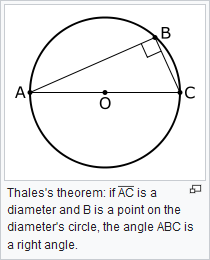
**We Stand on the Shoulders of Giants**

* ***Moscow Papyrus***(1890 BC), ***Rhind Papyrus***(1550 BC), and **Babylonian Tablets** (**Plimpton 322** – 1900 BC)
  + *Seked –* slope (Rhind Papyrus)
* **Thales of Miletus** (624/23 – 548/545 BC)
  + Born in Miletus, Ionia, Asia Minor
  + First philosopher in Greek tradition and (pre-Socratic) scientific philosophy
  + Hypothesized Earth floats on water
  + First use of deductive reasoning in geometry
  + Predicted the solar eclipse of May 28, 585 BC
  + Thales’ theorem
  + Hylozoist
  + “Olive Baron”
* **Pythagoras of Samos** (570 – 495 BC)
  + Born in Samos and died in either Croton or Metapontum
  + Pythagorean theorem
  + Theory of Proportions
  + Identified Venus
  + Believed Earth to be a sphere and that the universe was governed by mathematical laws
  + May have started *musica universalis*
* **Heraclitus of Ephesus** (535 – 475 BC)
  + Doctrine of change: “*Panta rhei*” – “everything flows” (change is the only constant)
  + Believed in the unity of opposites
* **Philolaus** (470 – 385 BC)
  + Successor of Pythagoras
  + Credited with originating the theory that Earth is not the center of the Universe.
    - “Pythagorean” astronomical system
  + Believed that the limited and unlimited aspects of the universe combine in harmony.
* **Socrates** (470 – 399 BC)
  + Born and died in Athens, Greece
  + First moral philosopher
  + Socratic method
  + Heretic and “gadfly” of the state
  + Sentenced to death for corrupting the minds of Athenian youth
* **Democritus** (460 – 370 BC)
  + Theory of atomic universe
  + Flat-Earther
* **Plato** (428/427/424/423 – 348/347 BC)
  + Born and died in Athens, Greece
  + Founded the Academy
  + Theory of Forms
  + Notable students:
    - Eudoxus of Cnidus
* **Archytas of Tarentum** (428 – 350 BC)
  + Greek philosopher, mathematician, music theorist, astronomer, statesman
  + Irrational Numbers and Number Theory
  + Harmonic Mean
  + Founder of Mathematical Mechanics
* **Aristotle** (384 – 322 BC)
  + Born in Stagira, Chalcidian League and died in Euboea, Macedonian Empire
  + Founded the Lyceum
  + Wrote a book on pretty much everything
    - physics, biology, zoology, metaphysics, logic, ethics, aesthetics, poetry, theatre, music, rhetoric, psychology, linguistics, economics, politics, and government.
  + Believed that “objects tend toward a point due to their inner *gravitas* (heaviness)” and seek a “final cause” or “end”
    - Constant force = uniform motion
    - “Continuation of motion depends on the continued action of a force”
  + Interpreted light in terms of in terms of “act” and “potency” as “the act of a transparent body, inasmuch as it is transparent”
  + Tutored Alexander the Great
* **Menaechmus** (380 – 320 BC)
  + Likely discovered conic sections while solving the Delian problem of doubling the square
  + When said to have been tutoring Alexander the Great, he was asked for a shortcut to understanding geometry. He replied to Alexander, “O King, for traveling over the country, there are royal road and roads for common citizens, but in geometry there is one road for all.” (Beckmann 1989)
* **Euclid of Alexandria** (325 – 270 BC)
  + Father of geometry
  + The author of *Elements, Data, On Divisions of Figures, Catoptrics* (more likely Theon of Alexandria), *Phaenomena, Optics, Conics, Pseudaria (Book of Fallacies), Surface Loci,* and a lost treatise on mechanics.
    - When asked by Ptolemy I if there was a shorter way to learn geometry, he replied “there is no royal road to geometry.”   
      \* Possibly conflated with the story about Menaechmus and Alexander the Great
* **Aristarchus of Samos** (310 – 230 BC)
  + Identified Philolaus’ “central fire” as the Sun and presented the first known heliocentric model of the universe.
