Chronology of main discoveries

... it is of course necessary to make some supposition respecting the nature of that medium, or ether, the vibrations of which constitute light, ... Now, if we adopt the theory of transverse vibrations, ... we are obligued to suppose the existence of a tangential force in the ether, ... In consequence of the existence of this force, the ether must behave, so far as regards the luminous vibrations, like an elastic solid.

... I have assumed, as applicable to the luminiferous ether in vacuum, the known equations of motion of an elastic medium, such as an elastic solid. These equations contain two arbitrary constants, depending upon the nature of the medium. The argument which Green has employed to shew [show] *that the luminiferous ether must be regarded as sensibly incompressible, in treating of the motions which constitute light (Camb. Phil. Trans., Vol. VII, p. 2) appears to me of great force. The supposition of incompressibility reduces the two arbitrary constants to one; ...*

George Gabriel Stokes (Stokes, 1856)

As early as the 17th century it was known that light waves and acoustic waves are of a similar nature. Hooke believed light to be a vibratory displacement of a medium (the ether), through which it propagates at finite speed. Later, in the 19th century, Maxwell and Lord Kelvin made extensive use of physical and mathematical analogies to study wave phenomena in acoustics and electromagnetism. In many cases, this formal analogy becomes a complete mathematical equivalence such that the problems in both fields can be solved by using the same analytical (or numerical) methodology. Green (1842) made the analogy between elastic waves in an incompressible solid (the ether) and light waves. One of the most remarkable analogies is the equivalence between electric displacements and elastic displacements (Hooke's law) used by Maxwell to obtain his famous electromagnetic equations. Therefore, the study of acoustic wave propagation and light propagation are intimately related, and this fact is reflected in the course of scientific research.

The task of describing the principal achievements in the field of wave propagation is a difficult one, since many important scientists have been involved in the subject, contributing from different fields of research. Dates reveal connections and parallels; they furnish us with a basis for comparisons, which make historical studies meaningful and exciting. The following chronological table intends to give a brief glimpse of "evolution" and "causes and results" of the main scientific developments and ideas[1].

[1]Sources: Cajori (1929); Love (1944); Asimov (1972); Goldstine (1977); Ben-Menahem and Singh (1981); Cannon and Dostrovsky (1981); Pierce (1981); Rayleigh (1945); the web sites www.britannica.com, http://asa.aip.org and www.cartage.org.lb/en/themes, and the web site of the University of St. Andrews, Scotland (www-history.mcs.st-andrews.ac.uk/history).

600 BC, ca.	Thales of Miletus discovers that amber (*elektron* in Greek) rubbed with fur attracts light bodies.
580 BC, ca.	Pythagoras makes experiments on harmony and musical intervals. He relates the length of vibrating string to the pitch.
325 BC, ca.	Euclid describes the law of reflection in his *Optica*.
60, ca.	Heron writes his *Catoptrica*, where he states that light rays travel with infinite velocity.
139, ca.	Ptolemy measures angles of incidence and refraction, and arranges them in tables. He found those angles to be proportional (small-angle approximation).
990, ca.	al–Haythan writes his *Optics*. He shows that Ptolemy was in error, and refers for the first time to the "camera obscura".
1210, ca.	Grosseteste writes *De Natura Locorum* and *De Iride*.
1268, ca.	Bacon writes *The Communia Naturalium* and *The Communia Mathematicae*. He attributes the rainbow to the reflection of sunlight from single raindrops.
1269, ca.	Petrus Peregrinus writes *Epistola de Magnete*.
1270, ca.	John Peckham (died 1292) writes the treatise on optics *Perspectiva Communis*.
1270, ca.	Witelo writes *Perspectivorum Libri*, where he interprets the rainbow as reflection and refraction of light.
1307, ca	Dietrich of Freiberg gives the first accurate explanation of the rainbow.
1480	Leonardo da Vinci makes the analogy between light waves and sound.
1558	Della Porta publishes *Magia Naturalis*, where he analyzes magnetism.
1560 ca.	Maurolycus writes *Photismi de Lumine et Umbra*, about photometry.
1581	V. Galilei (Galileo's father) studies sound waves and vibrating strings.
1600	Gilbert writes *De Magnete*, and shows that the Earth is a magnet.
1608	Lippershey constructs a telescope with a converging objective lens and a diverging eye lens.
1611	De Dominis explains the decomposition of colors of the rainbow and the tides.
1611	Kepler publishes his *Dioptrica*, where he presents an empirical expression of the law of refraction. He discovers total internal reflection.
1620, ca.	Snellius obtains experimentally the law of refraction, although the discovery is attributed to Harriot.
1629	Cabeo writes *Philosophia Magnetica*, where he investigates electrical repulsion.
1636	Mersenne publishes his *Harmonie Universelle*, containing the first correct account of the vibrations of strings, and the first determination of the frequency of an audible tone (84 Hz).
1637	Descartes publishes Snell's law in his *La Dioptrique*, without mentioning Snell.
1638	Galileo publishes *Discorsi e Dimostrazioni Matematiche, intorno à due Nuove Scienze*, including a discussion of the vibration of bodies.
1641	Kircher writes *Magnes, De Arte Magnetica*. It contains the first use of the term "electro-magnetism".
1646	Browne introduces the term "electricity".
1646	Leibniz introduces the idea of internal tension.
1656	Borelli and Viviani measure the sound velocity in air and obtain 350 m/s.
1660	Boyle demonstrates from vacuum experiments that sound propagates in air.

1660	Hooke states his law: *Ut tensio sic vis* (The Power of any Spring is in the same proportion with the Tension thereof), published in 1678.
1661, ca.	Fermat demonstrates Snell's law using the principle of least time.
1665	Hooke publishes his *Micrographia*, where he proposes a theory of light as a transverse vibrational motion, making an analogy with water waves. (Mariotte enunciates the same law independently in 1680.)
1666	Grimaldi discovers the phenomenon of diffraction (in *Physico Mathesis of Lumine*).
1666	Newton performs his experiments on the nature of light, separating white light into a band of colours - red, orange, yellow, green, blue, and violet. He uses the corpuscular assumption to explain the phenomenon.
1669	Bartholinus observes double refraction in Iceland spar.
1675	Newton is against the assumption that light is a vibration of the ether.
1675	Boyle writes *Experiments and Notes about the Mechanical Origin or Production of Electricity.*
1675	Newton develops the theory of finite differences and interpolation, previously introduced by Harriot and Briggs.
1675	Newton argues that double refraction rules out light being ether waves.
1676	Römer measures the speed of light by studying Jupiter's eclipses of its four larger satellites.
1678	Huygens proposes the wave nature of light in his *Traité de la Lumière* (first published in 1690). He assumes the vibrations in the ether to be longitudinal. He also exposes the principle of wave-front construction. (A wave theory of light had been proposed earlier by Ango and Pardies.)
1678	Huygens provides a theoretical basis for double refraction.
1682	Pierre Ango publishes his *L'optique.*
1687	Newton publishes his *Principia.* He provides a theoretical deduction for the velocity of sound in air, and finds 298 m/s. The relation wavelength times frequency equal velocity is given.
1700, ca.	Sauveur introduces the terms "nodes", "harmonic tone", "fundamental vibration", and suggests the name "acoustics" for the science of sound.
1704	Newton publishes his *Opticks.*
1713	Taylor obtains a dynamic solution for the vibrating string (*Philosophical Transactions*).
1727	Euler proposes a linear relation between stress and strain.
1728	Bradley discovers the phenomenon of stellar aberration.
1729	Gray shows that electricity can be transferred with conducting wires.
1740	Bianconi shows that the velocity of sound in air increases with temperature.
1743	d'Alembert publishes his *Traité de Dynamique.*
1744	Euler introduces the concept of strain energy per unit length for a beam.
1744-51	D. Bernoulli and Euler obtain the differential equation and the dispersion relation for lateral vibrations of bars.
1745	Nollet writes *Essai sur l'Electricité des Corps.*
1747	d'Alembert derives the one-dimensional wave equation for the case of a vibrating string, and its solution for plane waves.

