Prefaces to the Collected Works of Wilhelm Weber

I present here the English translations of the prefaces of the six volumes of Wilhelm Weber's *Werke* which were published between 1892 and 1894.[1,2]

Posted in October 2024 at www.ifi.unicamp.br/~assis

[1]Translated and edited by A. K. T. Assis, www.ifi.unicamp.br/~assis
[2]All the Notes were written by AKTA.

Contents

Chapter 1

Prefaces to the Collected Works of Wilhelm Weber (1892-1894)

1.1 [Voigt, 1892] Preface to the First Volume

V. Voigt[3]

This First Volume of W. Weber's Collected Works contains treatises from the fields of acoustics, mechanics, optics and thermodynamics. The majority of these works date from the time *before* Weber was led by Gauss into the area of work in which his strength was to fully develop and his scientific personality was to grow to the importance that is generally recognized today.

The treatises collected here are primarily of historical interest; they only partly contain independent works, and even in these some of them must be rejected as incorrect. But in an edition which is primarily intended as a memorial to the great physicist, these landmarks of the beginnings of his development must not be missing.

The chronological order of the treatises could not be the sole criterion for their arrangement, as it would often have separated related works from one another. Rather, it seemed appropriate to form groups of works with related content, to introduce a chronological order within them, and to arrange the groups themselves in the two Parts of the Volume approximately according to the date of the treatise that opened them.

The First Part (Acoustics) is opened by the treatises I-XIII, written under Chladni's direct influence, which partly report critically on the acoustic work of others, partly repeat and continue experiments carried out by them.[4] The series concludes with a biography of Chladni and a paper on his acoustics.

A second series is formed by the treatises on the tones of reed pipes, in which Weber shares truly new and fundamental observations on an area that had hardly been dealt with before, and by a number of short notes on individual questions of acoustics; it is concluded by the short overview of the whole of acoustics written in 1835 for the Universallexikon der Tonkunst (Universal Lexicon of Music).

[3][Voi92]. Woldemar Voigt (1850-1919) was a German physicist.

[4]Ernst Chladni (1756-1827) was a German physicist and musician. He is specially known for the so-called Chladni figures or Chladni patterns, that is, the modes of vibration on a rigid surface.

Attached to this Part is one of the reviews that Chladni gave to his young friend's habilitation thesis, which is printed under article XIV.

You will search in vain for W. Weber's *doctoral dissertation* among the papers compiled here; according to the results of my inquiries, it was not printed and has not been found in manuscript form in his estate. The title "Theoria efficaciae laminarum maxime mobilium arcteque tubos aerem sonantem continentes claudentium" (The theory of the efficiency of the most movable plates and the trumpets closely containing the sounding air) suggests with certainty that it served in an extended form as a habilitation thesis.

If the treatises collected in the First Part bear witness to the continuous occupation with a closed area of physics, the treatises compiled in the Second Part (mechanics, optics, thermodynamics) provide information on problems that are dealt with more occasionally and for a shorter period of time.

The seeds for a greater development lie here especially in the treatises V-VII, in which the phenomena of the elastic aftereffect are subjected to an exact investigation for the first time according to an ingenious method by Gauss.

Of particular interest is also treatise XVI, in which the author presents and applies a very useful method for observing the difference between the adiabatic and isothermal dilatation of solid bodies, which he, however, still based on the standpoint of the older heat theory, utilizes in a substantially different way than is currently the case.

The present collected edition adheres strictly to the original publications — apart from the correction of individual obvious arithmetical and printing errors. With regard to form, it should be noted that citations which refer to a passage in the *same* treatise have simply been changed in accordance with the new edition, — citations which refer to other treatises by Weber have been left in their original form, except for the introduction of a consistent numbering of the volumes of Poggendorff's *Annalen*;[5] in the latter case, a reference to the corresponding passage in the collected edition has been added in square brackets below the page. Other additions by the editor are identified as such by the same symbol.

Göttingen, July 1892.

W. Voigt.

1.2 [Riecke, 1892] Preface to the Second Volume

E. Riecke[6]

The Second Volume of Wilhelm Weber's Collected Works contains his treatises in the area of magnetism. Gauss had devised new and highly sophisticated means of observation for the study of the Earth's magnetism and had shown how the strength of terrestrial magnetism could be expressed in the general units of length, mass and time independently of the variable strength of the oscillating magnetic needle.[7] After his appointment to the chair of physics

[5]Johann Christian Poggendorff (1796-1877) was a German physicist. He was the Editor of the *Annalen der Physik und Chemie* from 1824 to 1876. The modern *Annalen der Physik* is the successor to Poggendorff's *Annalen*.

[6][Rie92]. Eduard Riecke (1845-1915) was a German experimental physicist who studied under Wilhelm Weber at the University of Göttingen. In 1881 he succeeded Weber at Göttingen University.

[7]Gauss' work on the intensity of the Earth's magnetic force reduced to absolute measure was announced at the Königlichen Societät der Wissenschaften zu Göttingen in December 1832, [Gau32] with English trans-

in Göttingen, Weber took an eager and successful part in the further pursuit of the path thus opened up. He joined forces with Gauss in the publication of "Resultate aus den Beobachtungen des magnetischen Vereins" (Results from the Observations of the Magnetic Society), of which 6 volumes appeared from 1836-1841.[8] These were not only to contain the corresponding observations of the numerous places that had joined the Magnetic Society, their graphic representations and the explanations attached to them; they were also to include all work relating to the broad field of geomagnetism and thus provide the impetus for new advances in science. The significance of what Gauss and Weber created in the decade of their joint work does indeed go far beyond the goal they initially pursued. A large part of our present-day art of observation has developed from the problems they dealt with, and it is above all to Weber's credit that he extended the strict principles introduced by Gauss to the measurements of galvanism. Weber's contributions to the *Resultate* form the greater part of the treatises combined in this Second Volume of the collected works. The explanations of the term-observations, which were written by Weber for the last four volumes, serve the direct purposes of the Magnetic Society. These are only reproduced in excerpts, containing comments that characterize the entire activity of the Society or refer to important results of the observations. These explanations would be followed by the essays devoted to the description of the Göttingen Magnetic Observatory and the apparatus installed there. They are not only of great historical interest, but are still of immediate practical importance today due to the theories of the instruments, their errors and corrections they contain. Weber endeavored with great success to construct instruments for determining the elements of terrestrial magnetism while traveling that were both comprehensive and highly accurate. Several essays are devoted to the description of these instruments, some of which we still use today in a barely modified form, and to the presentation of the observations made with them.

