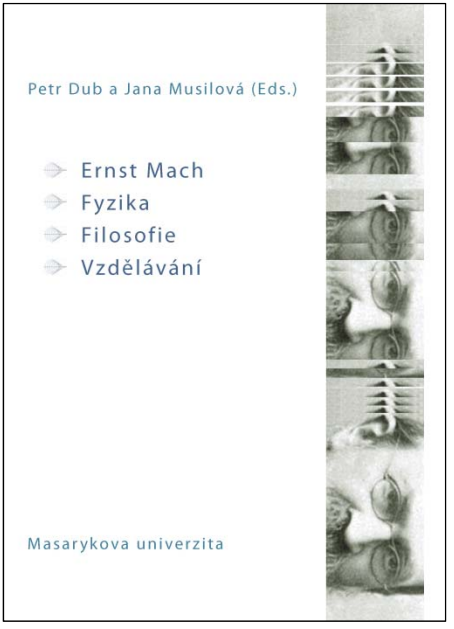
Klemens Rumpf
THE TIMES OF ERNST MACH AT THE UNIVERSITY OF GRAZ

Between 1864 and 1867 Ernst Mach held a professorship at the Karl-Franzens-University of Graz. He was the first one of numerous world-famous physicists acting at the Graz Institute of Physics in the course of time. His activity as a Professor of mathematics and later on of mathematical physics coincided with times of changes for the Physical Institute in Graz. Beside other work scopes Mach was particularly and intensively engaged with physiological phenomena and although the experimental possibilities were extremely constricted he performed experiments. Also after his leave Mach did not lose connection with the Institute and many years later he still kept in touch with colleagues from Graz. When he already held a chair for experimental physics in Prague he was strongly intended to return to the Graz Institute as successor of August Topler in 1876, but at last Mach gave precedence for this position to Ludwig Boltzmann. Of course, the excellent experimental possibilities at the newly erected building of Graz Institute of Physics were a great allure for an experimentalist. Today some apparatus and instruments concerned with Ernst Mach still exist at the Institute of Physics in Graz.



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Times of Ernst Mach at the University of Graz

Klemens Rumpf

Introduction

Ernst Mach is a famous scientist and well reported in literature. Therefore it is not necessary to say much about his biographical data which can be found elsewhere in a great number of articles or books dealing with Ernst Mach, e. g. [1, 2, 3, 4]. Nevertheless, the short scientific station of this great scientist at Karl-Franzens-University in Graz is one of the less described points of his life. To communicate the scientific situation of Ernst Mach in Graz, an overview about the times before, during and after Ernst Mach at the Graz University is given. Karl-Franzens-University of Graz, Austria's second oldest university – after the University of Vienna – can look back upon more than four hundred years of scientific tradition. From its foundation in 1585 up to the present day, natural science and especially physics has been a subject continuously present in the university's curricula. At the beginning scientific investigations basically were carried out in the fields of meteorology, astronomy, applied mathematics and optics due to their importance for building and understanding of instruments of observation. Research in the field of experimental physics of the same tenor as today was actuated from about 1830 on [5].

Reforms around the middle of the 19^{th} century together with some convenient developments at the Physical Institute in Graz led to the creation of a second professorship for mathematical physics at an early stage compared with other European universities. This is an important point in connection with Ernst Mach, because he was one of the holders of this chair.

Beside the publications also original instruments are of great advantage to report the scientific work of a single person or at an institute during a certain time period. Fortunately in Graz a great number of retained instruments give hints on main topics and actuality of research activities of a period especially around and during Ernst Mach's stay there.

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Special circumstances at Mach's arrival in Graz

When Ernst Mach came to Graz, he stayed at the so-called old University which was situated in the centre of the old town within the same building as at its foundation by the Jesuits. During the 18th century, a so-called mathematical tower was erected to enforce natural science at the Graz University (Figure 1). But problems with the construction of this building led to its demolishment in 1787. This astronomical observatory contained numerous apparatus and instruments mainly for astronomical and terrestrial observations. A detailed description of the mathematical tower and its instruments can be found elsewhere [5]. The equipment was not much extended later on, so that a great part of the experimental instrumentation during Mach's professorship in Graz was still from the mathematical tower.