1750	Michell writes *A Treatise on Artificial Magnets.*
1752	Euler introduces the idea of compressive normal stress as the pressure in a fluid.
1755	D. Bernoulli proposes the principle of "coexistence of small oscillations" (the superposition principle).
1759	Euler derives the wave equation for sound. He develops the method of images.
1759	Aepinus publishes *An Attempt of a Theory of Electricity and Magnetism.*
1759	Lagrange solves the problem of the vibrating string.
1760	Laplace introduces the first version of the "divergence theorem", later enunciated by Gauss in 1813.
1762	Canton demonstrates that water is compressible.
1764	Euler derives the "Bessel equation" in an analysis of vibrations of membranes.
1772	Cavendish writes *An attempt to explain some of the Principal Phenomena of Electricity by means of an Elastic Fluid.*
1773-79	Coulomb applies the concept of shear stress to failure of soils and frictional slip.
1776	Euler publishes th so-called "Euler's equation of motion" in its general form.
1776	Soldner calculates the deflection of light by the sun (0.85 arc-seconds), rederived later by Cavendish and Einstein.
1777	Lagrange introduces the concept of scalar potential for gravitational fields.
1782	Laplace derives the so-called "Laplace equation".
1785	Coulomb uses the torsion balance to verify that the electric-force law is inverse square.
1787	Chladni visualizes – experimentally – the nodes of vibrating plates.
1788	Lagrange publishes his *Mécanique Analytique.*
1799	Laplace publishes his *Traité du Mécanique Céleste.*
1799	Volta invents the electric battery.
1801	Ritter discovers the ultraviolet radiation .
1801	Young revives the wave theory of light. He introduces the principle of interference.
1802	Chladni publishes his *Die Akustik.*
1802	Chladni investigates longitudinal and torsional vibrations of bars experimentally.
1806	Young defines his modulus of elasticity and considers shear as an elastic strain.
1808	J. B. Biot measures the velocity of sound in iron.
1808	Chladni studies the vibrations of strings and plates, and longitudinal and torsional vibrations in rods.
1808	Laplace proposes a corpuscular theory of double refraction.
1808	Malus discovers polarization of light.
1808	Poisson publishes his memoir on the theory of sound.
1809	Young proposes a dynamic (wave) theory of light in crystals.
1811	Poisson publishes his *Traité de Mécanique.*
1811	Arago shows that some crystals alter the polarization of light.

1812 Biot shows that some crystals rotate the plane of polarization of light.
1813 Poisson derives the so-called "Poisson equation" as a relation between gravitational potential and mass density.
1814 Fraunhofer discovers the dark line spectrum. Light waves reveal the presence of specific elements in celestial bodies (Kirchhoff and Bunsen's paper, 1859).
1815 Brewster investigates the "Brewster angle" on the basis of his experiments and those of Malus.
1816 Fresnel establishes the basis for the "Fresnel-Kirchhoff theory of diffraction".
1816 Laplace shows that the adiabatic elasticity should be used to calculate the sound velocity in air.
1816 Young suggests the transversality of the vibrations of light, based on the fact that light of differing polarization cannot interfere. This solves many of the difficulties of the wave theory.
1820 Poisson solves the problem of propagation of compressional waves in a three-dimensional fluid medium.
1820 Oersted notes the relation between electricity and magnetism.
1820 Ampère models magnets in terms of molecular electric currents (electrodynamics).
1820 Biot and Savart deduce the formula for the magnetic strength generated by a segment of wire carrying electric current.
1821 Davy shows the resistance of a long conductor is proportional to its length and inversely proportional to its cross-sectional area.
1821 Fresnel interprets the interference of polarized light in terms of transverse vibrations.
1821 Navier derives the differential equations of the theory of elasticity in terms of a single elasticity constant.
1822 Seebeck discovers the thermoelectric effect.
1822 Cauchy introduces the notion of stress (strain) by means of six component stresses (strains). He also obtains an equation of motion in terms of the displacements and two elasticity constants.
1822 Fourier publishes his *Analytical Theory of Heat*, where he introduces the infinite series of sines and cosines (mathematical form of the superposition principle).
1823 Fresnel obtains his formulae for reflection and refraction of light.
1824 Hamilton publishes his first paper *On Caustics*.
1825 Ampère publishes his law, known also as Stokes theorem.
1825 Weber publishes his book *Wellenlehre*.
1826 Airy publishes his *Mathematical Tracts on Physical Astronomy*.
1826 Colladon and Sturm measure the speed of sound in water, obtaining 1435 m/s .
1826 Hamilton publishes his *Theory of Systems of Rays*. He introduces the characteristic function for optics.
1827 Ohm obtains the relation between electric current and resistance.
1828 Cauchy extends his theory to the general case of aeolotropy, and finds 21 elasticity constants – 15 of them are true elasticity constants (the "rari-constant" theory).
1828 Green introduces the concept of potential in the mathematical theory of electricity and magnetism. He derives the "Green's theorem".