The requirements and experiences that arose from this work inevitably led to questions of more general importance. This includes the study of the dependence of bar magnetism on temperature, the results of which have since been confirmed but hardly extended. Of the treatises relating to the doctrine of induced magnetism (IX, XX and XXIII of this Volume), we may regard the first as the forerunner of the investigations described in the treatise XXVIII of this Volume and in the third treatise on *elektrodynamische Maassbestimmungen* (Electrodynamic Measurements).[9] This earlier work leads to even less general results, as Weber seems not to have known the points of view of Poisson's theory when he wrote it.[10] The second treatise describes the effects of coercive force, which are closely related to those recently described as "hysteresis". In the Leipzig invitation paper, the magnetic properties

lations in [Gau33a], [Gau37a] and [Gau21a], see also [Rei02, pp. 138-150]. The original paper in Latin was published only in 1841, although a preprint appeared already in 1833 in small edition, [Gau41] and [Rei19]. Several translations have been published. There are two German versions, one by J. C. Poggendorff in 1833 and another one in 1894 translated by A. Kiel with notes by E. Dorn; a French version by Arago in 1834; two Russian versions, one by A. N. Drašusov of 1836 and another one by A. N. Krylov in 1952; an Italian version by P. Frisiani in 1837; an English extract was published in 1935, while a complete English translation by S. P. Johnson was published in 2003 and 2021; and a Portuguese version by A. K. T. Assis in 2003: [Gau33b], [Gau34], [Gau36], [Gau37b], [Gau94], [Gau35], [Gau52], [Gau75], [Gau03], [Ass03] and [Gau21b].

[8] [GW37], [GW38], [GW39], [GW40b], [GW41] and [GW43]. See also [GW40a].

[9] The 8th treatise on *Elektrodynamischen Maassbestimmungen* (Electrodynamic Measurements) was published posthumously. These 8 treatises have already been fully translated into English: [Web46] and [Web21c]; [Web52b] and [Web21d]; [Web52a] and [Web21g]; [KW57] and [KW21]; [Web64] and [Web21b]; [Web71], [Web72] and [Web21f]; [Web78] and [Web21e]; [Web94b] and [Web21a].

[10] Siméon Denis Poisson (1781-1840).

of steel are explained by the assumption that it is composed of parts of greater and lesser coercive force. The treatise on magnetic friction still contains almost everything we know about this subject today.

The treatises in the area of magneto-electricity are of particular interest, not only because of their own importance, but also because of their relationship to the [series of works on] *elektrodynamische Maassbestimmungen* (Electrodynamic Measurements). They form the bridge from magnetism to electrodynamics, the field to which Weber gave a new form through a series of epoch-making, truly classical works. Some of the treatises belonging to this field can in themselves be counted with the same right to galvanism or electrodynamics; they have been included in the present Volume because of their close relationship to others of purely magnetic content.

The treatise on unipolar induction forms the starting point for its own extensive literature and numerous controversies. Weber himself gave rise to these. He had first explained the phenomenon with the help of a peculiar idea, which was, however, linked to the assumption of the real existence of magnetic fluids; he later emphasized the contradiction of his [earlier] theory [of unipolar induction] with the laws of electrodynamics and the possibility of another explanation in a Note to the third treatise on *elektrodynamische Maassbestimmungen* (Electrodynamic Measurements), but without developing it himself. The first application of magnetic induction to the measurement of galvanic resistances can be found in the seventh treatise of this Volume. The induction inclinometer[11] described by Weber as early as 1837 is also of interest because the ingenious principle underlying its construction was later used in one of Weber's methods of absolute resistance measurement; and when he later gave the Earth inductor the form in which it has remained essentially unchanged ever since as one of the physicist's most important instruments, he did not limit himself to magnetic applications in the illustration of the new method of measurement, but added the important proof of how attenuation can be used as a measure of the sensitivity of a multiplier, which then provided a new solution for the fundamental task of galvanometry, the absolute resistance measurement. It is hardly necessary to recall the importance of this work for practical physics. The fact that Weber recognized the importance of magneto-electric forces in this direction early on is evident from his essays on the rotation inductor and magneto-electric machines, which cannot be regarded without interest as the forerunners of our electrotechnical literature, which is now so widespread.

Apart from two rearrangements required by the context, the treatises which we have attempted to characterize briefly in the foregoing have been printed in chronological order in the present Volume; a separation into individual groups did not seem expedient in view of the multiple relationships between them. As in the First Volume, the essays are printed strictly according to their first publication. Citations that refer to a passage in the same treatise have been changed in accordance with the new edition, while citations that refer to other treatises by Weber have been left in their original form. In the latter case, a reference to the corresponding passage in the complete edition is added below the page. In the same way, the frequent citations to treatises by Gauss are supplemented by a reference to the

[11]In German: *Induktionsinklinatorium*. The dip circle, dip needle, inclinometer or inclinatorium is an instrument used to measure the angle between the horizon and the direction of terrestrial magnetism (the dip angle). It consists essentially of a magnetic needle pivoted at the center of a vertical graduated circle. Weber's *Induktions-Inklinatorium* is a new instrument which he presented in 1837, [Web38]. It offered a novel way to circumvent the two main problems with dip circles: the effect of gravity, and the need to reverse the polarity of the needle, [WSH03].

complete edition of Gauss' Collected Works. These and all other additions by the editor are indicated by square brackets.

Göttingen, July 1892.

Eduard Riecke.

1.3 [Heinrich Weber, 1893] Preface to the Third Volume

Heinrich Weber[12]

The Third Volume contains the treatises published by Wilhelm Weber up to the end of 1857 in the areas of galvanism and electrodynamics in the same order in which they were published. As a result of this arrangement, the seven treatises to which Weber gave the common title "Elektrodynamische Maassbestimmungen" (Eletrodynamic Measurements) appear here separately from one another, and the first four of them are printed in this Volume under articles numbers V, X, XI and XV, while the later three are included in the Fourth Volume.[13]

It would have been desirable to combine these seven treatises of fundamental importance, which follow on harmoniously from one another and appear as a rounded whole, in one Volume. However, the division of the treatises into two Volumes would have been so uneven that it seemed advisable to refrain from such a combination of all seven treatises. Instead, the strictly chronological arrangement has ensured that, with only a few exceptions, treatises of related content follow one another, giving the reader an insight into the development of W. Weber's work in the areas of galvanism and electrodynamics.

Treatises I to IV deal specifically with the galvanic current; in particular, in treatise II, page 9, the absolute unit of measure for current intensities is first precisely specified, which Weber probably used for the first time in the treatise on magnetic friction (Volume II, pages 202 and 203). Treatises II and IV contain the theory of the tangent galvanometer, and in treatise III the electrochemical equivalent of water is subjected to precise measurement for the first time on the basis of the introduced absolute unit of [current] intensity.

The simultaneous occupation with galvanic currents and magnetic phenomena soon led Weber to a precise study of Ampère's investigations, the result of which is set down in the first treatise published under the title *Elektrodynamische Maassbestimmungen* (Electrodynamic Measurements), which is printed here under treatise number V.[14] With the aid of a number of instruments newly invented by him, Weber proves the correctness of Ampère's law in

[12][Web93]. Heinrich Weber (1839-1928) was a German physicist. He was the nephew of Wilhelm Eduard Weber (son of his older brother, the physician Ernst Heinrich Weber (1795-1878)). He was professor of physics at the Ducal Technical University Carolo-Wilhelmina from 1866 until his retirement in 1906.

[13]See footnote 9.