  + *On the Sizes and Distances of the Sun and Moon*
* **Archimedes of Syracuse** (287 – 212 BC)
  + Born and died in Syracuse, Sicily, Magna Graecia
  + Mathematician, physicist, engineer, inventor, astronomer
  + Anticipated calculus through infinite series and method of exhaustion
  + Accurate approximation of pi by measuring circles, spheres, cylinders, etc.
  + Created exponentiation
  + Archimedes’ screw
  + Archimedes’ box or Ostomachion
  + Wrote a manual on constructing an Antikythera
  + Developed statics and hydrostatics
    - *The Method of Mechanical Theorems*
    - *On Floating Bodies*
    - Archimedes’ principle – law of buoyancy
    - Calculated center of gravity of a triangle
  + Was killed by a soldier against their orders during Siege of Syracuse!
* **Eratosthenes of Cyrene** (276 – 195/194 BC)
  + Founder of geography
  + Founder of chronology
  + Created first global projection with parallels and meridians – latitude and longitude
  + Chief librarian at Library of Alexandria
  + Calculated circumference of Earth, tilt of Earth’s axis, and distance from Earth to Sun.
* **Apollonius of Perga** (240 – 190 BC)
  + Conic sections – defined ellipse, parabola, and hyperbola
* **Hipparchus of Nicaea** (190 – 120 BC)
  + Born in Nicaea, Kingdom of Bithynia and died in Rhodes, Roman Republic
  + Astronomer, geographer, mathematician
  + Founder of trigonometry
  + Discovered precession of equinoxes
  + First reliable predictions of solar eclipses
  + Created the first comprehensive star catalog
* **Marcus Vitruvius Pollio** (80/70 – after 15 BC)
  + Performed measurements to determine the specific gravity of objects
* **Claudius Ptolemy** (100 – 168 AD)
  + Born in Egypt and died in Alexandria
  + Mathematician, astronomer, geographer, astrologer
  + Wrote *Almagest, Geographia,* *Planetary Hypotheses, Optics, Harmonics* and *Phaseis (Risings of the Fixed Stars)* which included a star calendar/almanac
  + Believed music intervals should be based upon mathematical ratios like tetrachords and octaves (agreeing with the Pythagoreans and Pythagorean tuning though not explicitly the 3:2 ratio)
    - Inspired Kepler’s *Harmonice Mundi*
  + Theorized that light entered and left the eye in a cone and that size and shape of objects are determined by the angle, distance, and orientation.
    - Size-distance invariance
  + Maintained geocentrism for the next 1300 years
    - Nested spheres using epicycles
* **Diophantus of Alexandria**
* **Aryabhata**
* **John Philoponus** (490 – 570)
  + Byzantine scientist and philosopher
  + Theory of impetus
  + Said that impetus (momentum) diminishes over time
  + Criticized the Aristotelian concept of causation
* **Brahmagupta** (598 – 668)
  + Indian
  + Astronomer, mathematician
  + First to give rules to compute with zero and negative numbers
  + Believed in the attractive force of *gurutvakarshan*
* **Muhammad ibn Musa al-Khwarizmi** (780 – 850)
  + Persian mathematician and astronomer
  + Laid groundwork for modern algebra
* **Al-Kindi**
* **Al-Farabi**
* **Ibn al-Haytham** (965 – 1040)
  + Father of modern scientific method using experimental data and reproducible results
  + A founder of modern optics
* **Ibn Sīnā (Avicenna)** (980 – 1037)
  + Distinguished between “force” and “inclination”
  + Argued that an object inclined to move will continue in motion until the inclination is spent
* **Shen Kuo** (1031 – 1095)
  + Chinese scientist and statesman
  + Studied earthquakes and erosion
  + First to describe using a magnetic needle for navigation and the concept of “true north”
  + Camera obscura
* **Abu'l-Barakat al-Baghdaadi** (1080 – 1165)
* **Petrus Peregrinus de Maricourt** (fl. 1269)
  + “Taking a natural magnet or lodestone, which had been rounded into a globular form, he laid it on a needle and marked the line along which the needle set itself. Then laying the needle on other parts of the stone, he obtained more lines in the same way. When the entire surface of the stone had been covered with such lines their disposition became evident; they formed circles which girdled the stone in exactly the same way as the meridians of longitude girdle the earth; and there were two points at opposite ends of the stone through which all the circles passed, just as all the meridians pass through the north and south poles of the earth.
