Marian Smoluchowski – the forgotten genius of physics

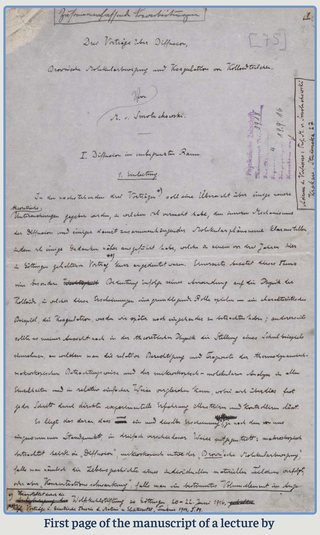
Marian Smoluchowski was born on May 28, 1872, in Vorderbrühl (then Austro-Hungary) and died on September 5, 1917, in Cracow, at the age of 45. His scientific legacy includes over 110 publications in English, French, German, and Polish.

Brownian motion – a type of erratic and jittery movement observed in small, still visible particles suspended in liquids.

Source: M. Smoluchowski, *Outline of the Kinetic Theory of Brownian Motion and Turbid Solutions. Dissertations of the Mathematical-Natural Science Department of the Academy of Arts and Sciences in Cracow*, 1906

Smoluchowski was one of the most outstanding Polish physicists of the late 19th and early 20th centuries and a pioneer in modern physics. In 1904, he confirmed the possibility of observing fluctuations in physical quantities caused by the granular structure of matter. Based on this, he explained the phenomenon of ***Brownian motion*** (simultaneously with Albert Einstein), which contributed to confirming the hypothesis of the atomic structure of matter.

Smoluchowski co-developed the ***kinetic theory of matter***, was a forerunner in applying probabilistic theory and stochastic processes to describe physical phenomena, and was a pioneer in using probability calculus in studying physical phenomena. His achievements laid the foundation for statistical physics. Albert Einstein, among others, utilized Smoluchowski's research findings when formulating the theory of chaotic particle movement.



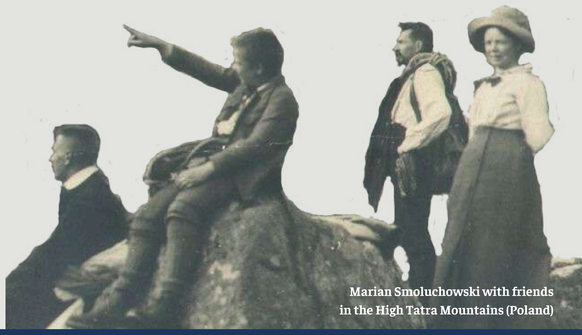
First page of the manuscript of a lecture by M. Smoluchowski in Göttingen, 1916

Smoluchowski equation – a term interchangeably used for several equations describing physical phenomena through stochastic processes. Currently understood as describing the Brownian motion of a single particle placed in an external force field.

Kinetic theory of matter – a theory explaining the macroscopic properties of matter by linking them to the movement and interactions of its microscopic components.

Source: PWN Encyclopedia

According to Prof. A. K. Wróblewski, an experimental physicist, historian of physics, expert in particle and high-energy physics, and a full member of the Polish Academy of Sciences, Smoluchowski is one of four Poles who made discoveries worthy of the Nobel Prize.



Marian Smoluchowski with friends in the High Tatra Mountains (Poland)