[14][Note by AKT:] André-Marie Ampère (1775-1836). Ampère's masterpiece was published in 1826, [Amp26] and [Amp23]. There is a complete Portuguese translation of this work, [Cha09] and [AC11]. Partial English translations can be found at [Amp65] and [Amp69]. Complete and commented English translations can be found in [Amp12] and [AC15]. A huge material on Ampère and his force law between current elements can be found in the homepage *Ampère et l'Histoire de l'Électricité*, `http://www.ampere.cnrs.fr` and [Blo05], at the homepage of the Friends of André-Marie Ampère, `https://saama.fr`, and at the homepage of the Ampère Museum, `https://amperemusee.fr/en`.

the sharpest possible terms, and then establishes his fundamental law of electrical action, by which the electrostatic, electrodynamic and induction phenomena are traced back to a common basis.

In the treatises designated here as VII and XI, Weber turns to the study of diamagnetism, which shortly after its discovery by Faraday in 1846 became of outstanding importance for the theory of magnetism, insofar as the explanation of diamagnetic phenomena simultaneously brought about a decision between the hitherto equally valid hypotheses about the nature of magnetism.[15] Weber not only succeeded in comparing the magnitude of diamagnetic and magnetic forces, but also in generating diamagnetic induction currents and determining the relationship between their intensity and that of magnetic induction currents. These investigations then led to a precise conception of the nature of magnetism and diamagnetism.

The construction of the Earth inductor, which was initially only used for inclination measurements, led Weber to establish an absolute unit of measure for electromotive forces. At the same time, however, this also provided the absolute unit of measure for galvanic resistance with the aid of the previously established absolute unit of measure of [current] intensity according to Ohm's law.[16] The units of measurement are discussed in depth in the treatise X, and the methods of measuring resistance according to absolute units are discussed in detail. This system of units, which is based on magnetic actions, has become generally accepted today with only minor modifications.

The fundamental law established by Weber contains a constant whose numerical value he determined jointly with Rudolph Kohlrausch and published in the treatise listed under number XV.[17] Knowledge of this constant makes it possible to express quantities measured in magnetic or electrodynamic units in mechanical units or vice versa.

These few words may suffice to give an indication of the wealth of intellectual work contained in the following treatises, which, in addition to their theoretical importance, also form a model for experimental research. As in the first two Volumes, remarks and citations that do not originate from Weber himself are indicated by square brackets; only in the case of some citations has the page number of the original text been directly replaced by the corresponding page number of the present Volume for the convenience of the reader. The treatises by Gauss frequently cited in the text have been accompanied by a location reference in Gauss' Collected Works.

Brunswick, January 1893.

Heinrich Weber.

1.4 [Heinrich Weber, 1894] Preface to the Fourth Volume

Heinrich Weber[18]

The Fourth Volume follows on directly from the Third Volume in terms of content. It

[15] Michael Faraday (1791-1867). See [Far46a] and [Far46b].

[16] Georg Simon Ohm (1789-1854). Ohm's law is from 1826: [Ohm26a], [Ohm26c], [Ohm26d], [Ohm26b] and [Ohm27] with French translation in [Ohm60] and English translation in [Ohm66].

[17] See footnote 9.

[18] [Web94a].

contains all the treatises and essays in the areas of galvanism and electrodynamics that Wilhelm Weber published in the period 1858-1880, as well as a number of treatises and essays that have been found in his estate. An essay with remarks on the Munich Magnetic Observatory, which was only discovered after the publication of the first three Volumes and could therefore no longer be included in the Second Volume, to which it belongs in terms of content, is also included as an Appendix.

The treatises, with the exception of those forming the handwritten posthumous works and the Appendix, have been arranged in chronological order, for the same reasons that prompted the same arrangement in the Third Volume. The last three of the seven treatises published under the joint title "Elektrodynamische Maassbestimmungen" (Electrodynamic Measurements), the first four of which were printed in the Third Volume, can be found under treatises numbers V, VIII and XII and an eighth treatise belonging to them, which has not yet been published, is included as the first treatise in the handwritten posthumous works.[19]

While the first four treatises of the *Elektrodynamische Maassbestimmungen* (Electrodynamic Measurements) mainly deal with the investigation of the reciprocal forces that electric particles exert on each other or on other bodies, the following treatises, which are included in this Volume, are primarily concerned with the movements of the electric particles caused by these forces. It was a curious coincidence that when Wilhelm Weber was about to publish his first paper on this subject, Kirchhoff, who had been working on the laws of galvanic currents at the same time, had already presented the editor of the *Annalen für Physik und Chemie* with a treatise on the same subject a short time earlier.[20] The remark by J. C. Poggendorff included under number VI, to which Wilhelm Weber himself refers (Wilhelm Weber's *Werke*, Vol. IV, p. 130), refers to this. It was not until six years later that Wilhelm Weber published his treatise on electrical oscillations (number V), in which he then combined the content of the previously withdrawn treatise with a comprehensive experimental investigation, in which Rudolph Kohlrausch participated until his death in 1858. In this treatise, Wilhelm Weber introduces the mass of electric fluids for the first time and then develops the equations for the movement of electricity in wires, especially in those of circular shape, according to the general laws of mechanics, without assuming, as Kirchhoff did, the validity of Ohm's law even in cases where the current intensity in the individual current elements is different and subject to rapid change.

In the following treatises VIII and XII of the *Elektrodynamische Maassbestimmungen*, to which treatises VII, IX and above all treatise X "Ueber die Bewegung der Elektricität in Körpern von molekularer Konstitution" (On the motions of electricity in bodies of molecular constitution) published in Poggendorff's *Annalen* are to be counted as connecting links, W. Weber enters into investigations for which the energy principle forms the basis. In treatise number VIII, in particular, the relation of the fundamental law of electric action to the energy principle is examined more closely, and it is shown that there is no contradiction between the fundamental law and the latter principle, as has been asserted by others, unless assumptions are made about initial states whose compatibility with existing nature requires special proof. At the beginning of treatises X and XII, Wilhelm Weber then proceeds to detailed considerations of the energy principle by showing that the energy principle formulated in the usual way, to which Carl Neumann had drawn attention, is capable of extensions which, depending on their nature, lead to different results.[21] The extension which Wilhelm

[19]See footnote 9.

[20]Gustav Kirchhoff (1824-1887) was a German physicist and mathematician. See footnote 5.

[21]Carl Gottfried Neumann (1832-1925) was a German mathematician, the son of the mineralogist, physicist

Weber gives to this principle consists in the assumption that the energy of interaction and the relative living force of two particles are homogeneous quantities whose sum is always equal to a constant. If this extension is valid, then the initial conditions can no longer be assumed to be completely arbitrary; on the contrary, all assumptions which in themselves contradict the underlying principle are excluded from the outset. Wilhelm Weber also derives the ordinary energy principle from the principle of the conservation of energy formulated by him and shows how the law of electrodynamic potential results from his principle and the law of electrostatic potential.