1828 Poisson predicts the existence of compressional and shear elastic waves. His theory predicts a ratio of the wave velocities equal to $\sqrt{3}/1$, and Poisson ratio equal to 1/4.
1830 Cauchy investigates the propagation of plane waves in crystalline media.
1830 Savart measures the minimum and maximum audible frequencies (8 and 24000 vibrations per second, respectively).
1831 Faraday shows that varying currents in one circuit induce a current in a neighboring circuit.
1832 Henry independently discovers the induced-currents effect.
1832 Gauss independently states Green's theorem.
1833 Hamilton introduces the concept of "eikonal equation", the term eikonal being introduced into optics by Bruns.
1833 Hamilton develops the basic geometric concepts of slowness surfaces for anisotropic media. He predicts conical refraction, that is verified experimentally by Lloyd .
1834 Hamilton publishes his *On a General Method in Dynamics*. The Hamiltonian concept for dynamics is introduced .
1835 Gauss formulates "Gauss's law".
1835 MacCullagh and Neumann generalize Cauchy's theory to anisotropic media.
1836 Airy calculates the diffraction pattern produced by a circular aperture.
1837 Green discovers the boundary conditions of a solid/solid interface.
1837 Green derives the equations of elasticity from the principle of conservation of energy. He defines the strain energy, and finds 21 elasticity constants in the case of aeolotropy (the "multi-constant" theory).
1837 Faraday introduces the concept of the dielectric permittivity.
1838 Faraday explains electromagnetic induction, showing that magnetic and electric induction are analogous.
1838 Airy develops the theory of caustics.
1838 Green solves the reflection-refraction problems for a fluid/fluid boundary and for a solid/solid boundary (the ether) and applies the results to light propagation.
1839 Cauchy proposes an elastic ether of negative compressibility.
1839 Green, like Cauchy in 1830, investigates crystalline media and obtains the equations for the propagation velocities in terms of the propagation direction.
1839 MacCullagh proposes an elastic ether without longitudinal waves, based on the rotation of the volume elements.
1839 Lord Kelvin finds a mechanical-model analogue of MacCullagh's ether.
1842 Doppler discovers the "Doppler effect".
1842 Mayer states that work and heat are equivalent. His paper is rejected in the *Annalen der Physik*.
1842 Lord Kelvin uses the theory of heat to obtain the continuity equation of electricity.
1844 Scott Russell discovers the solitary wave.
1845 Faraday discovers the magnetic rotation of light. He introduces the concept of field.
1845 Neumann introduces the vector potential. The next year, Lord Kelvin shows that the magnetic field can be obtained from this vector.

1845 Stokes identifies the modulus of compression and the modulus of rigidity, as corresponding to resistance to compression and resistance to shearing, respectively.
1846 Faraday publishes *Thoughts on Ray Vibrations* in *Philosophical Magazine*. He suggests the electromagnetic nature of light.
1846 Weber combines electrostatics, electrodynamics and induction, and proposes an electromagnetic theory.
1847 Helmholtz writes a memoir about the conservation of energy. The paper is rejected for publication in the *Annalen der Physik*.
1848 Kirchhoff generalizes Ohm's law to three dimensions.
1849 Meucci invents the telephone.
1849 Stokes shows that Poisson's two waves correspond to irrotational dilatation and equivoluminal distortion.
1849 Fizeau confirms Fresnel's results using interferometry.
1850 Foucault measures the velocity of light in water to be less than in air. Newton's emission theory – which predicts the opposite – is abandoned.
1850 Stokes introduces a (wrong) concept of anisotropic inertia to explain wave propagation in crystals.
1850 Lord Kelvin states Stokes theorem without proof and Stokes provides a demonstration.
1853 Lord Kelvin gives the theory of the RLC circuit.
1854 Lord Kelvin derives the telegraphy equation without the inductance (a diffusion equation).
1855 Lord Kelvin justifies Green's strain-energy function on the basis of the first and second laws of thermodynamics.
1855 Palmieri devises the first seismograph.
1855 Weber and Kohlrausch find an electromagnetic velocity equal to $\sqrt{2}$ the light velocity.
1856 Lord Kelvin introduces the concepts of eigenstrain ("principal strain") and eigenstiffness ("principal elasticity").
1857 Kirchhoff derives the telegraphy equation including the inductance. He finds a velocity close to the velocity of light.
1861 Riemann modifies Weber's electromagnetic theory.
1861 Kirchhoff derives the theory of the black body.
1863 Helmholtz introduces the concept of "point source".
1863 Helmholtz publishes his *Lehre von den Tonemfindgungen* about the theory of harmony.
1864 Maxwell obtains the equations of electromagnetism. The electromagnetic nature of light is demonstrated.
1867 Maxwell introduces the "Maxwell model" to describe the dynamics of gases.
1867 Lorenz develops the electromagnetic theory in terms of retarded potentials.
1870 Christiansen discovers anomalous dispersion of light in solutions.
1870 Helmholtz shows that Weber's theory is not consistent with the conservation of energy.

1870 Helmholtz derives the laws of reflection and refraction from Maxwell's equations, which were the subject of Lorentz's thesis in 1875.
1871 Rankine publishes equations to describe shock waves (later also published by Hugoniot in 1889).
1871 Rayleigh publishes the so-called "Rayleigh scattering" theory, which provides the first correct explanation of why the sky is blue.
1872 Bétti states the reciprocity theorem for static fields.
1873 Maxwell publishes his *Treatise on Electricity and Magnetism.*
1873 Rayleigh derives the reciprocity theorem for vibrating bodies.
1874 Boltzmann lays the foundations of hereditary mechanics ("Boltzmann's superposition principle").
1874 Cornu introduces the "Cornu spiral" for the solution of diffraction problems.
1874 Meyer introduces the "Voigt solid".
1874 Umov introduces the vector of the density of energy flux.
1875 Kerr discovers the *Kerr effect.* A dielectric medium subject to a strong electric field becomes birefringent.
1876 Pochhammer studies the axial vibrations of cylinders.
1877 Christoffel investigates the propagation of surfaces of discontinuity in anisotropic media.
1877 Rayleigh publishes *The Theory of Sound.*
1879 Hall discovers the "Hall effect".
1880 Pierre and Jacques Curie discover piezoelectricity.
1880 Kundt discovers anomalous dispersion in the vapor of sodium.
1881 Michelson begins his experiments to detect the ether.
1884 Poynting establishes from Maxwell's equations that energy flows and can be localized.
1885 Lamb and Heaviside discover the concept of skin depth.
1885 Somigliana obtains solutions for a wide class of sources and boundary conditions.
1885 Lord Rayleigh predicts the existence of "Rayleigh surface waves".
1887 Voigt performs experiments on anisotropic samples (beryl and rocksalt).
The "multi-constant" theory – based on energy considerations – is confirmed.
The "rari-constant" theory – based on the molecular hypothesis – is dismissed.
1887 Heaviside writes Maxwell's equations in vector form. He invents the modern vector calculus notation, including the gradient, divergence and curl of a vector.
1887 Voigt, investigating the Doppler effect in the ether, obtains a first version of "Lorentz transformations".
1888 Hertz generates radio waves, confirming the electromagnetic theory. He discovers the photoelectric effect and predicts a finite gravitational velocity.
1889 Fitzgerald suggests that the speed of light is an upper bound.
1889 Reuber-Paschwitz detects P waves in Potsdam generated by an earthquake in Japan. Global seismology is born.
1890 Hertz replaces potential by field vectors and deduces Ohm's, Kirchhoff's and Coulomb's laws.
1893 Pockels discovers the *Pockels effect*, similar to the *Kerr effect.*

