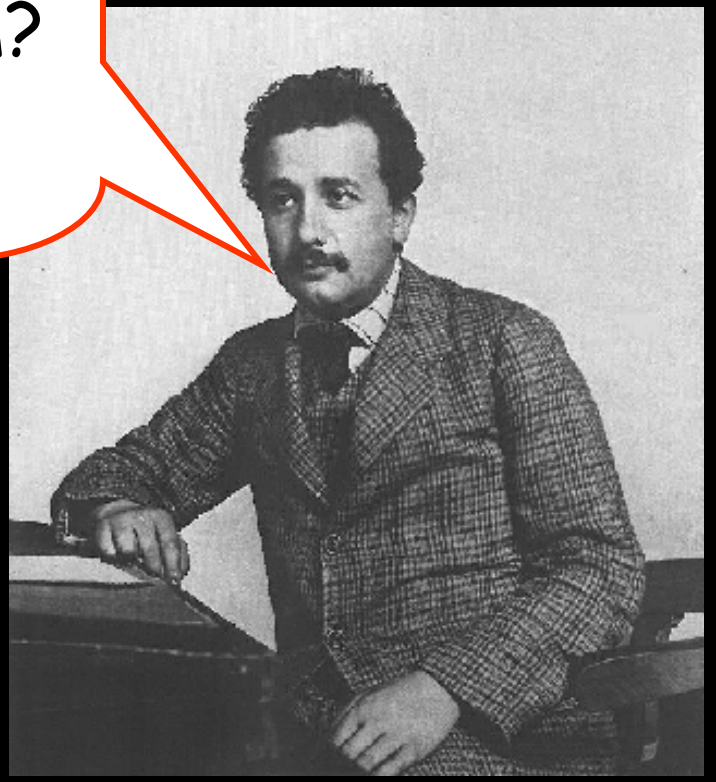
Light is a *wave* (caused by varying *electric* and *magnetic* fields)