Following on from the laws of motion of two particles that are only subject to their interaction, which have already been developed in treatise VIII, special cases are then discussed in detail in treatise XII. Of particular importance are also the investigations carried out in treatise X, on the motion of electricity in bodies of molecular constitution, in which the galvanic, magnetic and thermal actions, which can occur simultaneously in ponderable bodies, are brought into the field of consideration. In doing so, Wilhelm Weber abandons his earlier view of the galvanic current as a double current and, taking up earlier considerations (Wilhelm Weber's *Werke*, Vol. III, p. 403), gives a clear idea of the generation of thermal energy by the galvanic current and of the cause of resistance in metallic conductors.

The above-mentioned treatises are now joined organically by the first treatise included in the handwritten posthumous works, which has not yet been published and which, according to the title given to it by W. Weber himself, is the eighth of the seven treatises published under the title "Elektrodynamische Maassbestimmungen". Wilhelm Weber may well have suspected that he would not be able to go into the details of the immense field of phenomena covered by the observations in this treatise, and so individual sections appear as pointers to the paths leading to a further expansion of the field of research.

On the basis of the assumption that all ponderable molecules are mere compounds of equal quantities of positive and negative electricity, and that the attractive force of equal quantities of dissimilar electricity is greater than the repulsive force of the same quantities of similar electricity, Wilhelm Weber moves from the field of the pure theory of electricity to that of ponderable bodies. He shows how the various kinds of ponderable molecules, especially those of the elements, can be thought of as composed of electric molecules, furthermore how metallic conductors differ from glassy and crystalline bodies, and how, on the basis of this difference, the propagation of electricity and heat in the former takes place in a different way, namely by ballistic motion, than that of light and heat in the latter, namely by wave motion. According to Wilhelm Weber's view presented here, the luminiferous aether is a static medium made up of positive electric molecules.

The original manuscript of this treatise contains, in addition to the Sections included here, four other Sections whose titles are given in a Note added at the end of the treatise. Since Wilhelm Weber himself later excluded these Sections from the treatise, it was necessary to refrain from publishing them. It should be noted, however, that the entire estate has been handed over to the Royal Library in Göttingen for safekeeping, thus preserving the possibility of gaining insight into the content of these Sections.

In addition to these treatises on the nature of electricity and ponderable bodies, the present Volume contains two more of particular importance, namely treatise number III "Zur Galvanometrie" (On galvanometry) and treatise number XIV, published in collaboration with Zöllner, of which the latter is Wilhelm Weber's last experimental work.[22] In

and mathematician Franz Ernst Neumann (1798-1895).

[22] Johann Karl Friedrich Zöllner (1834-1882) was a German astrophysicist.

the former, the methods of absolute resistance measurements are discussed and a complete theory as well as the most advantageous construction of galvanometers are given and the copying methods are subjected to a detailed examination, while the latter deals with the establishment of a standard conductor whose resistance can be determined at any time according to absolute units, which should facilitate the general application of absolute units in electrodynamics. Wilhelm Weber was no longer able to carry out the originally planned comparison of the resistance of this standard conductor with today's generally accepted practical unit of resistance, the ohm.

In addition to the above-mentioned treatise on *elektrodynamischen Maassbestimmungen*, the handwritten posthumous works also contains essays and treatises, some of which originate from very different periods of Wilhelm Weber's life. Some of them were undoubtedly intended for publication, although perhaps in a different form, but for unknown reasons were not published; others, on the other hand, are transcripts, interwoven with various remarks which Wilhelm Weber quickly threw in to support his memory, the compilation of which could often only be accomplished by overcoming great difficulties. Of these, the larger treatise "Über Maassbestimmungen" (On Measurements) should be emphasized here, which has not lost its importance even today after the general acceptance of the absolute system of units. Although this treatise was not written until after 1864, Wilhelm Weber's posthumous notes from 1834 show that at that time he had already reduced the most important physical quantities to absolute units utilizing the basic units of length, time and mass. The essay "Über die Einrichtung des Bifilargalvanometers" (On the setup of the bifilar galvanometer) is in any case of much earlier origin than the addition added to it in 1864, which deals with the simultaneous measurement of geomagnetism and current intensity in absolute units. Finally, the two essays "Bemerkungen zu der Abhandlung: Untersuchungen über den galvanischen Lichtogen, von Edlund" (Comments on the paper: "Investigation into the electric arc" by Prof. E. Edlund) and "Elektroskopische und elektrodynamische Wirkung der freien Elektricität geschlossener Ketten" (Electroscopic and electrodynamic actions of free electricity in closed circuits) lead to a different field, because both refer to the charge on the surface of conductors in which the electricity is in motion.

We have refrained from publishing some of the essays that were also found in the estate, partly because they date from very early in Wilhelm Weber's life and no longer offer anything new today, and partly because their content has been included in later treatises. To confirm this, the documents may be listed and their essential content indicated.

The first essay belonging here, which is entitled "Der Dämpfer" (The damper), was intended to be included in the *Resultate aus dem Beobachtungen des magnetischen Vereins* (Results from the Observations of the Magnetic Society), 1837. After explaining the purpose of a damper, the action of a closed metal ring as a multiplier, then as an inductor and finally, when both actions are combined, as a damper, is considered in more detail. The paper concludes with a calculation of the reduction in vibration of the [magnetized] needle and a comparison of the damping action with the action of a damping rod. A second essay, "Über die Einrichtung der Multiplikatoren" (On the setup of multipliers), is the forerunner of the detailed considerations given later in the treatise "On galvanometry". The third essay "Über ein neues Galvanometer" (On a new galvanometer) deals with the setting up, installation and testing of the bifilar galvanometer and its use for absolute [current] intensity measurements and for determining the electrochemical equivalent of oxygen and hydrogen, an application which Wilhelm Weber discusses in detail in the essay on the electrochemical equivalent of water (Wilhelm Weber's *Werke*, Vol. III, p. 13). The fourth essay, comprising only a few pages, deals with "Die absolute Messung der in einer Leidener Flasche vorhandenen freien Elektricität" (The absolute measurement of the free electricity present in a Leiden jahr). The measurement is based on oscillation and deflection experiments of a movably suspended, charged Franklin's plate, on which another charged Franklin's plate acts from a distance. This task has been solved in a more perfect way in the treatise, *Elektrodynamische Maassbestimmungen, insbesondere Zurückführung der Stromintensität auf mechanisches Maass* (Electrodynamic measurements, specially attributing mechanical units to measures of current intensity) (Wilhelm Weber's *Werke*, Vol. III, p. 618). Finally, the resolution is a document comprising 11 quarto pages without a heading, which contains the proposal to produce an arbitrary unit of measure for galvanic resistance to facilitate galvanic measurements, especially for technical applications, and to distribute a large number of copies of this unit. However, this practical unit of measure must be measured precisely in absolute units. This is followed by the derivation of the oscillation equation of a magnetic needle within a multiplier, if self-induction is taken into account.