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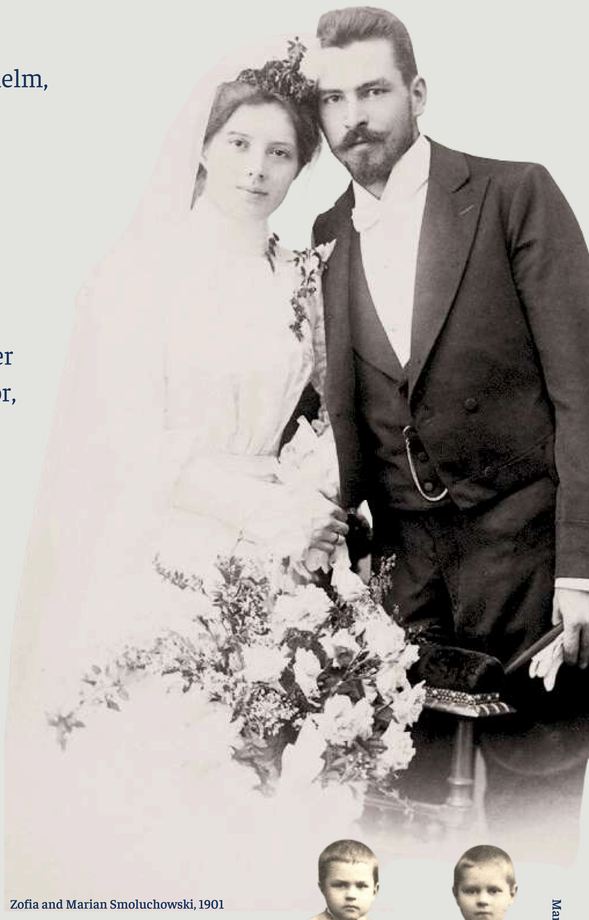
The Smoluchowski Family

Marian Smoluchowski was the son of Wilhelm, who had a law doctorate and served as the head of the Polish Affairs Department in Emperor Franz Joseph's chancellery, and Teofilia Szczepanowska.

His mother, Teofilia, was the granddaughter of Antoni Popliński – a philologist, educator, librarian, editor, printing house owner, and former director of the Raczyński Library in Poznań.
Teofilia had siblings, Stanisław Szczepanowski (an economist, engineer, pioneer of the oil industry, member of the Austrian parliament, and the Galician Regional Sejm), Benigna Szczepanowska-Wolska, who significantly influenced Marian Smoluchowski's interest in art, and Maria Szczepanowska-Jarecka.



Zofia and Marian Smoluchowski, 1901

Marian had an older brother, ***Tadeusz***, who was a doctor of chemistry, a mountaineer, climber, sports activist, and one of the pioneers of skiing in Poland.
Marian and Tadeusz Smoluchowski were among the leading mountaineers of the Eastern Alps.

Marian and Tadeusz Smoluchowski

Children of Zofia and Marian Smoluchowski, Aldona and Roman

The Smoluchowski brothers in the Tatra Mountains (Poland)

On June 1, 1901, Marian Smoluchowski married ***Zofia Baraniecka***, the daughter of a mathematics professor at Jagiellonian University. They had two children – ***Aldona*** (born 1902) and ***Roman*** (born 1910).

The scientist's marriage was the happiest time of his life, evident in his scientific work, during which he formulated and developed his most important theories.

Marian received immense support from his wife in his scientific work. Zofia assisted him in various ways, including proofreading his works.

Admit that in these seven years we have drunk so much true happiness, as is very rarely allotted to anyone, even in a much longer life.

– Marian Smoluchowski in a letter to his wife, 1908

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Education and early work

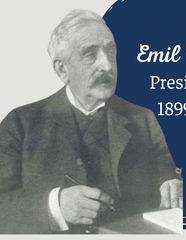
In 1880, Marian Smoluchowski began his education at the prestigious private school Collegium Theresianum in Vienna, Austria, where his teacher **Alois Höfler** instilled in him a love for physics. After graduating in 1890, he commenced his studies in physics at the University of Vienna, earning his doctorate in physical sciences with highest distinction on May 15, 1895.

From November 1896 to August 1897, Smoluchowski undertook a scientific journey, studying under eminent scientists.
In Paris, under **Gabriel Lippmann**, he delved into the Kirchhoff-Clausius laws.
In Glasgow, at **Lord Kelvin**'s laboratory, he participated in research on the electrical conductivity of ionized gases induced by Roentgen rays.
In Berlin, at **Emil Warburg**'s laboratory, he conducted studies on polarization, among other topics.
Each laboratory stint resulted in the publication of scientific articles.