  + Struck by the analogy, Peregrinus proposed to call these two points the *poles* of the magnet: and he observed that the way in which the magnets set themselves and attract each other depends solely on the position of their poles, as if these were the seat of the magnetic power. Such was the origin of those theories of poles and polarization which in later ages have played so great a part in natural philosophy.”
* **Thomas Aquinas** (1225 – 7 March 1274)
  + Largely responsible for the adoption of Aristotelianism in Europe (13th century)
  + Thomist philosophy – “metaphysics is the supreme natural science, not physics”
* **William of Ockham** (1285 – 10 April, 1347)
  + Introduced principles which undermined Aristotelianism and led to rejection of medieval philosophy associated with the Renaissance
  + Began the study of rotational dynamics
* **Jean Buridan**
* **Leonardo da Vinci**
* **Nicolaus Copernicus** (19 February 1473 – 24 May 1543)
  + Proposed relation between Earth and Sun (year of his death) such that the Earth was in motion rather than stationary
* **William Gilbert** (24 May 1544 – 30 November 1603)
  + Greatly extended the work of Peregrinus
  + Appointed physician to Queen Elizabeth
  + “Published a work on magnetism and electricity, with which the modern history of both subjects begins.”
  + “… in magnetism he made the capital discovery of the reason why magnets set in definite orientations with respect to the earth; which is, in that the earth is itself a great magnet, having one of its poles in high northern and the other in high southern latitudes.”
  + “Gilbert went further, and conjectured that magnetic forces were capable of accounting for the earth’s gravity and the motions of the planets.”
  + Showed “that the same effects (of attractive power shown by amber) are induced by friction in quite a large class of bodies, among which he mentioned glass, sulphur, sealing-wax and various precious stones.”
  + Coined the term *electric* force (Gilbert needed to distinguish the magnetic and electric forces)
    - “Between the magnetic and electric forces Gilbert remarked many distinctions. The lodestone requires no stimulus of friction such as is needed to stir glass and sulphur into activity. The lodestone attracts only magnetizable substances, whereas electrified bodies attract everything. The magnetic attraction between two bodies is not affects by interposing a sheet of paper or a linen cloth, or by immersing the bodies in water; whereas the electric attraction is readily destroyed by screens. Lastly, the magnetic force tends to arrange bodies in definite orientations while the electric force merely tends to heap them together in shapeless clusters.
    - “The substantive *electricity* was introduced by Sir Thomas Browne in his *Pseudodoxia epidemica*.”
    - “Being a physician, he was well acquainted with the doctrine that the human body contains various humours or kinds of moisture – phlegm, blood, choler and melancholy – which, as they predominated, were supposed to determine the temper of mind, and when he observed that electrifiable bodies were almost all hard and transparent, and therefore (according to the ideas of that time) formed by the consolidation of watery liquids, he concluded that the common menstruum of these liquids must be a particular kind of humour, to the possession of which the electrical properties of bodies were to be referred. Friction might be supposed to warm or otherwise excite or liberate the humour, which would then issue from the body as an effluvium and form an atmosphere around it. The effluvium must, he remarked, be very attenuated, for its emission cannot be detected by the senses.”
    - “The existence of an atmosphere of effluvia round every electrified body might indeed have been inferred, according to Gilbert’s ideas, from the single fact of electric attraction. For he believed that matter cannot act where it is not; and hence if a body acts on all surrounding objects without appearing to touch them, something must have proceeded out of it unseen.”
    - “The whole phenomenon appears to him to be analogous to the attraction which is exercised by the earth on falling bodies; for in the latter case he conceived of the atmospheric air as the effluvium by which the earth draws all things downwards to itself.”