A great part of the instrumentation came from the traditional workscope of land surveying during the times of the Jesuit University in Graz. Joseph Liesganig – a famous

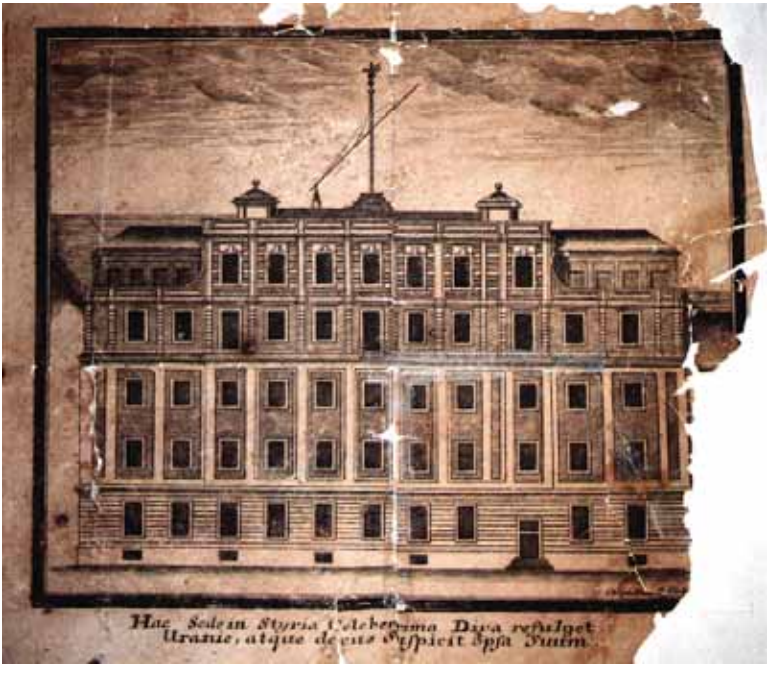


Figure 1: The astronomical observatory (mathematical tower) at the old University in Graz erected 1745 (Styrian archive) which contained a lot of instruments. Some of them were still available when Mach came to the University in 1864.