1894	Korteweg and de Vries obtain the equation for the solitary wave.
1894-901	Runge and Kutta develop the Runge-Kutta algorithm.
1895	Lorentz gives the "Lorentz transformations" to first order in the normalized velocity.
1896	Rudzki applies the theory of anisotropy to seismic wave propagation.
1897	Marconi's first wireless-telegraphy patent.
1899	Knott derives the equations for the reflection and transmission of elastic plane waves at plane interfaces.
1900	Marconi's second wireless-telegraphy patent.
1902	Poynting and Thomson introduce the "standard linear solid" model, referred to here as the Zener model.
1903	Love develops the theory of point sources in an unbounded elastic space.
1904	Lamb obtains the Green's function for surface Rayleigh waves.
1904	Volterra publishes his theory of dislocations based on Somigliana's solution.
1904	Volterra introduces the integro-differential equations for hereditary problems.
1905	Einstein investigates the photoelectric effect and states that light is discrete electromagnetic radiation.
1906	Oldham (1906) discovers the Earth's core by using P-wave amplitudes.
1908	Mie develops the "Mie scattering" theory, describing scattering of spherical particles.
1909	Cosserat publishes his theory of micropolar elasticity (Cosserat and Cosserat, 1909).
1909	Mohorovičić discovers the "Moho" discontinuity on the basis of seismic waves.
1911	Debye introduces the ray series or "Debye expansion".
1911	Love discovers the "Love surface waves".
1912	L. F. Richardson patents the first version of sonar.
1912	Sommerfeld introduces the "Sommerfeld radiation condition".
1915	Galerkin publishes his finite-element method.
1919	Mintrop discovers the seismic head wave.
1920-27	The WKBJ (Wentzel, Kramers, Brillouin, Jeffreys) approximation is introduced in several branches of physics.
1923	de Broglie proposes the model by which tiny particles of matter, such as electrons, display the characteristics of waves.
1924	Stoneley (1924) publishes his paper about "Stoneley interface waves".
1925	Walter Elsasser describes electron diffraction as a wave property of matter.
1926	Born develops the "Born approximation" for the scattering of atomic particles.
1926	Jeffreys establishes that the outer Earth's core is liquid by using S waves.
1926	Schrödinger works out the mathematical description of the atom called "wave mechanics", based on Hamilton's principle.
1926	Klein-Fock-Gordon equation: a relativistic version of the Schrödinger wave equation.
1927	Paul Dirac presents a method to represent the electromagnetic field as quanta.
1928-35	Graffi studies hereditary and hysteretic phenomena based on Volterra's theory.

1928 Nyquist introduces the sampling theorem.
1928 Sokolov proposes an ultrasonic technique to detect flaws in metals.
1932 Debye and Sears observe the diffraction of light by ultrasonic waves.
1934 Frenzel and Schultes (1934) discover sonoluminescence (Born and Wolf, 1964, p. 594).
1935 Richter and Gutenberg invented the Richter magnitude scale.
1936 Lehmann discovers the Earth's inner core on the basis of P waves generated by the 1929 New-Zeland earthquake.
1937 Bruggeman shows that finely layered media behave as anisotropic media.
1938 S. M. Rytov develops the ray theory for electromagnetic waves.
1939 Walter Elsasser states that eddy currents in the liquid core, due to the Earth's rotation, generate the observed magnetic field.
1939 Cagniard (1939) publishes his method for solving transient elastic-wave propagation.
1939 Graffi extends the reciprocal theorem of Bétti to dynamic fields, although the concept dates back to Helmholtz (1860) and Rayleigh (1973)
1940 Firestone develops and ultrasonic pulse-echo metal-flaw detector.
1941 Biot publishes the theory of consolidation.
1941 Karl T. Dussik makes the first attempt at medical imaging with ultrasound.
1941 Kosten and Zwikker (1941) propose a scalar theory, predicting the existence of two compressional waves.
1943 Terzaghi publishes his *Theoretical Soil Mechanics*.
1944 Frenkel publishes his paper on the dynamics of porous media and the seismoelectric effect. The equations are nearly identical to Biot's poroelastic equations.
1944 Peshkov observes second (thermal) sound in liquid helium II.
1947 Scholte identifies the interface wave traveling at liquid-solid interfaces.
1948 Feynman develops the path integral formulation.
1948 Gabor describes the principle of wave-front reconstruction, the basis of holography.
1949 Kyame (1949) publishes his theory about waves in piezoelectric crystals.
1949 Mindlin publishes the Hertz-Mindlin model to obtain the rock moduli as a function of differential pressure.
1951 Gassmann derives the "Gassmann modulus" for a saturated porous medium.
1952 Lighthill (1952) publishes the aeroacoustics equation.
1953 Haskell (1953) publishes his matrix method for wave propagation.
1953 Kornhauser (1953) publishes the ray theory for moving fluids.
1956 Biot publishes the dynamic theory of porous media and predicts the slow compressional wave.
1958 de Hoop develops the Cagniard-de Hoop technique.
1958 McDonal, Angona, Milss, Sengbush, van Nostrand, and White publish field experiments indicating constant Q in the seismic frequency band.
1959 Knopoff and Gangi develop the reciprocity principle for anisotropic media.
1962 Backus obtain the transversely-isotropic equivalent medium of a finely layered medium.
1963 Deresiewicz and Skalak obtain the boundary conditions at an interface between porous media.

1963 Hashin and Shtrikman obtain bounds for the elastic bulk and shear moduli of a composite.
1964 Brutsaert presents a theory for wave propagation in partially saturated soils. The theory predicts three P waves.
1964 Hess (1964) provides evidence of the seismic anisotropy of the uppermost mantle.
1965 Shapiro and Rudnik (1965) observe fourth sound in helium II.
1966 de Hoop develops the reciprocity principle for anisotropic anelastic media.
1966 King performs laboratory experiments on partially-saturated rocks.
1968 Alterman and Karal use finite differences to compute synthetic seismograms.
1968 McAllister (1965) invents the Sodar.
1969 Waterman (1969) introduces the T-matrix formulation for acoustic scattering.
1971 Buchen investigates the properties of plane waves in viscoelastic media.
1971 First observational evidence that the inner core is solid (Dziewonski and Gilbert, 1971).
1971 O'Doherty and Anstey obtain their formula to describe stratigraphic filtering.
1972 Becker and Richardson explain the "Rayleigh window" phenomenon using viscoelastic waves .
1972 Lysmer and Drake simulate seismic surface waves with finite-elements methods.
1975 Brown and Korringa obtain the elasticity tensor for anisotropic porous media.
1975 White develops the theory describing the mesoscopic-loss mechanism.
1977 Currie, Hayes and O'Leary predict additional Rayleigh waves in viscoelastic media.
1977 Domenico performs laboratory experiments on unconsolidated reservoir sands.
1979 Allan M. Cormack and Godfrey N. Hounsfield receive the Nobel Prize for developing computer axial tomography (CAT).
1979 Burridge and Vargas obtain the Green's function for poroelasticity.
1980 Plona observes the slow compressional wave in synthetic media .
1981 Gazdag introduces the Fourier pseudospectral method to compute synthetic seismograms.
1981 Masters and Gilbert (1981) observe spheroidal mode splitting in the inner code, indicating anisotropy.
1982 Feng and Johnson predict a new surface wave at a fluid/porous medium interface.
1984 Day and Minster use internal variables (memory variables) to model anelastic waves .
1990 Santos, Douglas, Corberó and Lovera generalize Biot's theory to the case of one rock matrix and two saturating fluids. The theory predicts a second slow P wave.
1994 Leclaire, Cohen-Ténoudji and Aguirre-Puente generalize Biot's theory to the case of two rock matrices and one saturating fluid. The theory predicts two additional slow P waves and a slow S wave.
1994 Helbig introduces Kelvin's theory of eigenstrains in seismic applications.
2004 Pride, Berryman and Harris show that the mesoscopic loss is the dominant mechanism in fluid-filled rocks at seismic frequencies.