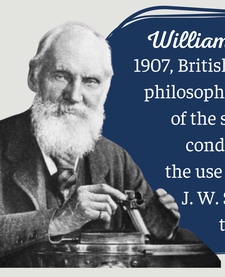
Hasenöhrl is my best student, and Smoluchowski is the very best of the best.

– Alois Höfler

Gabriel Lippmann – 1845-1921, French physicist and member of the French Academy of Sciences. He first described electrocapillary phenomena (1873) and won the Nobel Prize in Physics (1908) for developing a color reproduction method based on light interference.



Emil Warburg – 1846-1931, German physicist. President of the German Physical Society from 1899 to 1905. Discovered the magnetocaloric effect in iron (1881).



William Thomson (lord Kelvin) – 1824-1907, British physicist, mathematician, and natural philosopher. Formulated his own interpretation of the second law of thermodynamics and conducted research on electricity and the use of submarine cables. Together with J. W. Strutt (Lord Rayleigh), he isolated the then-unknown argon (Ar).

In August 1897, already a recognized scholar, Smoluchowski returned to Vienna, where in 1898 he obtained his habilitation degree and the right to teach physics at the University of Vienna. In 1899, at the invitation of the authorities of Lviv University, Smoluchowski moved to Lviv, where he assumed the position of professor and subsequently took charge of the Chair of Theoretical Physics, becoming ***the youngest professor in the Austro-Hungarian monarchy***.

Kirchhoff-Clausius laws – the laws describe the relationship between thermal radiation and the medium in which the radiating body is immersed

Source: Jagiellonian Digital Library

Faculty of Physics, University of Vienna

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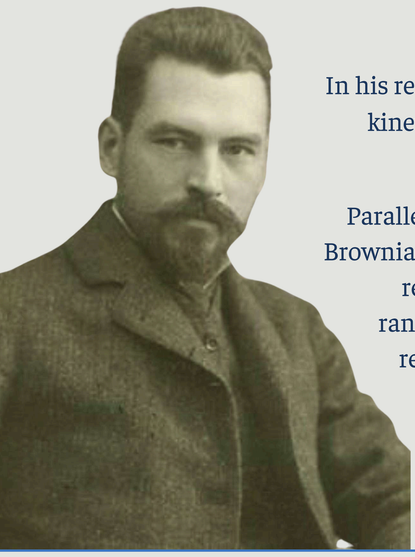
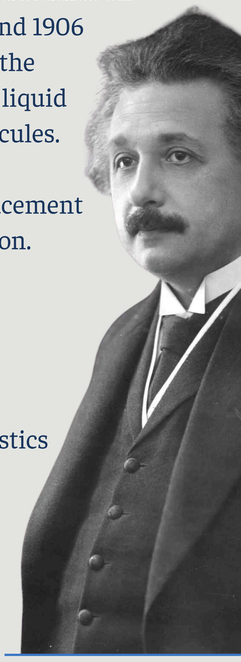
Parallel research of Smoluchowski and Einstein



In his research, Marian Smoluchowski primarily focused on the kinetic theory of gases and the atomistic view of matter.

Parallel to Albert Einstein, Smoluchowski conducted studies on Brownian motion. In their works, published in 1905 and 1906 respectively, the scientists demonstrated that the random movements of suspension particles in a liquid result from their bombardment by liquid molecules. The physical quantity to be determined experimentally is the mean squared displacement of a given particle in a specific direction.



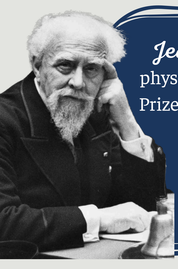
Smoluchowski and Einstein proved, using different methods, that the physical quantity is related to Avogadro's number and the temperature of the liquid. Today, the relationship describing the quantitative characteristics of Brownian motion is known as the Einstein-Smoluchowski equation.