The writings compiled in this Volume under the title "Nachlass" (Posthumous works) can only be handed over to the public with all reservations, since it must appear doubtful whether Wilhelm Weber intended them for printing, especially in the form in which they were found in the estate. Although it was obvious to make changes to the wording and presentation in various places, as Wilhelm Weber would undoubtedly have done himself in the event of publication, this was not done in all cases, as the heading *"handschriftlicher" Nachlass* ("handwritten" posthumous works) already sufficiently indicates. All quotations and additions which do not originate from Wilhelm Weber himself are, as in the previous Volumes, also indicated in this Volume by square brackets.

Brunswick, January 1894.

Heinrich Weber.

1.5 [Riecke, 1893] Preface to the Fifth Volume

Eduard Riecke[23]

Three of the sons of the Wittenberg theologian Michael Weber devoted themselves to the study of the natural sciences and the close intellectual community that bound them together throughout their lives was commemorated in two epoch-making works, one of which, the *Wellenlehre* (Wave Theory), arose from the joint work of Wilhelm Weber and his older brother Ernst Heinrich, the other, *die Mechanik der Gehwerkzeuge* (Mechanics of the Human Walking Apparatus), from the joint work of Wilhelm and his younger brother Eduard.[24] In the preface to the *Wellenlehre*, the brothers report on a coincidental external reason for their investigations. However, it can be assumed that their attention had already been drawn to problems of wave theory at an earlier stage. In the first place, through their friendly relationship with Chladni, the founder of experimental acoustics, to whom the work is dedicated.[25] The older brother, however, who was already a professor in Leipzig at the time of the joint work, also had the physiological applications of wave theory in the background

[23][Rie93].

[24]Ernst Heinrich Weber (1795-1878) was a German physician. Eduard Friedrich Weber (1806-1871) was a German anatomist and physiologist. See [WW25] and [WW36] with English translation in [WW92].

[25]See footnote 4.

of his thoughts. Two years after the publication of the joint work, he published the first of the treatises that made him the founder of an exact physical theory of blood circulation.

The *Wellenlehre* (Wave Theory) is one of the classic works of physical literature, above all because of its beautiful and fundamental investigations into the waves of incompressible fluids. What is said about this in the first main part of the work must still be read today by everyone who wants to become more familiar with this part of hydrodynamics. The numerous observations, the measurements carried out with such simple means in the most meaningful way still contain enough stimulation for further experimental and theoretical investigations. The peculiar attempt to build a bridge from the discovered laws of wave motion to the phenomena of vortices was, of course, doomed to fail, since the later progress of science revealed an essential difference between the two types of motion. In the context of the whole, however, the three paragraphs on the formation of vortices could not be suppressed.

The second main part of the work deals with waves in relation to sound and light; it is less extensive than the first and is no longer as directly relevant as the first part. The allusion in § 249 to a connection between the sound of a string and the shape it alternately assumes as it vibrates has been replaced by a comprehensive theory of overtones and vocal sounds; new methods of observation, new instrumental aids of great perfection have been created, and the results of research have been made more generally accessible through excellent works. Weber's *Wellenlehre* (Wave Theory), however, always contains a series of fundamental observations in its part devoted to acoustics, to which every presentation of acoustics still refers. With reference to this, we recall the measurements of the speed of rope waves, the studies on reed pipes and the occurrence of silence in the vicinity of vibrating tuning forks.

Only a few paragraphs are devoted to the wave theory of light; optics was far removed from the authors' own experimental work and Fresnel had only opened the series of his works a few years earlier; in the same year as the *Wellenlehre*, the translation of a Fresnel treatise appeared for the first time in the Poggendorff's *Annalen der Physik*.[26]

The same principles were applied to the present reprint of the *Wellenlehre* as to the reprint of the collected treatises in the earlier Volumes. The sign for the beginning of a new paragraph had been omitted in some places in the original work, for example in § 3 and § 143, the sign for § 219 was used twice; these oversights could easily be corrected using the detailed table of contents printed before the work. There were a number of discrepancies between the text and the figures, with parts of the figures or individual letters missing. In most cases, there could be no doubt about the small changes and additions that had to be made to ensure consistency. In all these cases, the text or the figure was changed or supplemented according to the circumstances. A Note on pages 96 and 98 draws attention to a major deviation, which could only be completely eliminated by a more radical change to the text. In Figure 15, the missing letters have not been added, as the necessary indications are not given; incidentally, the understanding of the relevant § 94 is not impaired by this. We have refrained from transferring the length measurements based on Paris feet to the metric system. The observations are not concerned with the determination of absolute physical constants, but with the measurement of phenomena whose course depends on the specific conditions of the experiment. On the other hand, the value in grams is added for weights that are given in the medicinal weight, which is foreign to physicists; an overview of the units of the medicinal weight used by the authors is given in a Note on page 128. The column titles of the original had to be changed because of the differences in the typesetting. As a rule, the content of the entire section is given on the left-hand page, while the heading on the right-hand page

[26] Augustin-Jean Fresnel (1788-1827). See [Fre25].

follows the original version as closely as possible. The extracts from the works of Laplace, La Grange, Gerstner, Poisson and Cauchy contained in the third section have been compared with the originals and the text and formulas were subsequently improved in some places. Additions and comments by the editor are indicated by square brackets. In the table of contents, the numbers in brackets indicate the relevant pages of the original.

Göttingen, March 1893.

Eduard Riecke.

1.6 [Merkel and Fischer, 1894] Preface to the Sixth Volume

F. Merkel and O. Fischer[27]

The publication of this Sixth Volume of Weber's Collected Works was undertaken by W. Braune in Leipzig, who was not only closely related to the Weber family, but also had to be regarded as the most qualified editor of the "Mechanik der menschlichen Gehwerkzeuge" (Mechanics of the Human Walking Apparatus) in terms of his entire line of work.[28] As with numerous other works, he had invited Otto Fischer in Leipzig to collaborate with him. However, before both could begin their work, W. Braune was taken away from science by an untimely death. He was replaced by a full member of the *Königl. Gesellschaft der Wissenschaften* (Royal Society of Sciences [of Göttingen]), Fr. Merkel in Göttingen, who was now responsible for the edition together with O. Fischer.

October 1893.

Fr. Merkel (in Göttingen) and O. Fischer (in Leipzig).

[27][MF94]. Friedrich Sigmund Merkel (1845-1919) was a German anatomist. Otto Fischer (1861-1916) was a German physiologist and mathematician.

[28]Christian Wilhelm Braune (1831-1892) was a German anatomist. He was son-in-law to Wilhelm Weber's older brother, Ernst Heinrich Weber. See footnote 24.

Bibliography

[AC11] A. K. T. Assis and J. P. M. d. C. Chaib. *Eletrodinâmica de Ampère: Análise do Significado e da Evolução da Força de Ampère, Juntamente com a Tradução Comentada de Sua Principal Obra sobre Eletrodinâmica*. Editora da Unicamp, Campinas, 2011.

[AC15] A. K. T. Assis and J. P. M. C. Chaib. *Ampère's Electrodynamics — Analysis of the Meaning and Evolution of Ampère's Force between Current Elements, together with a Complete Translation of His Masterpiece: Theory of Electrodynamic Phenomena, Uniquely Deduced from Experience*. Apeiron, Montreal, 2015. Available at www.ifi.unicamp.br/~assis.