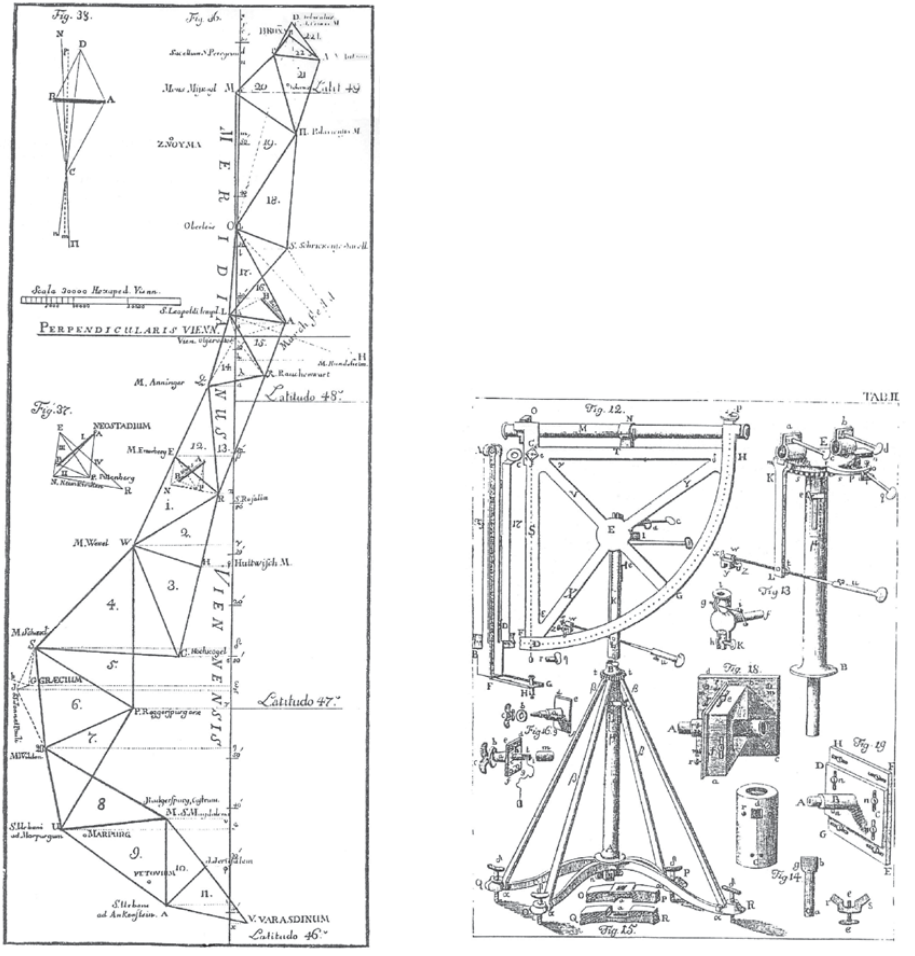


Figure 2: Left: Triangle chain measured from Brünn (Brno) over Vienna and Graz to Varasdin by the Graz Jesuit Josef Liesganig. The so-called „Wiener Neustätter baseline“ can also be seen. Right: Typical instruments used by Liesganig. Such types of instruments used for astronomical and terrestrial observation were traditionally the main part of the instrumentation at the Graz University and fractions of this equipment could also be found by Ernst Mach when he came to Graz.

geodesist from Graz University – performed meridian surveying using a triangle chain between Brünn (Brno) and Varasdin (Figure 2).

In 1832 a small physical laboratory was installed (Figure 3). This was also the only special laboratory at the University when Ernst Mach held a chair at Karl-Franzens-University. Of course some rooms could be used or adapted to perform experiments, but there was no laboratory environment.

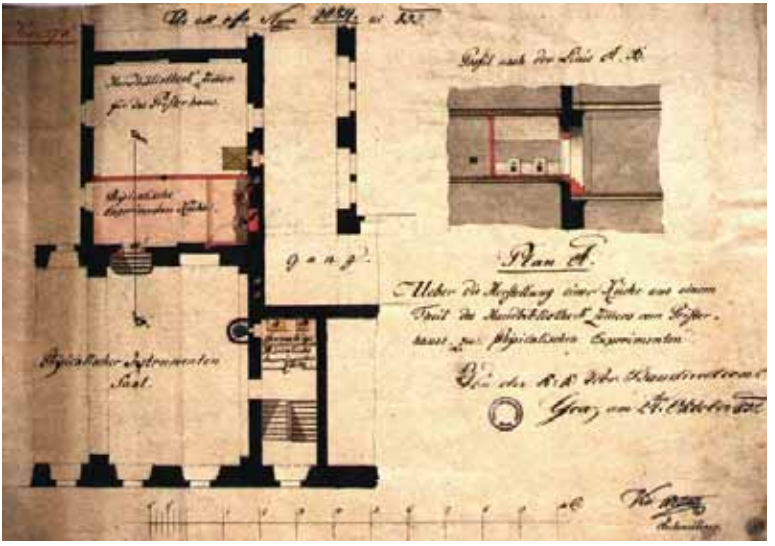


Figure 3: Ground plan of the small physical laboratory established in 1832 at the old University in Graz. When Ernst Mach arrived in Graz in 1864 this was still the only equipped room with the intention to be a physical laboratory.

Between 1830 and 1850 only a small number of additional instruments were acquired for instance to figure out magnetic and meteorological observations which can also be deduced from publications of the scientists in Graz during this period of time [5].