Fate prematurely cut short his inspired activity as a researcher and teacher... let us hold high his example and work.

– Albert Einstein, after the death of Marian Smoluchowski

Smoluchowski's research garnered interest from scientists worldwide.

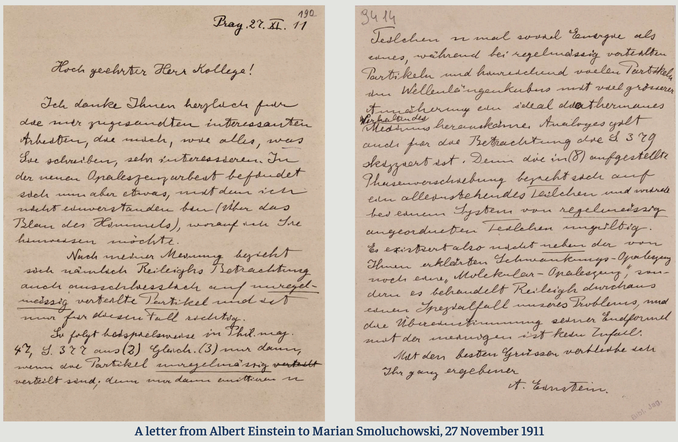
French physicist ***J. B. Perrin*** subsequently conducted studies on the random motion of suspension particles in a liquid, quantitatively verifying the ***Einstein-Smoluchowski equation***.
Experimental research on the non-uniform distribution of colloidal solution particles was also carried out by R. Zsigmondy and T. Svedberg, who confirmed the formulas introduced by Smoluchowski.



Jean Baptiste Perrin – 1870-1942, French physicist, chemist, politician, winner of the Nobel Prize in Physics for his work on the discontinuous structure of matter and his discovery of equilibrium in deposition processes. President of the French Academy of Sciences in 1936.

Einstein-Smoluchowski equation – a relation between the diffusion coefficient D and the distance λ that a particle can jump when diffusing in a time τ. The equation, which is **$D = \lambda^2/2\tau$**, gives a connection between the microscopic details of particle diffusion and the macroscopic quantities associated with the diffusion, such as the viscosity

Source: Oxford University Press



A letter from Albert Einstein to Marian Smoluchowski, 27 November 1911

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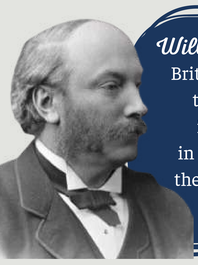
Why is the sky blue?

Although the question ***Why is the sky blue?*** was answered in 1871 by John William Strutt (Lord Rayleigh), Marian Smoluchowski had an influence on solving this issue.



William Strutt (Lord Rayleigh) – 1842-1919, British physicist, pioneer in acoustics and optics, the basis of the theory of wave propagation in fluids. Winner of the Nobel Prize (1904) in Physics for his research into the densities of the major gases, resulting in the discovery, with W. Thomson, of argon (Ar).

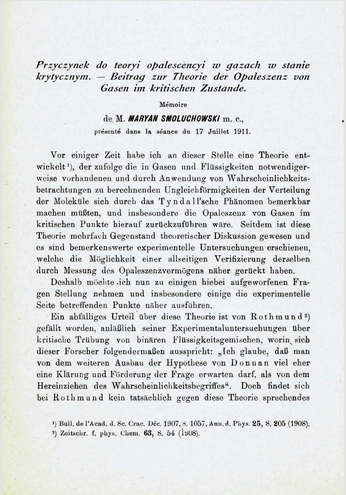
In 1904, Smoluchowski confirmed the possibility of observing ***fluctuations*** of physical quantities caused by the granular structure of matter, which contributed to the scientific and academic community's acceptance of the existence of atoms.