Leonardo's manuscripts

Leonardo da Vinci (1452-1519)[2]

"Leonardo perceived intuitively and used effectively the right experimental method a century before Francis Bacon philosophised about it inadequately, and Galileo put it into practice (Dampier, 1961).

Description of wave propagation, interference and Huygens' principle (1678):

Everything in the cosmos is propagated by means of waves... (Manuscript H, 67r, Institut de France, Paris.) *I say: if you throw two small stones at the same time on a sheet of motionless water at some distance from each other, you will observe that around the two percussions numerous separate circles are formed; these will meet as they increase in size and then penetrate and intersect one another, all the while maintaining as their respective centres the spots struck by the stones. And the reason for this is that water, although apparently moving, does not leave its original position, because the openings made by the stones close again immediately.. Therefore, the motion produced by the quick opening and closing of the water has caused only a shock which may be described as tremor rather than movement. In order to understand better what I mean, watch the blades of straw that because of their lightness float on the water, and observe how they do not depart from their original positions in spite of the waves underneath them caused by the occurrence of the circles. The reaction of the water being in the nature of tremor rather than movement, the circles cannot break one another on meeting, and as the water is of the same quality all the way through, its parts transmit the tremor to one another without changing position.* (Manuscript A, 61r, Institut de France, Paris.)

Description of the effect discovered by Doppler in 1842:

If a stone is flung into motionless water, its circles will be equidistant from their centre. But if the stream is moving, these circles will be elongated, egg-shaped, and will travel with their centre away from the spot where they were created, following the stream. (Manuscript I, 87, Institut de France, Paris.)

Description of Newton's prism experiment (1666):

If you place a glass full of water on the windowsill so that the sun's rays will strike it from the other side, you will see the aforesaid colours formed in the impression made by the sun's rays that have penetrated through that glass and fallen in the dark at the foot of a window and since the eye is not used here, we may with full certainty say that these colours are not in any way due to the eye. (Codex Leicester, 19149r, Royal Library, Windsor.)

[2]Sources: White (2000); http://www.gutenberg.org/

Leonardo's scientific approach to investigate the refraction of light:

Have two trays made parallel to each other... and let one by 4/5 smaller than the other, and of equal height. Then enclose one in the other and paint the outside, and leave uncovered a spot the size of a lentil, and have a ray of sunlight pass there coming from another opening or window. Then see whether or not the ray passing in the water enclosed between the two trays keeps the straightness it had outside. And form your rule from that. (Manuscript F, 33v, Institut de France, Paris.)

Description of atmospheric refraction, discovered by Brahe in the 16th century:

To see how the sun's rays penetrate this curvature of the sphere of the air, have two glass spheres made, one twice the size of the other, as round as can be. Then cut them in half and put one inside the other and close the fronts and fill with water and have the ray of sunlight pass as you did above [here he is referring to his earlier simpler refraction experiment]. *And see whether the ray is bent. And thus you can make an infinite number of experiments. And form your rule.* (Manuscript F, 33v, Institut de France, Paris.)

Explanation of the blue sky, before Tyndall's 1869 experiments and Rayleigh's 1871 theory:

I say that the blue which is seen in the atmosphere is not given its own colour, but is caused by the heated moisture having evaporated into the most minute and imperceptible particles, which the beams of the solar rays attract and cause to seem luminous against the deep, intense darkness of the region of fire that forms a covering among them. (Codex Leicester, 4r Royal Library, Windsor.)

Statement about light having a finite velocity, before Römer's conclusive measurement in 1676:

It is impossible that the eye should project the visual power from itself by visual rays, since, as soon as it opens, that front [of the eye] *which would give rise to this emanation would have to go forth to the object, and this it could not do without time. And this being so, it could not travel as high as the sun in a month's time when the eye wanted to see it.* (Ashburnham I & II, Biblioathèque Nationale, Paris.)

Description of the principle of the telescope:

It is possible to find means by which the eye shall not see remote objects as much diminished as in natural perspective... (Manuscript E, 15v, Institut de France, Paris.) *The further you place the eyeglass from the eye, the larger the objects appear in them, when they are for persons fifty years old. And if the eye sees two equal objects in comparison, one outside of the glass and the other within the field, the one in the glass will seem large and the other small. But the things seen could be 200 ells* [a little over 200 m] *from the eye...* (Manuscript A, 12v, Institut de France, Paris.) Construct glasses to see the Moon magnified. (Codex Atlanticus, 190r,a, Ambrosiana Library, Milan.)

A statement anticipating Newton's third law of motion (1666):

As much pressure is exerted by the object against the air as by the air against the body. (Codex Atlanticus, 381, Ambrosiana Library, Milan.)

The principle of least action, stated before Fermat in 1657 and Hamilton in 1834:

Every action in nature takes place in the shortest possible way. (Quaderni, IV, 16r.)

Leonardo described fossil shells as the remains of ancient organisms and put forward a mass/inertia theory to describe seabed and continent up- and down-lifting as mountains eroded elsewhere on the planet. The evolution and age of the Earth and living creatures, preceding George Cuvier (1804) and Charles Lyell (1863), and plate tectonics, anticipating Wegener (1915):

That in the drifts, among one and another, there are still to be found the traces of the worms which crawled upon them when they were not yet dry. And all marine clays still contain shells, and the shells are petrified together with the clay. From their firmness and unity some persons will have it that these animals were carried up to places remote from the sea by the deluge. Another sect of ignorant persons declare that Nature or Heaven created them in these places by celestial influences, as if in these places we did not also find the bones of fishes which have taken a long time to grow; and as if, we could not count, in the shells of cockles and snails, the years and months of their life, as we do in the horns of bulls and oxen, and in the branches of plants that have never been cut in any part...

And within the limits of the separate strata of rocks they are found, few in number and in pairs like those which were left by the sea, buried alive in the mud, which subsequently dried up and, in time, was petrified...

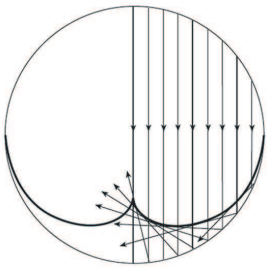
Great rivers always run turbid, being coloured by the earth, which is stirred by the friction of their waters at the bottom and on their shores; and this wearing disturbs the face of the strata made by the layers of shells, which lie on the surface of the marine mud, and which were produced there when the salt waters covered them; and these strata were covered over again from time to time, with mud of various thickness, or carried down to the sea by the rivers and floods of more or less extent; and thus these layers of mud became raised to such a height, that they came up from the bottom to the air. At the present time these bottoms are so high that they form hills or high mountains, and the rivers, which wear away the sides of these mountains, uncover the strata of these shells, and thus the softened side of the earth continually rises and the antipodes sink closer to the centre of the earth, and the ancient bottoms of the seas have become mountain ridges...

