# HE MEASURED LIGHT PRESSURE

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## ABSTRACT

Pyotr Lebedev has entered the history of science as an experimenter-physicist who first investigated millimetric electromagnetic waves, measured pressure of light on solids and rarefied gases, and as an organizer of collective research and large research laboratories, that can be deemed as a model for modern scientific institutions. For the history of MIIT University he is significant due to the fact that he was the first head of the department of physics, and it happened in a year of establishment of MIIT University, exactly exactly 120 years ago.

*Keywords: history of science, Pyotr Lebedev, light pressure, millimetric electromagnetic waves, scientific school.*

**Background.** *A physicist, Corresponding Member of the Russian Academy of Sciences, professor, founder of the first Russian scientific school of physicists Pyotr Lebedev was born on March, 8 (February, 24 old style) 1866 in Moscow in a family of merchants.*

*At first, he studied reading and writing at home. Then a ten-year boy was sent to the commercial arm of the German Peter and Paul Evangelical church school. After talking with the officer electrician A. N. Beknev he, fascinated by physics and electricity, went to a technical school. Here, in comparison with the commercial department the students received a larger amount of knowledge in mathematics, physics and biology. The curriculum included also the study of chemistry, drawing, German and French. In addition, the young man was admitted to a physical office to help a teacher keep in order equipment and prepare it for demonstrations in class. After graduating from secondary school he was able to work a few months at a factory as a technician.*

**Objective.** *The objective of the author is to investigate life and work of a prominent Russian scientist Pyotr Lebedev.*

**Methods.** *The author uses general scientific methods, historical-retrospective analysis.*

**Results.**

**Why comets twist a tail**

*Pyotr Lebedev had a desire to get a university diploma, but Moscow University accepted only people with public school certificate and knowledge of Latin and Greek, so Lebedev in 1884 entered Imperial Moscow Technical School (now Moscow State Technical University named after N. E. Bauman). There he had to acquire, among other things, plumbing, carpentry and turning skills. He taught his staff afterwards to use those crafts for manufacture of various physical devices.*

*In 1887, not graduating from college, on the advice of professor V. S. Scheglyaev a student went to Germany to the University of Strasbourg (now in France), to study physics at the laboratory of German experimenter A. Kundt, who soon became the head of the department of the University of Berlin. Lebedev followed him as he moved to Berlin and besides classes of Kundt listened to theoretical lectures of H. Helmholtz. Since the metropolitan university again required knowledge of Latin and Greek, then in 1890 he returned to Strasbourg. He worked at the laboratory of F. Kolraush, where in 1891 he introduced the experimental thesis «On measurement of dielectric constant vapors and the theory of dielectrics Clausius-Mossotti», passed exams and received an academic degree and a status of Doctor of Philosophy of University of Strasbourg.*

*Along with writing his doctoral dissertation in 1890, Lebedev became interested in the theory of*

*comet tails. At the beginning of a new era the Roman philosopher L. A. Seneca knew that comet tails deviate from the sun. German astronomer J. Kepler, the English physicist I. Newton and other scientists had suggested that the reason for this deviation can be mechanical light pressure. At the end of XVIII century physicist and astronomer A. Haratsaker pointed out that, according to travelers, the sun's rays with their pressure slow down the Danube. English physicist J. C. Maxwell on the basis of his electromagnetic theory of light calculated theoretical value of light pressure equal when it falls on the absorbent surface to quotient of division of light energy coming in second by speed of light. For sunlight striking upon the earth's surface, this pressure is approximately 5 $10^{-8}$ g / cm$^2$.*

*The problem of light pressure, stretching back three centuries and remaining unresolved, Lebedev was engaged seriously and permanently. In 1891 his article was published «On the repulsive force of radiating bodies», in which, based on known data about sun radiation, he first physically reasonably proved that in case of very small particles repulsive force of light pressure must exceed gravitational attraction, so the deviation of comet tails indeed, may be explained by the pressure of light.*