Lord Rayleigh explained the phenomenon of the blue sky as an effect of light scattering on particles suspendedin the air, which is inversely proportional to the fourth power of the wavelength of light. This means that blue light is scattered more intensely than red light, resulting in the blue color of the sky.

Fluctuation – random deviations of a certain quantity from its average value.

Source: Integrated Educational Platform of the Ministry of National Education of Poland

Smoluchowski initially conducted research on the phenomenon of ***opalescence*** under critical conditions, through which he presented an original theory. According to Smoluchowski's theory, when a beam of light passes through a heterogeneous gas (due to the motion of molecules), it is visible due to the lateral scattering of light. In the case of very small particles in a suspension medium, the scattered light appears blue.



Przyczynek do teoryi opalescencyi w gazach w stanie krytycznym. — Beitrag zur Theorie der Opaleszenz von Gasen im kritischen Zustande.

Mémoire

de M. **MARYAN SMOLUCHOWSKI** m. c.,

présenté dans la séance du 17 Juillet 1911.

Vor einiger Zeit habe ich an dieser Stelle eine Theorie entwickelt [1]), der zufolge die in Gasen und Flüssigkeiten notwendigerweise vorhandenen und durch Anwendung von Wahrscheinlichkeitsbetrachtungen zu berechnenden Ungleichförmigkeiten der Verteilung der Molekule sich durch das Tyndal'sche Phänomen bemerkbar machen müßten, und insbesondere die Opalescenz von Gasen im kritischen Punkte hierauf zurückzuführen wäre. Seitdem ist diese Theorie mehrfach Gegenstand theoretischer Diskussion gewesen und es sind bemerkenswerte experimentelle Untersuchungen erschienen, welche die Möglichkeit einer allseitigen Verifizierung derselben durch Messung des Opaleszenzvermögens näher gerückt haben.

Deshalb möchte ich nun zu einigen hiebei aufgeworfenen Fragen Stellung nehmen und insbesondere einige die experimentelle Seite betreffenden Punkte näher ausführen.

Ein abfälliges Urteil über diese Theorie ist von Rothmund [2]) gefällt worden, anläßlich seiner Experimentaluntersuchungen über kritische Trübung von binären Flüssigkeitsgemischen, worin sich dieser Forscher folgendermaßen ausspricht: „Ich glaube, daß man von dem weiteren Ausbau der Hypothese von Donan viel eher eine Klärung und Förderung der Frage erwarten darf, als von dem Hereinziehen des Wahrscheinlichkeitsbegriffes". Doch findet sich bei Rothmund kein tatsächlich gegen diese Theorie sprechendes

[1]) Bull. de l'Acad. d. Sc. Cracovie Déc. 1907, s. 1057, Ann. d. Phys. **25**, S. 205 (1908).
[2]) Zeitschr. f. phys. Chem. **63**, S. 54 (1908).

Title page of a publication by Marian Smoluchowski presenting the theory of critical opalescence, 1911

Opalescence – the scattering of light occurring in turbid media, caused by the reflection of light rays from the particles of the dispersed phase, and in liquids where there are no suspensions but density fluctuations occur

Source: PWN Encyclopedia

Marian Smoluchowski's non-scientific passions included literature, art, music, painting. During mountain trips and holidays, he created numerous watercolour paintings.

The board contains a fragment of one of the watercolours painted by M. Smoluchowski during his stay on Hel (Poland) in 1924.

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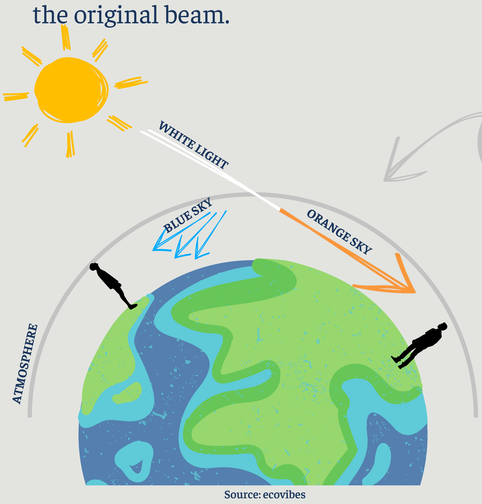
Why is the sky blue? – experimental research

Smoluchowski then explained the ***theory of the blue color of the sky*** indirectly from the density fluctuations of gas molecules and directly from opalescence near the critical state. During the analysis of opalescence under ordinary conditions, he demonstrated that light scattering due to density fluctuations leads to a mathematical description consistent with Rayleigh's explanation.