To sum up, there are the following traditional workscopes at the Faculty of Art in Graz:

- Astronomy,
- Meteorology,
- Optics (associated with astronomy),
- Land Surveying,
- Mathematics and Geometry.

The predecessors of Ernst Mach in Graz were Julius Wilhelm Gintl, Carl Hummel and Viktor v. Lang. Gintl was a Professor of Physics between 1836 and 1847. He erected a magnetic observatory and was engaged in meteorological observations. He became renowned for his investigations and publications on telegraphy. Hummel was a Professor of Physics from 1850 to 1867, the same year when Ernst Mach left Graz to occupy a chair at the University of Prague. Hummel was the first one who offered sophisticated lectures at the Graz Physical Institute and carried out the first inventory of the scientific equipment. Lang was the first Professor of Mathematical Physics in Graz. He came to the University in Graz at the same time as Ernst Mach and was a pioneer of solid state physics dealing with the physics of crystals. But Lang complained about the lack of laboratories and left Graz in 1866.

Generally it can be said that Ernst Mach found the following situation when he came to the old University (Figure 4) in Graz in 1864:

- one professor of experimental physics,
- one professor of mathematical physics,
- not enough research laboratories,
- poor experimental equipment.

Figure 4: The old University in Graz where Ernst Mach was a Professor between 1864 and 1867.

From the facts described so far, the possible workscopes in physics in the mid 1860s at the University of Graz can be deduced now:

- Physics of Crystals,
- Nature Studies (Meteorology, Magnetic Observations),
- Electrical Phenomena,
- Teaching and Demonstration,
- Optical Investigations.

Mach's scientific activities in Graz

The best way to investigate the scientific work of Ernst Mach during his stay in Graz is given by his publications during this time together with the instruments and apparatus which are well preserved at the Institute of Physics. In the frame of this work, the detailed analysis and description of Mach's papers and equipment will not be reported, but some results will be given to complete the overview about the times around Ernst Mach's professorship in Graz and his activities there.

Under the conditions explained above, Ernst Mach came to Graz holding his first professorship of mathematics with the permission to give lectures in medical physics from 1864 to 1866. It is interesting to note that Mach's first lecture which he gave in Graz as professor of mathematics was in the field of physics dealing with mechanics (Table 1). His second professorship in Graz was mathematical physics. Despite the constricted experimental possibilities, he performed experiments beside his teaching activities (Table 1). Mach's workscopes in Graz were:

- Teaching
- Theory of Sound
- Experimental Physiology.

During his three-year stay at Karl-Franzens-University of Graz, Ernst Mach published about 30 works (Table 2). This means an average publication rate of 10 publications per year. The two most important topics during Mach's time in Graz were acoustics (Figure 5) and physiology. Beside his publications some instruments, apparatus and detailed models about human ear as well as human eye keep records about these activities (Figure 6).

After Mach left Graz, acoustics was still a research topic at the University, continued by August Töpler and Ludwig Boltzmann. The first one was a Professor of experimental physics after Carl Hummel from 1868 on whereas the latter one was the successor of Ernst Mach at the chair of mathematical physics.

There is also an interesting parallel between Ernst Mach and Ludwig Boltzmann concerning their activities at the Physical Institute in Graz. Boltzmann was two times in