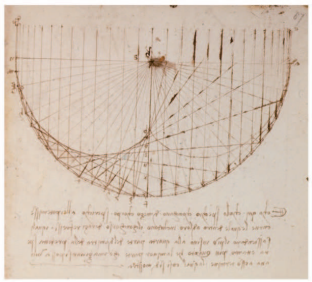
The centre of the sphere of waters is the true centre of the globe of our world, which is composed of water and earth, having the shape of a sphere. But, if you want to find the centre of the element of the earth, this is placed at a point equidistant from the surface of the ocean, and not equidistant from the surface of the earth; for it is evident that this globe of earth has nowhere any perfect rotundity, excepting in places where the sea is, or marshes or other still waters. And every part of the earth that rises above the water is farther from the centre. (Codex Leicester, Royal Library, Windsor.)

The theory of evolution, stated before Maupertuis (1745) and Charles Darwin (1859):

Nature, being inconstant and taking pleasure in creating and making constantly new lives and forms, because she knows that her terrestrial materials become thereby aug-

mented, is more ready and more swift in her creating than time in his destruction... (Codex Leicester, Royal Library, Windsor.)





The coffee cup caustic. The bright line seen in a coffee cup on a sunny day is a caustic. Consider the Sun as a point source of light and constructs rays according to geometrical optics. Parallel rays reflected in the inner surface generate a curved surface (caustic), which is the envelope of the rays. The caustic has a cusp at its center (paraxial focus). Note that the surface is brighter below the caustic (e.g., Nye, 1999). This phenomenon has been described by Bernoulli (1692) and Holditch (1858). Leonardo has predicted the phenomenon. He is arguing that in concave mirrors of equal diameter, the one which has a shallower curve will concentrate the highest number of reflected rays on to a focal point, and *as a consequence, it will kindle a fire with greater rapidity and force* (Codex Arundel, MS 263, f.86v-87, British Library, London). Seismic reflections from a geological syncline produce these types of caustics.

A list of scientists

L'ère nouvelle commence à Galilèe, Boyle et Descartes, les fondateurs de la Philosophie expérimentale; tous trois consacrent leur vie à méditer sur la nature de la lumière, des couleurs et des forces. Galilèe jette les bases de la Mécanique, et, avec le télescope à réfraction, celles de l'Astronomie physique; Boyle perfectionne l'expérimentation; quant à Descartes, il embrasse d'une vue pénétrante l'ensemble de la Philosophie naturelle.

Alfred Cornu (Cornu, 1900)

The following scientists have contributed to the understanding of wave propagation from different fields – optics, music, rheology, electromagnetism, acoustics, ray and field theory, differential calculus, seismology, etc. This list includes scientists born during and before the 19th century[3].

Thales of Miletus	ca. 634 BC	ca. 546 BC	Greece
Pythagoras	ca. 560 BC	ca. 480 BC	Greece
Aristotle	ca. 384 BC	ca. 322 BC	Greece
Euclid of Alexandria	ca. 325 BC	ca. 265 BC	Egypt
Chrysippus of Soli	ca. 279 BC	ca. 207 BC	Greece
Vitruvius	ca. 25 BC		Rome
Heron of Alexandria	ca. 10	ca. 75	Egypt
Ptolemy, Claudius	ca. 85	ca. 165	Egypt
Boethius, Anicius Manlius Severinus	ca. 480	ca. 525	Rome
Ibn al–Haythan	ca. 965	ca. 1040	Iraq
al–Ghazzali, Abu Hamid Muhammad	1058	1111	Iran
Grosseteste, Robert	1168	1253	England
Bacon, Roger	1214	1294	England
Petrus Peregrinus	ca. 1220	ca. 1270	France
Witelo	ca. 1230	ca. 1275	Poland
Dietrich of Freiberg	1250	1310	England
Buridan, Jean	ca. 1295	1358	England
Pacioli, Luca	1445	1514	Italy

[3]The sources are the Dictionary of Scientific Biography, Gillispie, C. C., Ed., Charles Scribner's Sons (1972), the web site of the University of St. Andrews, Scotland (www-history.mcs.st-andrews.ac.uk/history), the web site of Eric Weisstein's Treasure Trove of Scientific Biography (www.treasure-troves.com), the web site of the University of Florence, Italy (www.math.unifi.it/matematicaitaliana), the web site of the University of Göttingen, Germany (www.uni-geophys.gwdg.de), www.asap.unimelb.edu.au (Bright Sparcs), www.encyclopedia.com, www.explore-biography.com, www.bookrags.com, www.univie.ac.at, and www.sparkmuseum.com. Names in bold font appear in the chronology. The place of birth is indicated

Leonardo da Vinci	1452	1519	Italy
Agricola, Georgius Bauer	1490	1555	Germany
Maurolycus, Franciscus	1494	1575	Italy
Galilei, Vincenzo	1520	1591	Italy
Cardano, Girolamo	1501	1576	Italy
Della Porta, Giambattista	1535	1615	Italy
Gilbert, William	1544	1603	England
Brahe, Tycho	1546	1601	Sweden
De Dominis, Marco Antonio	1560	1624	Italy
Harriot, Thomas	1560	1621	England
Bacon, Francis	1561	1626	England
Briggs, Henry	1561	1630	England
Galilei, Galileo	1564	1642	Italy
Lippershey, Hans	1570	1619	The Netherlands
Kepler, Johannes	1571	1630	Germany
Scheiner, Christoph	ca. 1573	1650	Germany
Risner, Friedrich	ca. 1580		Germany
Snel van Royen (**Snellius**) Willebrord	1580	1626	The Netherlands
Cabeo, Nicolo	1585	1650	Italy
Mersenne, Marin	1588	1648	France
Gassendi, Pierre	1592	1655	France
Descartes, René	1596	1650	France
Cavalieri, Bonaventura	1598	1647	Italy
Fermat, Pierre de	1601	1665	France
Guericke, Otto von	1602	1686	Germany
Kircher, Athanasius	ca. 1602	1680	Germany
Browne, Thomas	1605	1682	England
Borelli, Giovanni	1608	1677	Italy
Divini, Eustachio	1610	1685	Italy
Wallis, John	1616	1703	England
Grimaldi, Francesco María	1618	1663	Italy
Mariotte, Edme	ca. 1620	1684	France
Picard, Jean	ca. 1620	1682	France
Viviani, Vincenzo	1622	1703	Italy
Bartholinus, Erasmus	1625	1698	Denmark
Cassini, Giovanni Domenico	1625	1712	Italy
Morland, Samuel	1625	1695	England
Boyle, Robert	1627	1691	Ireland
Huygens, Christiaan	1629	1695	The Netherlands
Hooke, Robert	1635	1702	England
Pardies, Ignace Gaston	1636	1673	France
Gregory, James	1638	1675	England
Ango, Pierre	1640	1694	France
Newton, Isaac	1642	1727	England
Römer, Olaf	1644	1710	Denmark
Flamsteed, John	1646	1719	England