Smoluchowski created an apparatus that helped him provide a detailed answer to the question ***Why is the sky blue?***. It consisted of a metal tube divided into several chambers, coated inside with a mixture of soot and glycerin. Lenses and diaphragms were arranged to focus the light from an arc lamp inside the tube. Through a window in the wall of the tube, Smoluchowski could observe the light bent at a right angle to the original beam.



Source: ecovibes

Rayleigh scattering – process, in which shorter wavelengths of sunlight (blue) are scattered more strongly than others by the Earth's atmosphere. As the Sun moves across the sky, the angle of incidence changes, affecting the colours of the sky: from intense blues at midday to warm shades of red during sunrise and sunset.

Source: ecovibes

Additionally, he developed a tool for gas purification and a cylindrical capacitor to remove ions. Unfiltered air, due to scattering by floating and glowing dust particles, emitted relatively intense lateral light, whereas purified air emitted polarized light with a weak bluish opalescence.
These were Smoluchowski's last experimental studies.

However, each of us has observed it [the phenomenon of opalescence] countless times when admiring the blue of the sky or the glow of the rising sun. If the air were a completely transparent and homogeneous medium, the sky during the day would have to be black, and it owes its brightness and blue color only to the fact that it is to some extent a turbid medium... The blue of the sky, for anyone who can read the book of nature, is an obvious proof of the correctness of atomistics, as it proves that the air has a granular structure.

– Marian Smoluchowski at a session of the Polish Academy of Arts and Sciences, 1911

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Devoted alpinist and mountaineer

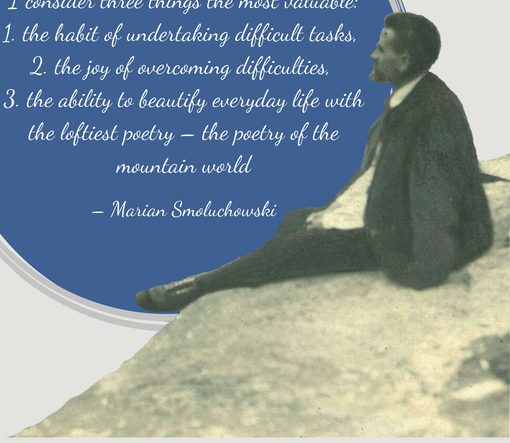
Marian Smoluchowski, along with his brother Tadeusz, was among the ***leading European alpinists*** and was frequently awarded for his achievements.

Over many years of climbing, mainly during the winter months from November to March, the brothers conquered routes of varying difficulty regardless of the season. Their joint climbs often resulted in the ***discovery of new paths and routes***.

In just three years (***1891-1893***) they discovered a total of ***24 new climbing routes*** and made ***16 first ascents of then-unclimbed mountain peaks***. By 1891-1894, Marian and Tadeusz Smoluchowski were among ***the world's leading alpinists***. The brothers had a particular fondness for climbing in the Dolomites (Italy) of the Eastern Alps.