[Amp23] A.-M. Ampère. Mémoire sur la théorie mathématique des phénomènes électro-dynamiques uniquement déduite de l'expérience, dans lequel se trouvent réunis les Mémoires que M. Ampère a communiqués à l'Académie royale des Sciences, dans les séances des 4 et 26 décembre 1820, 10 juin 1822, 22 décembre 1823, 12 septembre et 21 novembre 1825. *Mémoires de l'Académie Royale des Sciences de l'Institut de France*, 6:175–387, 1823. Despite this date, the work was only published in 1827.

[Amp26] A.-M. Ampère. *Théorie des Phénomènes Électro-dynamiques, Uniquement Déduite de l'Expérience*. Méquignon-Marvis, Paris, 1826.

[Amp65] A.-M. Ampère. On the Mathematical Theory of Electrodynamic Phenomena, Experimentally Deduced. In R. A. R. Tricker, *Early Electrodynamics — The First Law of Circulation*, pages 155–200, New York, 1965. Pergamon. Partial English translation by O. M. Blunn of Ampère's work "Mémoire sur la théorie mathématique des phénomènes électro-dynamiques uniquement déduite de l'expérience", *Mémoires de l'Académie royale des Sciences de l'Institut de France*, Vol. 6, pp. 175-387 (1823), issued 1827.

[Amp69] A. M. Ampère. The solenoid. Circuits and magnetic shells. In W. F. Magie, editor, *A Source Book in Physics*, pages 456–460, New York, 1969. McGraw-Hill. Extracts from "Théorie des phénomènes électrodynamiques uniquement déduite de l'expérience," Paris, 1826.

[Amp12] A.-M. Ampère. Mathematical Theory of Electrodynamic Phenomena, Uniquely Derived from Experiments. Translated by M. D. Godfrey. Available at https://archive.org/details/AmpereTheorieEn and https://sites.google.com/site/michaeldgodfrey/physics-information-and-communication, 2012.

[Ass03] A. K. T. Assis. Tradução de uma obra de Gauss. *Revista Brasileira de Ensino de Física*, 25:226–249, 2003. Paper in Portuguese: "Translation of a work by Gauss".

[Blo05] C. Blondel, 2005. Ampère et l'Histoire de l'Électricité. Site of the CNRS which was coordinated by Christine Blondel. Available at www.ampere.cnrs.fr.

[Cha09] J. P. M. d. C. Chaib. *Análise do Significado e da Evolução do Conceito de Força de Ampère, juntamente com a Tradução Comentada de sua Principal Obra sobre Eletrodinâmica*. PhD thesis, University of Campinas — UNICAMP, Campinas, Brazil, 2009. Supervisor: A. K. T. Assis. Available at www.ifi.unicamp.br/~assis and http://repositorio.unicamp.br/Acervo/Detalhe/435449.

[Far46a] M. Faraday. Experimental researches in electricity. Twentieth series. *Philosophical Transactions*, 136:21–40, 1846. Read December 18, 1845. Reprinted in *Great Books of the Western World*, R. M. Hutchins (editor), (Encyclopaedia Britannica, Chicago, 1952), Vol. 45: Lavoisier, Fourier, Faraday. Pp. 607-619, §2243-2342.

[Far46b] M. Faraday. Experimental researches in electricity. Twenty-first series. *Philosophical Transactions*, 136:41–62, 1846. Read January 8, 1846. Reprinted in *Great Books of the Western World*, R. M. Hutchins (editor), (Encyclopaedia Britannica, Chicago, 1952), Vol. 45: Lavoisier, Fourier, Faraday. Pp. 619-632, §2343-2453.

[Fre25] A. Fresnel. Ueber das Licht. *Annalen der Physik und Chemie*, 3:89–128, 1825. Doi: 10.1002/andp.18250790107.

[Gau32] C. F. Gauss. Anzeige der "Intensitas Vis Magneticae Terrestris ad Mensuram Absolutam Revocata". *Göttingische gelehrte Anzeigen*, 205-207:2041–2058, 1832. Vol. 205 from December 24, 1832, pp. 2041-2048; Vols. 206 and 207 from December 27, 1832, pp. 2049-2058. Reprinted in C. F. Gauss's *Werke*, Vol. 5, pp. 293-304 (Königlichen Gesellschaft der Wissenschaften, Göttingen, 1867). Corrected version in: Astronomische Nachrichten 10, 1833, Nr. 238, pp. 349-360: Anzeige der Abhandlung des Herrn Hofraths Gauß: Intensitas vis magneticae terrestris ad mensuram absolutam revocata.

[Gau33a] C. F. Gauss. [abstract of the paper:] Intensitas vis magneticae terrestris ad mensuram absolutam revocata. *Philosophical Magazine*, 2:291–299, 1833.

[Gau33b] C. F. Gauss. Die Intensität der erdmagnetischen Kraft, zurückgeführt auf absolutes Maass. *Annalen der Physik und Chemie*, 28:241–273 and 591–615, 1833. Translated by J. C. Poggendorff.

[Gau34] C. F. Gauss. Mesure absolue de l'Intensité du Magnétisme terrestre. *Annales de Chimie et de Physique*, 57:5–69, 1834.

[Gau36] C. F. Gauss, 1836. Ob isměrenii zemnago magnitizma. (Soč[inenie] Karl[a] Frid[richa] Gaussa). Per[evël] A. Drašusov. Učenyja zapiski Imperatorskago universiteta čast 11, 1836, Nr. 7 (Januar), str. 3-22; Nr. 8 (Februar), str. 246-271; Nr. 9 (März), str. 341-381.

[Gau37a] C. F. Gauss. [abstract of the paper:] Intensitas vis magneticae terrestris ad mensuram absolutam revocata. *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London, from 1830 to 1837 inclusive*, 3:166–174, 1837.

[Gau37b] C. F. Gauss. Misura assoluta dell' intensità della forza magnetica terrestre. *Effemeridi astronomiche di Milano*, primo supplemento:3–132, 1837. Tradotta e commentata da P. Frisiani.

[Gau41] C. F. Gauss. Intensitas vis magneticae terrestris ad mensuram absolutam revocata. *Commentationes Societatis Regiae Scientiarum Goettingensis Recentiores*, 8:3–44, 1841. Delivered before the Society in 15 December 1832. Reprinted in C. F. Gauss's *Werke*, Vol. 5, pp. 79-118 (Königliche Gesellschaft der Wissenschaften, Göttingen, 1867).

[Gau94] C. F. Gauss. Die Intensität der erdmagnetischen Kraft auf absolutes Maass zurückgeführt. In E. Dorn, editor, *Ostwald's Klassiker der exakten Wissenschaften, Vol. 53*. Wilhelm Engelmann Verlag, Leipzig, 1894. Translation by A. Kiel, notes by E. Dorn. Reprinted in: *Carl Friedrich Gauss — Werke — Supplement* — Band 3: Varia: 15 Abhandlungen in deutscher Übersetzung. Mit einer Einleitung, einer Bibliographie und Registern herausgegeben von Karin Reich. Hrsg. von der Akademie der Wissenschaften zu Göttingen, Universitätsverlag Göttingen 2019, S. 533-594.