Leibniz, Gottfried Wilhelm	1646	1716	Germany
Tschirnhausen, Ehrenfried Walther	1651	1708	Germany
Sauveur, Joseph	1653	1716	France
Halley, Edmund	1656	1742	England
Hauksbee, Francis	1666	1736	England
Bernoulli, Johann	1667	1748	Switzerland
Gray, Stephen	1670	1736	England
Hermann, Jakob	1678	1733	Switzerland
Taylor, Brook	1685	1731	England
Musschenbroek, Pieter van	1692	1791	The Netherlands
Bradley, James	1693	1762	England
Bouguer, Pierre	1698	1758	France
Maupertuis, Pierre Louis Moreau	1698	1759	France
Cisternay du Fay, Charles-François de	1698	1739	France
Bernoulli, Daniel	1700	1782	The Netherlands
Kleist, Ewald Jürgen von	1700	1748	Germany
Nollet, Jean Antoine	1700	1770	France
La Condamine, Charles Marie de	1701	1774	France
Cramer, Grabriel	1704	1752	Switzerland
Franklin, Benjamin	1706	1790	USA
Euler, Leonard	1707	1783	Switzerland
Boscovich, Ruggiero Giuseppe	1711	1787	Italy
Lomonosov, Mikhail	1711	1765	Russia
Watson, William	1715	1787	England
Bianconi, Giovanni Ludovico	1717	1781	Italy
d'Alembert, Jean le Rond	1717	1783	France
Canton, John	1718	1772	England
Michell, John	1724	1793	England
Aepinus, Franz María Theodosius	1724	1802	Germany
Lamberts, Johann Heinrich	1728	1777	Germany
Spallanzani, Lazzaro	1729	1799	Italy
Cavendish, Henry	1731	1810	England
Wilcke, Johannes	1732	1796	Sweden
Priestley, Joseph	1733	1804	England
Coulomb, Charles Augustin de	1736	1806	France
Lagrange, Louis	1736	1813	Italy
Galvani, Luigi	1737	1798	Italy
Volta, Alessandro Giuseppe Antonio Anastasio	1745	1827	Italy
Laplace, Pierre Simon	1749	1827	France
Legendre, Adrien Marie	1752	1833	France
Rumford, Benjamin Thompson	1753	1814	USA
Chladni, Ernst Florens Friedrich	1756	1827	Germany
Olbers, Heinrich Wilhelm Matthäus	1758	1840	Germany
Fourier, Jean Baptiste Joseph	1768	1830	France
Nicol, William	1768	1851	Scotland
Seebeck, Thomas	1770	1831	Estonia

Young, Thomas	1773	1829	England
Biot, Jean Baptiste	1774	1862	France
Ampère, André Marie	1775	1836	France
Malus, Étienne Louis	1775	1812	France
Germain, Sophie	1776	1831	France
Ritter, Johann Wilhelm	1776	1810	Germany
Soldner, Johann Georg von	1776	1833	Germany
Gauss, Carl Friedrich	1777	1855	Germany
Oersted, Hans Christian	1777	1851	Denmark
Davy, Humprhey	1778	1829	England
Brewster, David	1781	1868	Scotland
Poisson, Simón Denis	1781	1840	France
Sturgeon, William	1783	1850	England
Bessel, Friedrich Wilhelm	1784	1846	Germany
Navier, Claude Louis Marie Henri	1785	1836	France
Peltier, Jean Charles Athanase	1785	1845	France
Arago, Dominique François	1786	1853	France
Fraunhofer, Joseph	1787	1826	Germany
Fresnel, Augustin Jean	1788	1827	France
Cauchy, Augustin Louis	1789	1857	France
Ohm, Georg Simon	1789	1854	Germany
Faraday, Michael	1791	1867	England
Mossotti, Ottaviano Fabrizio	1791	1863	Italy
Piola, Gabrio	1791	1850	Italy
Savart, Félix	1791	1841	France
Herschel, John Frederik William	1792	1871	England
Green, George	1793	1841	England
Babinet, Jacques	1794	1872	France
Lamé, Gabriel	1795	1870	France
Henry, Joseph	1797	1878	USA
Poiseuille, Jean Léonard Marie	1797	1869	France
Saint Venant, Adhémar Jean Claude Barré de	1797	1886	France
Neumann, Franz Ernst	1798	1895	Czech Republic
Clayperon, Benoit Paul Emile	1799	1864	France
Lloyd, Humphrey	1800	1881	Ireland
Airy, George Biddell	1801	1892	England
Fechner, Gustav Theodor	1801	1887	Germany
Colladon, Jean Daniel	1802	1893	Switzerland
Sturm, Jacques Charles	1802	1855	Switzerland
Doppler, Christian Andreas	1803	1853	Austria
Jacobi, Carl Gustav Jacob	1804	1851	Germany
Lenz, Heinrich Friedrich Emil	1804	1865	Germany
Weber, Wilhelm Edward	1804	1891	Germany
Dirichlet, Gustav Peter	1805	1859	Germany
Hamilton, William Rowan	1805	1865	Ireland
Palmieri, Luigi	1807	1896	Italy

Meucci, Antonio	1808	1896	Italy
Scott Russell, John	1808	1882	Scotland
Liouville, Joseph	1809	1882	France
MacCullagh, James	1809	1847	Ireland
Menabrea, Federigo	1809	1896	Italy
Mallet, Robert	1810	1881	Ireland
Grove, William Robert	1811	1896	Wales
Angström, Anders Jöns	1814	1874	Sweden
Mayer, Julius Robert	1814	1878	Germany
Sylvester, James Joseph	1814	1897	England
Joule, James Prescott	1818	1889	England
Fizeau, Armand	1819	1896	France
Foucault, Jean Léon	1819	1868	France
Stokes, George Gabriel	1819	1903	Ireland
Rankine, William John Macquorn	1820	1872	Scotland
Tyndall, John	1820	1893	Ireland
Chebyshev, Pafnuty Lvovich	1821	1894	Russia
Helmholtz, Hermann von	1821	1894	Germany
Cecchi, Filippo	1822	1887	Italy
Clausius, Rudolf Julius Emmanuel	1822	1888	Germany
Galton, Francis	1822	1911	England
Hermite, Charles	1822	1901	France
Krönig, A. K.	1822	1879	Germany
Lissajous, Jules Antoine	1822	1880	France
Bétti, Enrico	1823	1892	Italy
Kronecker, Leopold	1823	1891	Poland
Kirchhoff, Gustav Robert	1824	1887	Russia
Kerr, John	1824	1907	Scottland
Thomson, William (Baron Kelvin of Largs)	1824	1907	Ireland
Beer, August	1825	1863	Germany
Riemann, Georg Friedrich Bernhard	1826	1866	Germany
Christoffel, Elwin Bruno	1829	1900	Germany
Lorenz, Ludwig	1829	1891	Denmark
Maxwell, James Clerk	1831	1879	Scotland
Tait, Peter Guthrie	1831	1901	Scotland
Crookes, William	1832	1919	England
Neumann, Carl Gottfried	1832	1925	Russia
Clebsch, Rudolf Friedrich Alfred	1833	1872	Germany
Beltrami, Eugenio	1835	1900	Italy
Newcomb, Simon	1835	1909	USA
Stefan, Josef	1835	1893	Austria
Mascart, Élèuthere, Élie Nicolas	1837	1908	France
van der Waals, Johannes Diderik	1837	1923	The Netherlands
Mach, Ernst	1838	1956	Slovakia
Morley, Edward William	1838	1923	USA
Hankel, Hermann	1839	1873	Germany