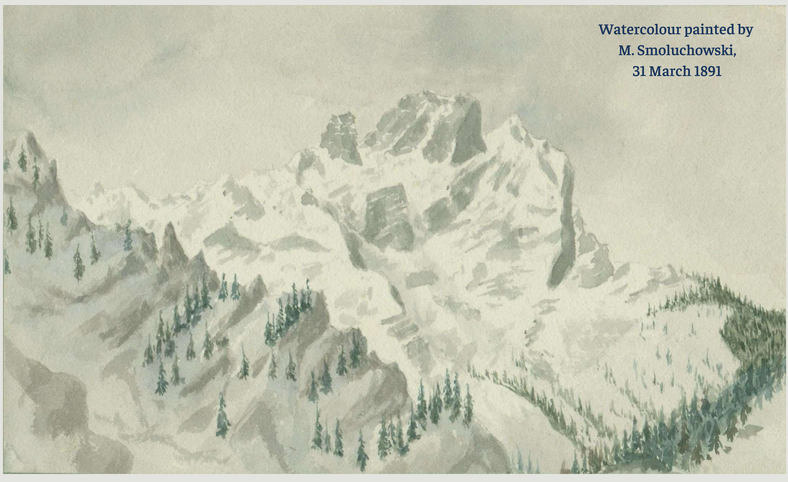
Of what the mountains gave me, I consider three things the most valuable: 1. the habit of undertaking difficult tasks, 2. the joy of overcoming difficulties, 3. the ability to beautify everyday life with the loftiest poetry – the poetry of the mountain world

– Marian Smoluchowski



From 1909, Marian Smoluchowski frequented the Tatra Mountains (Poland). Initially, he embarked exclusively on ski trips, mainly in the Western Tatras, and later also on climbing expeditions.

Marian Smoluchowski held numerous positions related to his passion for the mountains, including president and board member of the M. Copernicus Society of Naturalists and chairman of the Tourist Section of the Tatra Society.



Watercolour painted by M. Smoluchowski, 31 March 1891

Examples of mountain peaks climbed by Marian Smoluchowski between 1891 and 1893

Date of climbing	Peak and its height	Mountain chain
July 27, 1892	Laaser Spitze, 3303 m	Rhaetian Alps Italy
July 27, 1892	Schluderspitze, 3230 m	Rhaetian Alps Italy
August 18, 1892	Piz Ciavazes, 2828 m	Dolomites Italy
August 29, 1892	Nördliche Gabelspitze, 3076 m	High Tauern Austria
September 5, 1893	Fünffingerspitze, 2996 m	Dolomites Italy

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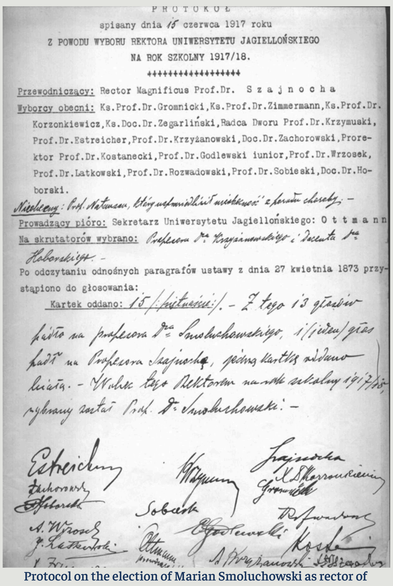
Authority in the world of science

In the 1916/1917 academic year, Smoluchowski was ***Dean of the Faculty of Philosophy at Jagiellonian University*** and was ***a member of the organizing committee of the Mining Academy*** (Cracow).

When he was offered the position of Professor of Theoretical Physics at the re-establishing University of Warsaw, with the prospect of promotion to the head of the newly created institute, the Jagiellonian University Senate, wishing to retain him, proposed he take on the role of Rector for the 1917/1918 academic year. Smoluchowski accepted the Jagiellonian University's offer.



PROTOKÓŁ
spisany dnia 15 czerwca 1917 roku
Z POWODU WYBORU REKTORA UNIWERSYTETU JAGIELLOŃSKIEGO
NA ROK SZKOLNY 1917/18.