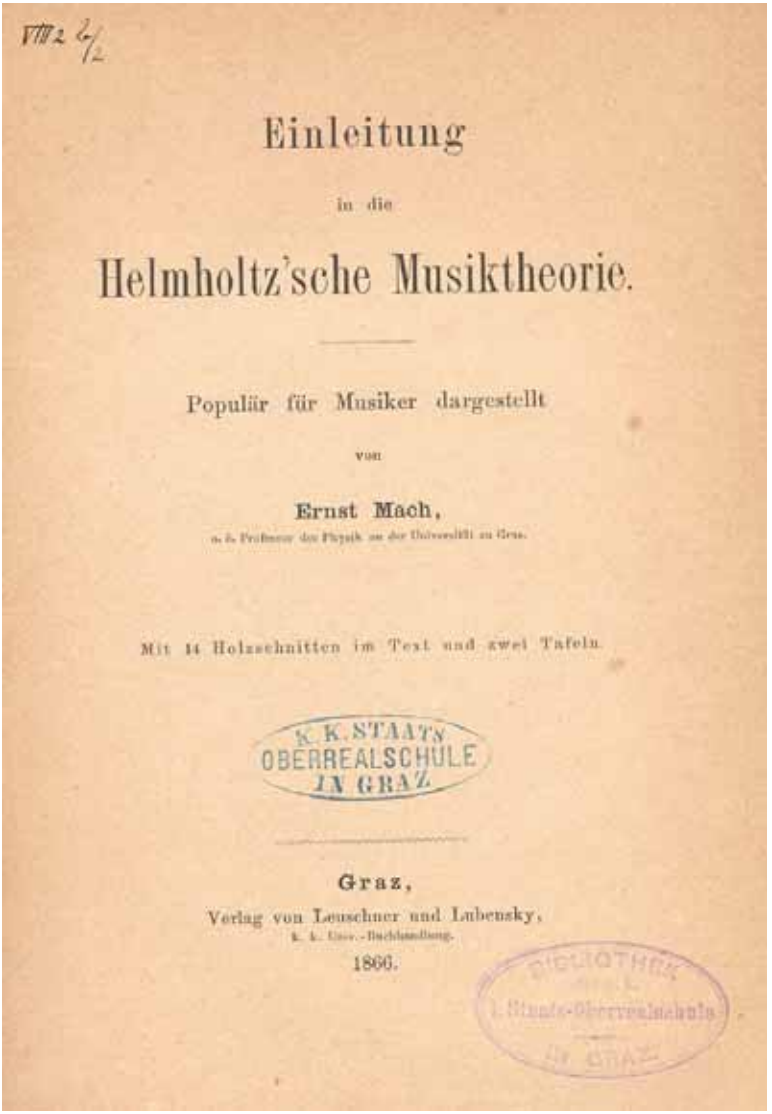
SS 1864	- Prinzipien der analytischen Mechanik
WS 1864/65	- Einleitung in die Analysis, Elemente der Differential- und Integralrechnung - Mathematische Übungen - Medizinische Physik; allg. Einleitung, Mechanik fester und flüssiger Körper, Akustik - Elemente der Psychophysik
SS 1865	- Analysis (Fortsetzung); Elemente der Lehre von den Differentialgleichungen - Übungen über neuere Geometrie (Fortsetzung)
WS 1865/66	- analytische Geometrie - mathematische Übungen - physikalische und physiologische Akustik
SS 1866	- Principien der analytischen Mechanik - physiologische Optik - Besprechung über ausgewählte Kapitel der Physik
WS 1866/67	- Grundlehren der Physik (Forschungsmethoden, Mechanik, Molecularphysik, Wärmelehre) - Besprechungen über ausgewählte Kapitel der Physik

Table 1: The lectures given by Ernst Mach at the University of Graz.

Graz and also had two different chairs there, the first time as a Professor of Mathematical Physics and the second time as a Professor of Experimental Physics. All physicists around the second half of the 19th century can be assigned clearly to theoreticians or experimentalists, except these two famous scientists. Of course their positions were clearly defined as a Professor of Experimental Physics or of Mathematical Physics or (as in the case of Mach) of Mathematics. But considering their professorships, as well as their scientific activities and publications, they both stand in between experimental physics and theoretical physics. Anyway, both of them were excellent experimentalists and they figured out important experimental investigations, but Boltzmann became more famous for his lasting theoretical works whereas Mach gained famousness mostly for his experimental results.