Kundt, August Adolf	1839	1894	Germany
Abbe, Ernst Karl	1840	1905	Germany
Kohlrausch, Friedrich	1840	1910	Germany
Cornu, Marie Alfred	1841	1902	Ireland
Pochhammer, Leo August	1841	1920	Germany
Boussinesq, Valentin Joseph	1842	1929	France
Lie, Marius Sophus	1842	1899	Norway
Reynolds, Osborne	1842	1912	England
Strutt, John William (Third Baron Rayleigh)	1842	1919	England
Christiansen, Christian	1843	1917	Austria
Boltzmann, Ludwig	1844	1906	Austria
Branly, Edouard Eugène Désiré	1844	1940	France
Lamb, Horace	1844	1934	England
Lippmann, Gabriel	1845	1921	France
Röngten, Whilhem Conrad	1845	1923	Germany
Umov, Nikolai Alekseevich	1846	1915	Russia
Mittag-Leffler, Gösta Magnus	1846	1927	Sweden
Castigliano, Carlo Alberto	1847	1884	Italy
Floquet, Gaston	1847	1920	France
Bruns, Ernst Heinrich	1848	1919	Germany
Korteweg, Diederik Johannes,	1848	1941	The Netherlands
Rowland, Henry Augustus	1848	1901	USA
Hopkinson, John	1849	1898	England
Cerruti, Valentino	1850	1909	Italy
Goldstein, Eugen	1850	1939	Poland
Gray, Thomas	1850	1908	Scotland
Heaviside, Olivier	1850	1925	England
Milne, John	1850	1913	England
Voigt, Woldemar	1850	1919	Germany
Bartoli, Adolfo	1851	1896	Italy
Fitzgerald, George Francis	1851	1901	Ireland
Hugoniot, Pierre Henri	1851	1887	France
Lodge, Oliver Joseph	1851	1940	England
Michelson, Albert	1852	1931	Germany
Poynting, John	1852	1914	England
Lorentz, Hendrik Antoon	1853	1928	The Netherlands
Poincaré, Jules Henri	1854	1912	France
Curie, Jacques	1855	1941	France
Ewing, James Alfred	1855	1935	Scotland
Hall, Edwin Herbert	1855	1938	USA
Sekiya, Seiki	1855	1896	Japan
Knott, Cargill Gilston	1856	1922	Scotland
Runge, Carl David Tolmé	1856	1927	Germany
Thomson, Joseph John,	1856	1940	England
Hertz, Heinrich Rudolf	1857	1894	Germany
Larmor, Joseph	1857	1842	Ireland

Mohorovičić, Andrija	1857	1936	Croatia
Oldham, Richard Dixon	1858	1936	Ireland
Planck, Max	1858	1947	Germany
Cesàro, Ernesto	1859	1906	Italy
Curie, Pierre	1859	1906	France
Reid, Harry Fielding	1859	1944	USA
Chree, Charles	1860	1928	England
Somigliana, Carlo	1860	1955	Italy
Volterra, Vito	1860	1940	Italy
Reuber-Paschwitz, Ernst von	1861	1895	Lithuania
Wiechert, Emil	1861	1928	Lithuania
Hilbert, David	1862	1943	Germany
Lenard, Phillipp	1862	1947	Hungary
Rudzki, Maurycy Pius	1862	1916	Poland
Wiener, Otto Heinrich	1862	1927	Germany
Love, Augustus Edward Hough	1863	1940	England
Michell, John Henry	1863	1940	Australia
Pérot, Jean-Baptiste Alfred	1863	1925	France
Minkowski, Hermann	1864	1909	Germany
Wien, Wilhem Carl Werner Otto Fritz Franz	1864	1928	Germany
Hadamard, Jacques Salomon	1865	1963	France
Pockels, Friedrich Carl Alwin	1865	1963	Italy
Zeeman, Pieter	1865	1943	The Netherlands
Cosserat, Eugène Maurice Pierre	1866	1931	France
Fabry, Marie Paul Auguste Charles	1867	1945	France
Kolosov, Gury	1867	1936	Russia
Kutta, Wilhelm	1867	1944	Germany
Mie, Gustav	1868	1957	Germany
Millikan, Robert Andrews	1868	1953	USA
Omori, Fusakichi	1868	1923	Japan
Sabine, Wallace Clement	1868	1919	USA
Sommerfeld, Arnold Johannes	1868	1951	Russia
Galerkin, Boris Grigorievich	1871	1945	Russia
Rutherford, Ernest	1871	1937	New Zealand
Langévin, Paul	1872	1946	France
Levi-Civita, Tullio	1873	1941	Italy
Whittaker, Edmund Taylor	1873	1956	England
Marconi, Guglielmo	1874	1937	Italy
Prandtl, Ludwig	1875	1953	Germany
Angenheister, Gustav	1878	1945	Germany
Frechét, Maurice René	1878	1973	France
Timoshenko, Stephen	1878	1972	Ucraina
Mintrop, Ludger	1880	1956	Germany
Wegener, Alfred	1880	1930	Germany
Einstein, Albert	1879	1955	Germany
Herglotz, Gustav	1881	1953	Austria

Zoeppritz, Karl	1881	1908	Germany
Bateman, Harry	1882	1946	England
Born, Max	1882	1970	Poland
Geiger, Ludwig Carl	1882	1966	Switzerland
Macelwane, James Bernard	1883	1956	USA
Mises, Richard von	1883	1953	USA
Terzaghi, Karl von	1883	1963	Czech Republic
Debye, Peter Joseph William	1884	1966	The Netherlands
Weyl, Hermann Klaus Hugo	1885	1955	Germany
Taylor, Geoffrey Ingram	1886	1975	England
Loomis, Alfred Lee	1887	1975	USA
Radon, Johann	1887	1956	Czech Republic
Schrödinger, Erwin	1887	1961	Austria
Courant, Richard	1888	1972	Poland
Lehmann, Inge	1888	1993	Denmark
Raman, Chandrasekhara Venkata	1888	1970	India
Brillouin, Léon	1889	1969	Russia
Gutenberg, Beno	1889	1960	Germany
Hubble, Edwin Powell	1889	1953	USA
Nyquist, Harry	1889	1976	Sweden
Jeffreys, Harold	1891	1989	England
de Broglie, Louis Victor	1892	1987	France
Watson-Watt, Robert	1892	1973	France
Gordon, Walter	1893	1940	Germany
Knudsen, Vern Oliver	1893	1974	USA
Lanczos, Cornelius	1893	1974	Hungary
Frenkel, Yacov Il'ich	1894	1952	Russia
Klein, Oskar	1894	1977	Sweden
Kramers, Hendrik Anthony	1894	1952	The Netherlands
Stoneley, Robert	1894	1976	England
Wiener, Norbert	1894	1964	USA
Hund, Friedrich	1896	1997	Germany
Sokolov, Sergei	1897	1971	Russia
Firestone, Floyd	1898	1986	USA
Fock, Vladimir Aleksandrovich	1898	1974	Russia
Sears, Francis Weston	1898	1975	USA
Wentzel, Gregor	1898	1978	Germany
Richter, Charles Frances	1900	1985	USA