[Gau35] C. F. Gauss. The absolute measure of magnetic force. In W. F. Magie, editor, *A Source Book in Physics*, pages 519–524, New York, 1935. McGraw-Hill.

[Gau52] C. F. Gauss, 1952. Intensivnost semnoj magnitnoj sily, privedennaja k absoljutnoj mere. In: B. M. Janovskij (Hrsg): Karl Fridrich Gauss. Izbrannye trudy po zemnomu magnetizmu. Perevod A. N. Krylova. Moskau 1952, str. 23-75.

[Gau75] C. F. Gauss. Letter from Gauss to Schumacher, April 29, 1845. In *Carl Friedrisch Gauss, Werke, Ergänzungsreihe, Vol. V, Briefwechsel C. F. Gauss — H. C. Schumacher, Part 2*, pages 436–440. Georg Olms Verlag, Hildesheim, 1975.

[Gau03] C. F. Gauss. The intensity of the earth's magnetic force reduced to absolute measurement. Translated in 1995 from the German by Susan P. Johnson, edited by L. Hecht. Available since 2003 at http://21sci-tech.com/translation.html, 2003.

[Gau21a] C. F. Gauss. [Gauss, 1832, Abstract of the paper:] *intensitas vis magneticae terrestris ad mensuram absolutam revocata*. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume I: Gauss and Weber's Absolute System of Units, pages 37–45, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Gau21b] C. F. Gauss. The absolute measure of the earth's magnetic force. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume I: Gauss and Weber's Absolute System of Units, pages 49–80, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[GW37] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1836*, volume I. Dieterichschen Buchhandlung, Göttingen, 1837.

[GW38] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1837*, volume II. Dieterichschen Buchhandlung, Göttingen, 1838.

[GW39] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1838*, volume III. Dieterichschen Buchhandlung, Göttingen, 1839.

[GW40a] C. F. Gauss and W. Weber. *Atlas des Erdmagnetismus nach den Elementen der Theorie Entworfen — Supplement zu den Resultaten aus den Beobachtungen des magnetisches Vereins unter Mitwirkung von C. W. B. Goldschmidt*. Weidmann'sche Buchhandlung, Leipzig, 1840. Reprinted in C. F. Gauss's *Werke*, Vol. 12, pp. 335-408 (Königlichen Gesellschaft der Wissenschaften, Göttingen, 1929).

[GW40b] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1839*, volume IV. Weidmannschen Buchhandlung, Leipzig, 1840.

[GW41] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1840*, volume V. Weidmannschen Buchhandlung, Leipzig, 1841.

[GW43] C. F. Gauss and W. Weber. *Resultate aus den Beobachtungen des magnetisches Vereins im Jahre 1841*, volume VI. Weidmannschen Buchhandlung, Leipzig, 1843.

[KW57] R. Kohlrausch and W. Weber. Elektrodynamische Maassbestimmungen insbesondere Zurückführung der Stromintensitäts-Messungen auf mechanisches Maass. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 3:221–292, 1857. Reprinted in *Wilhelm Weber's Werke*, Vol. 3, H. Weber (ed.), (Springer, Berlin, 1893), pp. 609-676.

[KW21] R. Kohlrausch and W. Weber. Electrodynamic measurements, fourth memoir, specially attributing mechanical units to measures of current intensity. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume III: Measurement of Weber's Constant c, Diamagnetism, the Telegraph Equation and the Propagation of Electric Waves at Light Velocity, pages 141–199, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[MF94] F. Merkel and O. Fischer. Untitled. In *Wilhelm Weber's Werke*, volume 6: Mechanik der menschlichen Gehwerkzeuge, page iii, Berlin, 1894. Springer.

[Ohm26a] G. S. Ohm. Bestimmung des Gesetzes, nach welchem Metalle die Kontakt-Elektrizität leiten, nebst einem Entwurfe zu einer Theorie des Voltaschen Apparates und des Schweiggerschen Multiplikators. *Journal für Chemie und Physik*, 46:137–166, 1826. Reprinted in *Ostwald's Klassiker der exakten Wissenschaften*, Nr. 244, C. Piel (ed.), (Akademische Verlagsgesellschaft, Leipzig, 1938), pp. 8-29.

[Ohm26b] G. S. Ohm. Ein Nachtrag zu dem vorstehenden Aufsatz. *Annalen der Physik und Chemie*, 7:117–118, 1826.

[Ohm26c] G. S. Ohm. Versuch einer Theorie der durch galvanische Kräfte hervorgebrachten elektroskopischen Erscheinungen. *Annalen der Physik und Chemie*, 6:459–469, 1826.

[Ohm26d] G. S. Ohm. Versuch einer Theorie der durch galvanische Kräfte hervorgebrachten elektroskopischen Erscheinungen (Beschluss). *Annalen der Physik und Chemie*, 7:45–54, 1826.

[Ohm27] G. S. Ohm. *Die Galvanische Kette, mathematisch bearbeitet*. T. H. Riemann, Berlin, 1827.

[Ohm60] G. S. Ohm. *Théorie Mathématique des Courants Électriques*. L. Hachette et Co., Paris, 1860. Traduction, préface et notes de J.-M. Gaugain.

[Ohm66] G. S. Ohm. The galvanic circuit investigated mathematically. In R. Taylor, editor, *Scientific Memoirs,* Vol. 2, pages 401–506, New York, 1966. Johnson Reprint Corporation. English translation by W. Francis.

[Rei02] K. Reich. *Gauß' Werke in Kurzfassung*. Erwin Rauner, Augsburg, 2002. Algorismus, Studien zur Geschichte der Mathematik und der Naturwissenschaften, Vol. 39.

[Rei19] K. Reich, 2019. Die Intensität der erdmagnetischen Kraft: Nr. 15, pp. xxxix-xlii. In *Carl Friedrich Gauss — Werke — Supplement* — Band 3: Varia: 15 Abhandlungen in deutscher Übersetzung. Mit einer Einleitung, einer Bibliographie und Registern herausgegeben von Karin Reich. Hrsg. von der Akademie der Wissenschaften zu Göttingen, Universitätsverlag Göttingen 2019, S. 533-594.

[Rie92] E. Riecke. Vorwort zum zweiten Bande. In *Wilhelm Weber's Werke*, volume 2: Magnetismus, pages iii–vi, Berlin, 1892. Springer.

[Rie93] E. Riecke. Vorwort zum fünften Bande. In *Wilhelm Weber's Werke*, volume 5: Wellenlehre, pages iii–v, Berlin, 1893. Springer.

[Voi92] W. Voigt. Vorwort zum ersten Bande. In *Wilhelm Weber's Werke*, volume 1: Akustik, Mechanik, Optik und Wärmelehre, pages iii–iv, Berlin, 1892. Springer.