    - “Gilberts’ theory of electrical emanations commended itself generally to such of the natural philosophers of the seventeenth century as were interested in the subject; among whom were numbered Niccolo Cabeo (1585-1650), who was perhaps the first to observe that electrified bodies repel as well as attract; the English royalist exile, Sir Kenelm Digby (1603-65); and the celebrated Robert Boyle (1627-91). There were, however, some differences of opinion as to the manner in which the effluvia acted on the small bodies and set them in motion towards the excited electric; Gilbert himself had supposed the emanations to have an inherent tendency to reunion with the parent body; Digby likened their return to the condensation of a vapour by cooling; and other writers pictured the effluvia as forming vortices round the attracted bodies in the Cartesian fashion.”
    - “There is a well-known allusion to Gilbert’s hypothesis in Newton’s *Opticks*.”
* **Tycho Brahe** (14 December 1546 – 24 October 1601)
* **Galileo Galilei** (15 February 1564 – 8 January 1642)
  + Experimentalist
  + *Dialogue Concerning the Two Chief World Systems* (1632)
  + Galilean relativity – laws of motion are same in all inertial frames
  + Condemned by the Aristotelians
    - His response: “Eppur sui muove” – “And so it moves…”
  + Attempted to experimentally measure the speed of light using “two men with lanterns at a considerable distance”, unfortunately, “the interval of time required by the light for its journey was too small to be perceived this way”.
* **Johannes Kepler** (27 December 1571 – 15 November 1630)
  + Disproved the Aristotelian principle that celestial and terrestrial bodies are different
  + Emphasized the importance of mathematics in studying nature
  + “Chief inspiration” of Descartes
* **Isaac Beeckman** (10 December 1588 – 19 May 1637)
* **Pierre Gassendi** (22 January 1592 – 24 October 1655)
  + French philosopher, Catholic priest, astronomer, mathematician
  + Reintroduced the doctrine of the ancient atomists, which became the departure point for all subsequent natural philosophy
* **René Descartes** (31 March 1596 – 11 February 1650)
  + Epistemological rationalist
  + Aimed to create a theory of the universe “as far as possible in every detail”
  + Founder of modern philosophy
    - “cogito, ergo sum” = “I think, therefore I am”
  + Founder of mechanical philosophy (mechanist – mechanism)
  + Founder of analytic geometry
    - Cartesian coordinate system
  + Wrote three laws of motion in *Principle*, in attempt to make a general reconstruction of the physical universe
  + Postulated concept of “plenum” or “aether” and its mechanical properties as well as “vortices”
  + Supposed the “diversities of colour and light” to be caused by matter moving in different ways with “different rotary velocities”
    - Asserted dependence of colours on periodic time
  + “Give me matter and motion and I will construct the universe.”
  + “… attempted to account for magnetic phenomena by his theory of vortices. … he postulated a vortex of fluid matter round each magnet, the matter of the vortex entering by one pole and leaving by the other”
* **Pierre de Fermat** (31 October/6 December 1607 – 12 January 1665)
  + Principle of Least Time – “Nature always act by the shortest course.”
  + Developed the method or Adequality (similar to differential calculus)
* **Blaise Pascal**
* **Robert Boyle** (25 January 1627 – 31 December 1691)
  + *The Sceptical Chemist* 
    - Elements, compounds, and mixtures
* **Christiaan Huygens** (14 April 1629 – 8 July 1695)
  + Criticized Descartes as continuing the tradition of the Greeks rather than those like Galileo, and said he seemed to be jealous of Galileo’s success
  + “Huygens decided that the former alternative (that the motion of light is that of a medium as opposed to the corpuscular theory) is the only tenable one, since beams of light proceeding in direction inclined to each other do not interfere with each other in any way.”
  + From Torricelli’s work demonstrating “that light is transmitted as readily through a vacuum as through air”, “Huygens inferred that the medium or aether in which the propagation takes place must penetrate all matter, and be present even in all so-called vacua. Light, therefore, consists of disturbances, propagated with great velocity, in a highly elastic medium composed of very subtle matter.”
  + Huygen’s Principle
    - “Succeeded where Hooke and Pardies failed, in achieving the explanation of refraction and reflection.”
  + “Besides these, there is the matter of aether permeating all the crystal, bot between and within the parcels of the two kinds of matter, just mentioned; for I suppose both the little spheroids, and the matter which occupies the intervals around them, to be composed of small fixed particles, amongst which are diffused in perpetual motion the still finer particles of the aether.”