Przewodniczący: Rector Magnificus Prof.Dr. S z a j n o c h a
Wyborcy obecni: Ks.Prof.Dr.Gromnicki,Ks.Prof.Dr.Zimmermann,Ks.Prof.Dr. Korzonkiewicz,Ks.Doc.Dr.Zegarliński,Radca Dworu Prof.Dr.Krzymuski, Prof.Dr.Estreicher,Prof.Dr.Krzyżanowski,Doc.Dr.Zachorowski,Prorektor Prof.Dr.Kostanecki,Prof.Dr.Godlewski iunior,Prof.Dr.Wrzosek, Prof.Dr.Latkowski,Prof.Dr.Rozwadowski,Prof.Dr.Sobieski,Doc.Dr.Hoboraki.
Nieobecny: [illegible]
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Po odczytaniu odnośnych paragrafów ustawy z dnia 27 kwietnia 1873 przystąpiono do głosowania:
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Protocol on the election of Marian Smoluchowski as rector of the Jagiellonian University for the academic year 1917/1918

Smoluchowski ***died on September 5, 1917***, due to dysentery, a month before assuming the position of Rector at Jagiellonian University.

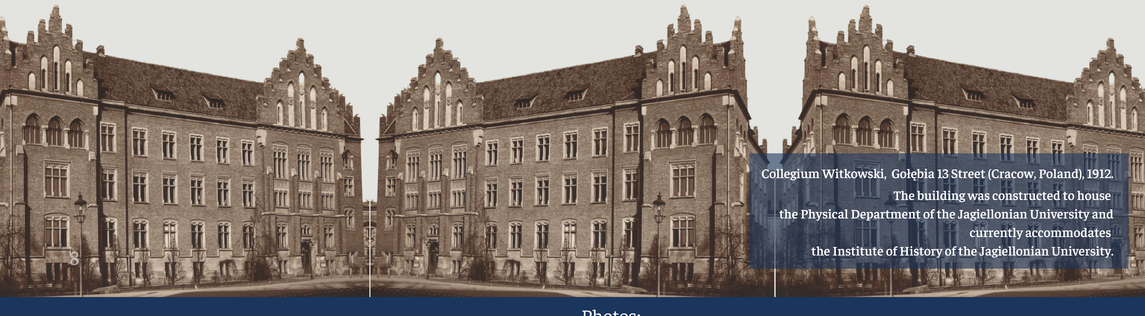
In the 1920s, ***three Nobel Prizes*** were awarded directly related to Smoluchowski's research. The recipients were ***R. A. Zsigmondy*** (1926, Chemistry), ***T. Svedberg*** (1926, Chemistry), and ***J. B. Perrin*** (1927, Physics). It is likely that had Smoluchowski not died prematurely, he too might have been nominated for or received a Nobel Prize for his scientific achievements.

We can never say anything certain about external reality

– Marian Smoluchowski

Selected Honors:

- ***1901***: Smoluchowski received an honorary degree from the Faculty of Law at the University of Glasgow
- ***1908***: Ludwig Haitinger Prize for work in the field of the theory of Brownian motion, density fluctuations, and opalescence (Vienna Academy of Sciences)
- ***1936***: Commander's Cross of the Order of Polonia Restituta (posthumously)
- since ***1965***: the Polish Physical Society awards the Marian Smoluchowski Medal
- ***1970***: by the decision of the International Astronomical Union, a crater on the Moon was named "Smoluchowski"
- since ***1986***: the Gesellschaft für Aerosolforschung awards the Smoluchowski Award
- since ***1988***: the Polish Physical Society, together with the Deutsche Physikalische Gesellschaft, jointly awards the Marian Smoluchowski–Emil Warburg Awar



Collegium Witkowski, Gołębia 13 Street (Cracow, Poland), 1912. The building was constructed to house the Physical Department of the Jagiellonian University and currently accommodates the Institute of History of the Jagiellonian University.

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- Larousse, www.larousse.fr/
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- Wikipedia, en.wikipedia.org/wiki/Main_Page

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