Years after Mach left for Prague

According to August Töpler's plans, today's building of the Physical Institute at Karl-Franzens-University was constructed and finished 1875. At these times it was a state of the art research centre with excellent instrumentation. The brilliant experimental conditions at the new building of the Physical Institute in Graz were a great temptation for Mach to come again to Graz after Töpler left for Dresden 1876. There are hints that Mach wanted to return to Graz [6] but the succession of Töpler in Graz was a decision of either Boltzmann or Mach. At that time Boltzmann stayed at the University of Vienna. It was a great controversy in Graz but at last Mach gave precedence for this position to Ludwig Boltzmann.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Einleitung

in die

Helmholtz'sche Musiktheorie.

Populär für Musiker dargestellt

von

Ernst Mach,

o. ö. Professor der Physik an der Universität zu Graz.

Mit 14 Holzschnitten im Text und zwei Tafeln.

Graz,

Verlag von Leuschner und Lubensky,

K. k. Univ.-Buchhandlung.

1866.

Figure 5: Title page of Ernst Mach's Introduction to the Theory of Sound after Helmholtz.

Zwei populäre Vorlesungen über musik. Akustik, 1865
Einleitung in d. Helmholtzsche Musiktheor., populär f. Musiker dargestellt, 1866
Zwei populäre Vorträge über Optik, 1867
Compendium der Physik für Mediciner, 1863
Über einige der physiolog. Akustik angehörige Erscheinungen, 1864
Vorläufige Bem. über d. Licht glühender Gase, 1864
Untersuchungen über den Zeitsinn des Ohres, Sitzungsber., 1865
Bemerkungen über die Accomodation des Ohres, Sitzungsber., 1865
Über die Wirkung der räumlichen Verteilung des Lichtreizes auf die Netzhaut (1. Abh.), 1865
Über Flüssigkeiten, welche suspendierte Körperchen enthalten, 1865
Über den Raumsinn des Ohres, Ann. d. Phys., 1865
Über einige der physiologischen Akustik angehörige Erscheinungen, 1864
Über die ansch. Darst. einiger Lehren der musikal. Akustik, 1865
Bem. zur Lehre vom räumlichen Sehen, 1865
Bemerkung über intermittirende Lichtreize, 1865
On the Visual Sensation Produced by Intermittent Excitations of the Retina, 1865
Über wissenschaftl. Anwendungen d. Photographie und Stereoskopie, 1866
Über den physiolog. Effect räumlich verteilter Lichtreize (2. Abh.), 1866
Über die physiolog. Wirkung räumlich verteilter Lichtreize (3. Abh.), 1866
Bem. über d. Effect intermittirender Tonreizungen, 1866
Über eine Vorrichtung zur mechanisch-graphischen Darstellung der Schwingungskurven, 1866
Über Wellen mit Flüss. gefüllter elast. Röhren, Unters. zur Naturlehre des Menschen und der Tiere, 1866
Untersuchungen über den Zeitsinn des Ohres, Unters. zur Naturlehre des Menschen und der Tiere, 1866, 1865
Bem. über die Accomodation des Ohres, Unters. zur Naturlehre des Menschen und der Tiere, 1866, 1865
Über Flüss. welche suspendirte Körperchen enthalten, Unters. z. Naturl. d. Menschen u. d. Tiere, 1866, 1865
Bem. über den Raumsinn des Ohres, Unters. zur Naturlehre des Menschen und der Tiere, 1866, 1865
Bem. über die Entw. der Raumvorstellungen, Zs. f. Phil. u. phil. Kritik, 49, 1866
Über die Longitudinalwellenmaschine, 1867
Über eine Longitudinalwellenmaschine, Repertorium für physik. Technik, math. und astron. 1867
On an arrangement for the graphical representation of curves of vibration by means of mechanism, 1867, 1866

Table 2: Publications of Ernst Mach during his scientific stay at the University of Graz.