*Then Lebedev returned to Moscow and became a part-time laboratory assistant, and in 1892 got a job as an assistant at the physics laboratory at Moscow University led by professor A. G. Stoletov. In 1895, he created an installation for generation and reception of electromagnetic radiation with a wavelength of 4 and 6 mm (in the experiments of the German physicist H. Hertz, they were 0,5 m), by which he first set their reflection, refraction, polarization, interference, double refringence and other phenomena inherent in*

*light waves. His instruments were miniature. Electromagnetic wave generator consisted of two platinum cylinders 1,3 mm long and 0,5 mm in diameter, mirrors had a height of 20 mm, ebonite prism for study of electromagnetic waves refraction was 18 mm high, 12 mm wide, and weighed about 2 g (prism Hertz for the same purposes, having a weight of 600 kg).*

**Cherished a place for his brother-in-law**

*In 1896, Lebedev was invited to head the department of physics at the then opening Imperial Moscow Engineering College (now Moscow State University of Railway Engineering). His work as a founder and first head of the department of physics of MIIT in encyclopedias and other publications (see the list of references to the article) is not mentioned, but at the time it coincided with the final stage of preparation of the master's thesis «Experimental investigation of ponderomotive action of waves on resonators». Since the experimental part of the work was of very high quality, exemplified rigor and wit, combined with bold scientific decisions, then Pyotr Lebedev at Moscow University was awarded, without prior defense of the master's thesis, a degree of Doctor of Physical and Mathematical Sciences.*

*The first part of the thesis was devoted to experimental study of interaction of electromagnetic resonators, the second to hydrodynamic resonators (oscillating balls in the liquid), the third to acoustic. In the experiment in accordance with the theory he discovered the identity of wave pressure on models in all three cases. The main conclusion of the study of ponderomotive action of wave-like motion, accompanied by the message of impulse or angular momentum, was a fundamental possibility to spread found general laws in the area of light and heat emission of individual molecules of bodies and to calculate the resulting intermolecular forces and their magnitude.*

*In 1897, Lebedev, gave a place at the department of Imperial College to his childhood friend and brother-in-law (wife's brother) A. A. Eichenwald, moved to Moscow University where he became a professor of physics in 1900, and later in the course of experiments found, and then measured the pressure of light on solid, confirming the theoretical prediction of Maxwell.*

*In his experiment light from volt electric arc light fell on the wing, suspended on a thin filament in a glass bulb from which the air was pumped. Vacuum was achieved by heating mercury drop in the vessel. Mercury vapors displaced air, evacuated by a pump. After lowering the temperature the pressure of remaining mercury vapors decreased. Thus the highest degree of vacuum was achieved. This technique applied subsequently in the pumps, was named after the American physicist I. Langmuir.*

*By twisting thread the pressure of light was determined. These were the torsion balance of the highest accuracy for those years. Winglet consisted of two pairs of thin platinum circles of different thickness: 0,1 and 0,01 mm, resulting in a rapid equalization of temperature. One of circles of each pair was shiny on both sides, in the other two, one side was coated with platinum black. In order to prevent movement (convection) of gas that occurs when the difference between the temperature of the winglet which absorbs light, and the glass bulb, the light was directed to one, then the other side of the winglet. In both cases, the convection was the same and the difference of deviations was not dependent on gas motion. Radiometric action (gas molecules are dropped out with larger speed from the illuminated side of the disk than from the shadow, and cause more impact, exceeding several times the radiation pressure) was weakened by increasing the cylinder volume and decreasing pressure. Radiometric forces were taken into account when comparing the results of incidence of light on the thick and thin blackened circles.*

*Lebedev reported about his experiments in 1900 in Paris at the World Congress of physicists. The following year, in German journal «Annals of Physics» he published the article «Experimental study of light pressure». The work of the scientist on light pressure measurement on a solid brought him worldwide fame and wrote his name in the history of experimental physics. In Russia, for these experiments he received the Award of Academy of Sciences and was elected a corresponding member. Proof of existence of light pressure had philosophical and ideological significance. Because of the existence of pressure of electromagnetic waves, among other things, a conclusion followed that they have a mechanical pulse, and hence mass, that is, they are material and matter exists not only in the form of substances, but also as electromagnetic field.*