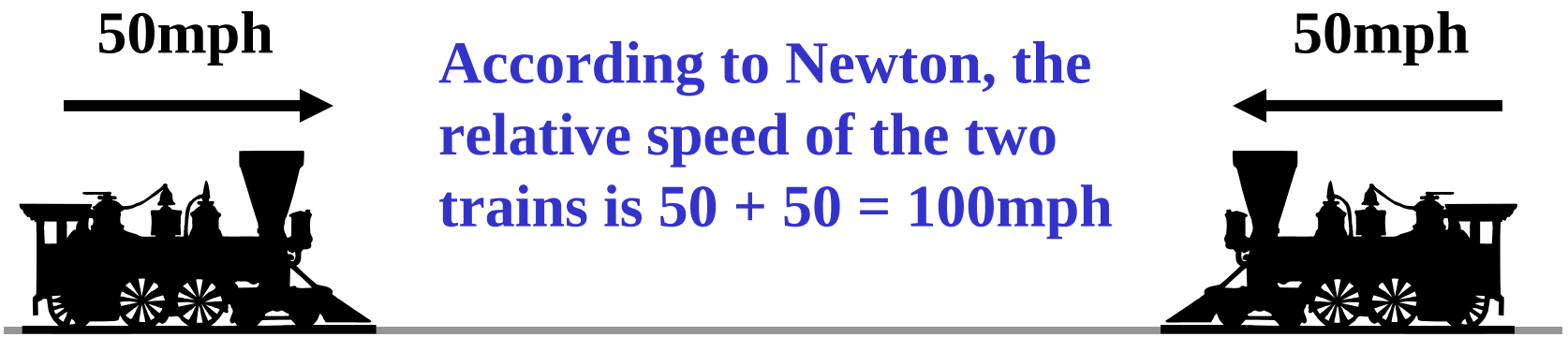


Light is a *wave* – *electromagnetic radiation*

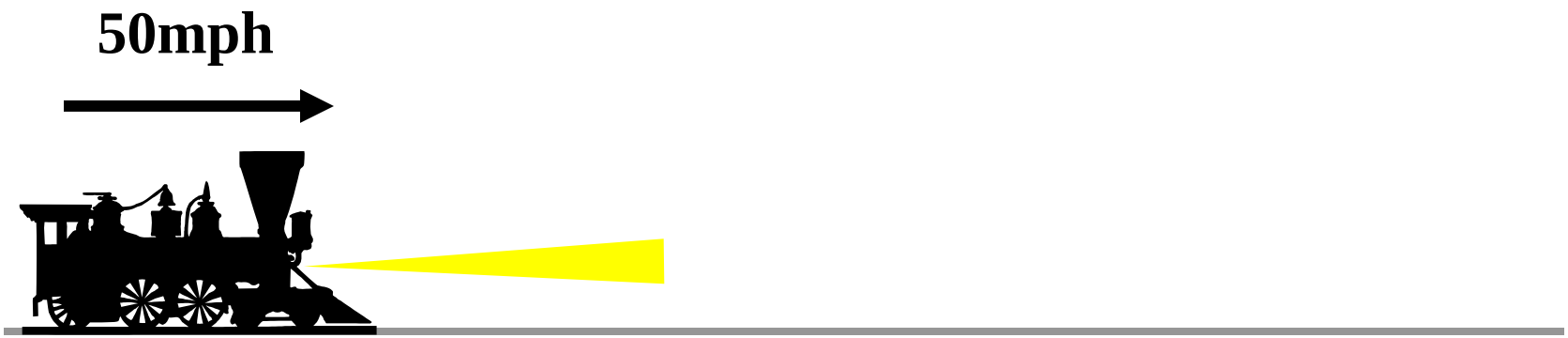


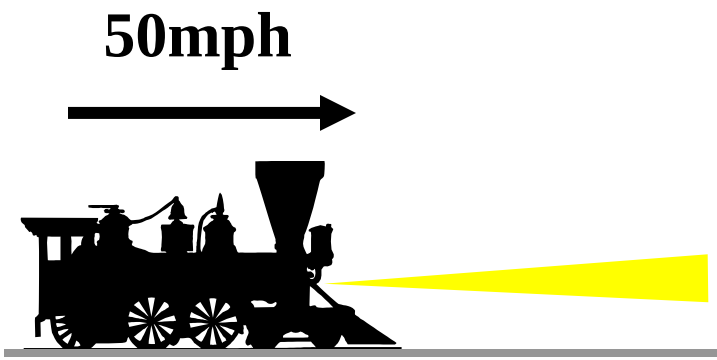
But what if I travelled *alongside* a light beam? Would it still wave?



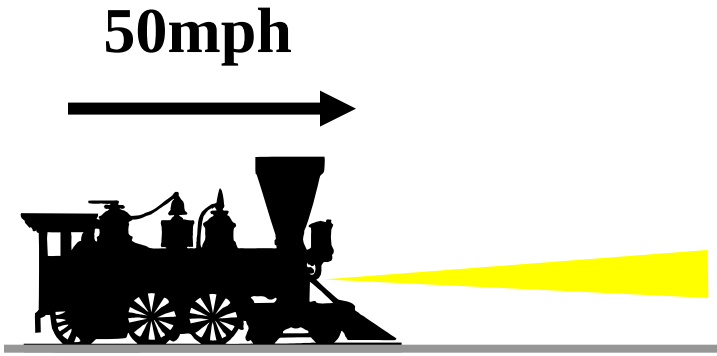


According to Newton, the relative speed of the two trains is 50 + 50 = 100mph


50mph



According to Einstein, the speed of light is *unchanged* by the motion of the train



According to Einstein, the speed of light is *unchanged* by the motion of the train

ON THE ELECTRODYNAMICS OF MOVING BODIES

By A. EINSTEIN

June 30, 1905

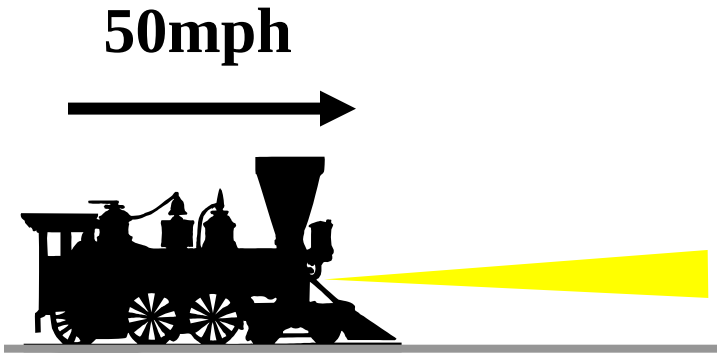
It is known that Maxwell's electrodynamics—as usually understood at the present time—when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise—assuming equality of relative motion in the two cases discussed—to electric currents of the same path and intensity as those produced by the electric forces in the former case.

Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.[1] We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies. The introduction of a "luminiferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor

[1]The preceding memoir by Lorentz was not at this time known to the author.

1

- Measurements of space and time are ***relative*** and depend on our motion



According to Einstein, the speed of light is *unchanged* by the motion of the train

ON THE ELECTRODYNAMICS OF MOVING BODIES

By A. EINSTEIN

June 30, 1905

It is known that Maxwell's electrodynamics—as usually understood at the present time—when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise—assuming equality of relative motion in the two cases discussed—to electric currents of the same path and intensity as those produced by the electric forces in the former case.

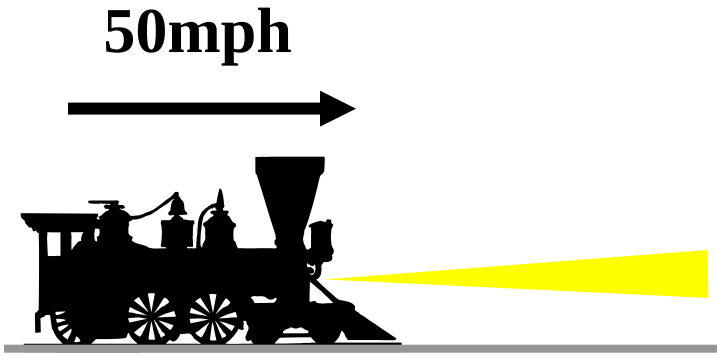
Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.[1] We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies. The introduction of a "luminiferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor

[1]The preceding memoir by Lorentz was not at this time known to the author.

1

- Measurements of space and time are ***relative*** and depend on our motion

"The only reason for time is so that everything doesn't happen at once."



According to Einstein, the speed of light is *unchanged* by the motion of the train

ON THE ELECTRODYNAMICS OF MOVING BODIES

By A. EINSTEIN

June 30, 1905

It is known that Maxwell's electrodynamics—as usually understood at the present time—when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighbourhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise—assuming equality of relative motion in the two cases discussed—to electric currents of the same path and intensity as those produced by the electric forces in the former case.

Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.[1] We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies. The introduction of a "luminiferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor

[1]The preceding memoir by Lorentz was not at this time known to the author.

1

- Measurements of space and time are *relative* and depend on our motion
- Unified *spacetime*
- Equivalence of **matter** and **energy**

$$E = mc^2$$