Nevertheless Ernst Mach did not lose connection with the Institute and years later he still kept in touch with colleagues from Graz. So it is highly probable that he came in closer contact with Töpler's Schlierenmethod and the original apparatus of Töpler during one of his visits at the Graz Institute in the 1870s. In 1887 Mach wrote to Töpler (Figure 7):

Meine verschiedenen akustischen Versuche fangen an sich zu einem Gesamtbild zu schliessen und ich hoffe dieselben bald gerundeter darstellen zu können. Wenn auch die Schlierenmethode nur eine von vielen Mitteln ist, die ich anwenden musste, so ist sie doch ein sehr wichtiges und ich glaube, dass Sie sich über die Ergebnisse mit freuen werden.

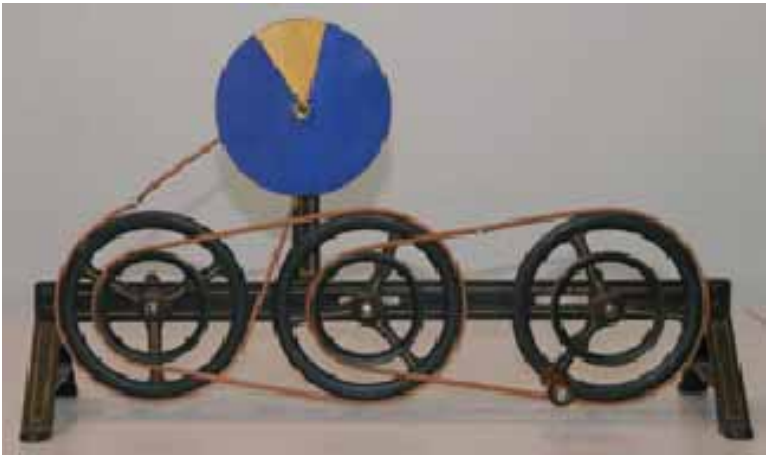

Figure 6: Apparatus to demonstrate the mixture of colours and the retardation of sensory cells within human eye. For the investigation of this physiological phenomenon Mach, also became renowned.

Conclusion

Ernst Mach's activities as a Professor of Mathematics and later on of Mathematical Physics coincided with times of changes at the Physical Institute in Graz. There he was intensively engaged with acoustics and physiological phenomena whereas he performed experiments, despite the fact that the experimental possibilities at the University were extremely constricted at these times. After he left, Mach did not lose connection and also visited the Graz Institute. It is probable that he came in contact with Töpler and his original apparatus of the Schlieren-method in Graz. When he already held a chair of Experimental Physics in Prague, he wanted to return to Graz to the newly erected building as a successor of August Töpler in 1876.

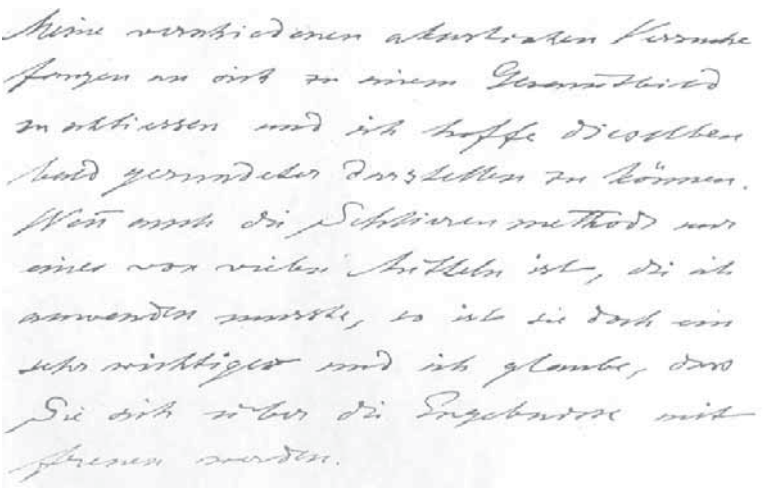

Figure 7: Part of a letter written in 1887 by Ernst Mach to August Töpler in Dresden.

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