[Web38] W. Weber. Das Induktions-Inklinatorium. In C. F. Gauss and W. Weber, editors, *Resultate aus den Beobachtungen des magnetischen Vereins im Jahre 1837*, volume II, chapter V, pages 81–96. Dieterichschen Buchhandlung, Göttingen, 1838. Reprinted in *Wilhelm Weber's Werke*, Vol. 2, E. Riecke (ed.), (Springer, Berlin, 1892), pp. 75-88.

[Web46] W. Weber. Elektrodynamische Maassbestimmungen — Über ein allgemeines Grundgesetz der elektrischen Wirkung. *Abhandlungen bei Begründung der Königlich Sächsischen Gesellschaft der Wissenschaften am Tage der zweihundertjährigen Geburtstagfeier Leibnizen's herausgegeben von der Fürstlich Jablonowskischen Gesellschaft (Leipzig)*, pages 211–378, 1846. Reprinted in *Wilhelm Weber's Werke*, Vol. 3, H. Weber (ed.), (Springer, Berlin, 1893), pp. 25-214.

[Web52a] W. Weber. Elektrodynamische Maassbestimmungen insbesondere über Diamagnetismus. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 1:485–577, 1852. Reprinted in *Wilhelm Weber's Werke*, Vol. 3, H. Weber (ed.), (Springer, Berlin, 1893), pp. 473-554.

[Web52b] W. Weber. Elektrodynamische Maassbestimmungen insbesondere Widerstandsmessungen. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 1:199–381, 1852. Reprinted in *Wilhelm Weber's Werke*, Vol. 3, H. Weber (ed.), (Springer, Berlin, 1893), pp. 301-471.

[Web64] W. Weber. Elektrodynamische Maassbestimmungen insbesondere über elektrische Schwingungen. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 6:571–716, 1864. Reprinted in *Wilhelm Weber's Werke*, Vol. 4, H. Weber (ed.), (Springer, Berlin, 1894), pp. 105-241.

[Web71] W. Weber. Elektrodynamische Maassbestimmungen insbesondere über das Princip der Erhaltung der Energie. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 10:1–61, 1871. Reprinted in *Wilhelm Weber's Werke*, Vol. 4, H. Weber (ed.), (Springer, Berlin, 1894), pp. 247-299.

[Web72] W. Weber. Electrodynamic measurements — Sixth memoir, relating specially to the principle of the conservation of energy. *Philosophical Magazine*, 43:1–20 and 119–149, 1872. Translated by Professor G. C. Foster, F.R.S., from the *Abhandlungen der mathem.-phys. Classe der Königlich Sächsischen Gesellschaft der Wissenschaften*, vol. x (January 1871).

[Web78] W. Weber. Elektrodynamische Maassbestimmungen insbesondere über die Energie der Wechselwirkung. *Abhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig, mathematisch-physischen Classe*, 11:641–696, 1878. Reprinted in *Wilhelm Weber's Werke*, Vol. 4, H. Weber (ed.), (Springer, Berlin, 1894), pp. 361-412.

[Web93] H. Weber. Vorwort zum dritten Bande. In *Wilhelm Weber's Werke*, volume 3: Galvanismus und Elektrodynamik. Erster Theil, pages iii–v, Berlin, 1893. Springer.

[Web94a] H. Weber. Vorwort zum vierten Bande. In *Wilhelm Weber's Werke*, volume 4: Galvanismus und Elektrodynamik. Zweiter Theil, pages iii–viii, Berlin, 1894. Springer.

[Web94b] W. Weber. Elektrodynamische Maassbestimmungen insbesondere über den Zusammenhang des elektrischen Grundgesetzes mit dem Gravitationsgesetze. In H. Weber, editor, Wilhelm Weber's *Werke,* Vol. 4, pages 479–525, Berlin, 1894. Springer.

[Web21a] W. Weber. Electrodynamic measurements, eighth memoir, relating specially to the connection of the fundamental law of electricity with the law of gravitation. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume IV: Conservation of Energy, Weber's Planetary Model of the Atom and the Unification of Electromagnetism and Gravitation, pages 173–210, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21b] W. Weber. Electrodynamic measurements, fifth memoir, relating specially to electric oscillations. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume III: Measurement of Weber's Constant c, Diamagnetism, the Telegraph Equation and the Propagation of Electric Waves at Light Velocity, pages 267–383, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21c] W. Weber. Electrodynamic measurements, first memoir, relating specially to a general fundamental law of electric action. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume II: Weber's Fundamental Force and the Unification of the Laws of Coulomb, Ampère and Faraday, pages 33–203, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21d] W. Weber. Electrodynamic measurements, second memoir, relating specially to measures of resistance. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume II: Weber's Fundamental Force and the Unification of the Laws of Coulomb, Ampère and Faraday, pages 291–441, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21e] W. Weber. Electrodynamic measurements, seventh memoir, relating specially to the energy of interaction. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume IV: Conservation of Energy, Weber's Planetary Model of the Atom and the Unification of Electromagnetism and Gravitation, pages 123–164, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21f] W. Weber. Electrodynamic measurements, sixth memoir, relating specially to the principle of the conservation of energy. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume IV: Conservation of Energy, Weber's Planetary Model of the Atom and the Unification of Electromagnetism and Gravitation, pages 67–111, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[Web21g] W. Weber. Electrodynamic measurements, third memoir, relating specially to diamagnetism. In A. K. T. Assis, editor, *Wilhelm Weber's Main Works on Electrodynamics Translated into English*, volume III: Measurement of Weber's Constant c, Diamagnetism, the Telegraph Equation and the Propagation of Electric Waves at Light Velocity, pages 11–83, Montreal, 2021. Apeiron. Available at www.ifi.unicamp.br/~assis.

[WSH03] D. Warner, R. Sherman, and K. Hentschel. The several faces of earth induction. *Bulletin of the Scientific Instrument Society*, 76:30–34, 2003.

[WW25] E. H. Weber and W. Weber. *Wellenlehre auf Experimente gegründet oder über die Wellen tropfbarer Flüssigkeiten mit Anwendung auf die Schall- und Lichtwellen*. Gerhard Fleischer, Leipzig, 1825. Reprinted in *Wilhelm Weber's Werke*, Vol. 5, E. Riecke (ed.), (Springer, Berlin, 1893). Available at http://archive.org/details/wilhelmweberswe00fiscgoog.

[WW36] W. Weber and E. Weber. *Mechanik der menschlichen Gehwerkzeuge. Eine anatomisch-physiologische Untersuchung*. Dietrich, Göttingen, 1836. Reprinted in *Wilhelm Weber's Werke*, Vol. 6, F. Merkel and O. Fischer (eds.), (Springer, Berlin, 1894). Available at http://archive.org/details/wilhelmweberswe03fiscgoog.

[WW92] W. Weber and E. Weber. *Mechanics of the Human Walking Apparatus*. Springer, Berlin, 1992. Translated by P. Maquet and R. Furlong.