**Cosmic links of light**

*In 1902 the scientist made at the congress of the German Astronomical Society a report on cosmic role of light pressure, indicating that the effect of light on the molecule depends on its selective absorption: for rays absorbed by gas, the pressure is conditioned with the law of Maxwell, and the rays not absorbed by gas, do not have the effect on it. At the same time he published an article «Thermal elements in a vacuum as a device for measuring radiant energy». The principle of thermal element in a vacuum is now successfully used in military equipment.*

*In 1907, Lebedev measured the pressure of light on rarefied gas that was particularly significant in assessing cosmic phenomena. In his tiny instrument gas under the pressure of absorbed light received rotary motion transmitted to a small piston and deflection was measured by shift of mirror light «sun twinkle». The convection of gas in the device was overcome by mixing the hydrogen which is a good conductor of heat and rapidly equalizes temperature inhomogeneity in the vessel. To get rid of radiometric effect the camera with two channels was used. In 1909, the scientist makes a report on the results obtained. A year later they were published in «Annals of Physics». For these experiments to measure light pressure on gases British Royal Institute elected Lebedev an honorary member.*

*In Russia Lebedev became a founder of a large collective research. He organized a physics laboratory at Moscow University with a relatively large number of employees. If in 1901 he had three employees, then in 1910 the number of employees reached 28. He in 1911 in a newspaper article «Russian society and Russian national laboratories», published in «Russian Vedomosti», justified the use of and need for creation of large research laboratories. It was, in fact, the country's first declaration of the system of science organization.*

*In the year of publication of the article in protest against reactionary actions of the Minister of Education, L. A. Casso related to harassment of students and restriction of university autonomy, Pyotr Lebedev, like many other professors of Moscow University, for personal reasons, resigned. Together*

*with him members of his laboratory left the university. He immediately received invitations from foreign academic institutions, but stayed at his home country.*

*In difficult conditions using private funds allocated by the Society of experimental sciences and their practical application named after Kh. S. Ledentsov, a new physical laboratory was organized in the basement of the city People's University named after liberal activist of education A. L. Shanyavsky. Here he in connection with the discovery in 1908 by the American astronomer G. E. Hale of magnetic fields of sunspots started but did not complete his last experimental work on testing the hypothesis of English physicist Sutherland with respect to redistribution of charges in the conductors under the influence of gravity.*

*According to this hypothesis, the planets and stars have «squeezing» of electrons from interior regions where pressure on the surface is high, due to which the inner regions are positively charged, and the surface of bodies – negatively. Rotation of bodies, together with redistributed in them electric charges should generate magnetic fields. Lebedev put forward the idea that if Sutherland hypothesis is correct, then in rapid rotation of electrically neutral bodies centrifugal forces as well as gravitational, will cause redistribution of charges and a magnetic field should emerge. The desired effect could not be found, it is now clear, due to insufficient sensitivity of the installation. The reason was not a lack of effect, and its evaluation for magnetic fields, which were unreasonably high.*

*Private donations were finally gathered to serve as funds for construction of the Physics Institute under the plan, drawn up by the scientist. Alas, the building was completed in 1916 – four years after the death of the author of the project. Tis building today serves as location of the Physical Institute of the Russian Academy of Sciences named after P. N. Lebedev.*

**Conclusion.** *The scientist suffered from heart disease. Worries about retiring completely sapped his health. Pyotr Lebedev died on 14th of March (1st of March, Old Style) 1912 at the age of 46 years. He was buried in Moscow at Alekseevskoe cemetery. In 1935, in connection with its liquidation the remains of Lebedev were transferred to the cemetery of Novodevichy Convent.*

*In 1969 the Gold Medal named after P. N. Lebedev was established, which is awarded by the Russian Academy of Sciences (until 1991 – the USSR Academy of Sciences) for outstanding work in the field of physics. By this step the scientific community confirmed above all the credibility and importance of progenitor of award, along with continuity and strength of traditions of the national school of physics.*

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