  + “He observed that the two rays which are obtained by the double refraction of a single ray afterwards behave in a way different from ordinary light which has not experienced double refraction and in particular, if one of these rays is incident on a second crystal of Iceland spar, it gives rise in some circumstances to two, and in others to only one, refracted ray.”
  + “attempted to interpret gravity in terms of… a Cartesian vortex… and, by the effect of its centrifugal force, to displace terrestrial objects toward the centre of the earth.”
* **Robert Hooke** (28 July 1635 – 3 March 1703)
  + Assistant of Robert Boyle
  + “Hooke’s theoretical investigations on light… [represent]… the transition from the Cartesian system to the fully developed theory of waves.”
    - Hooke’s theory regarded light as a rapid vibratory motion of small amplitude
    - Descartes’ theory postulated light as a statical pressure in a medium
  + Introduced the concept of “wave-front” and that the deflection of this wave-front was the “origin of the prismatic colours.”
  + Corrected the Cartesian error regarding “trajection” of light. “Although this is not in all respects successful, it represents a decided advance on the treatment of the same problem by Descartes, which rested on mere analogy.”
    - “… according to the most acute and excellent Philosopher Des Cartes, I suppose the sine of the angle on inclination in the first medium to be to the sine of refraction in the second, as the density of the first to the density of the second.  
      …  
      that the one propagates the pulse more easily and weakly, the other more slowly, but more strongly.”
  + Hooke’s theory of colour was “completely overthrown” by Newton within a few years
  + “The truth of Hooke’s hypothesis, that light is essentially a form of motion, seemed to Huygens to be proved by the effects observed with burning-glasses”
* **Isaac Newton** (25 December 1642 – 20 March 1726/27)
  + Conducted experiments on the “Phaenomena of Colours” with a triangular prism, which contradicted the “received laws of Refraction”, leading him to further experiment and discover “that ordinary white light is really a mixture of rays of every variety of colour, and that the elongation of the spectrum is due to the differences in the refractive power of the glass for these different rays.”
  + “Colours are not Qualifications of light derived from Refractions, or Reflections of natural bodies (as ‘tis generally believed), but Original and connate properties, which in divers Rays are divers.  
    …  
    Nor are there only Rays proper and particular to the more eminent colours, but even to
  + all their intermediate gradations.”
  + Newton’s theory of light resulted in an “acute controversy” with Robert Hooke
  + Newton identified “the incompetence of the wave-theory to account for the rectilinear propagation of light, and another was its inability to embrace the facts – discovered by Huygens and first interpreted correctly by Newton himself – of polarization.”
  + “whatever light be, I suppose it consists of rays differing from one another in contingent circumstances, as bigness, form or vigour.”
  + “differences of density of the aether between one material medium and another account on these principles for the reflection and refraction of light.”
  + “He supposed that when light is absorbed by a material body, vibrations are set up in the aether, and are recognizable as the heat which is always a generated in such cases. The conduction of heat from hot bodies to contiguous cold ones he conceived to be effected by vibrations of the aether propagated between them; and he supposed that it is the violent agitation of aethereal motions which excites incandescent substances that emit light.”
  + “Newton considered colour to be an inherent characteristic of light, and inferred that it must be associated with some definite quality of the corpuscles or aether vibrations.”
  + “if by any means those [aether vibrations] of unequal bigness be separated from one another, the largest beget a Sensation of a *Red* colour, the least or shortest of a deep *Violet*, and the intermediate ones, of intermediate colours; much after the manner that bodies, according to their several sizes, shapes and motions, excite vibrations in the Air of various bigness, which, according to those bigness, make several Tones in Sound.”
  + “the first enunciation of the great principle that homogeneous light is essentially *periodic* in its nature, and that differences of period correspond to differences of colour. The obvious analogy with sound was expressly mentioned by Huygens in his *Traite de la lumiere”*
  + “The interval between two consecutive dispositions to easy transmission or ‘length of fit’ varies, as he found, with the colour, being greatest for red light and least for violet.” This ‘length of fit’ corresponds “in some measure” to wave-length
  + “ in 1717 showed that a ray obtained by double refraction differs from a ray of ordinary light in the same way that a long rod who cross-section is a rectangle differs from a long rod whose cross-section is a circle; in other words, the properties of a ray of ordinary light are the same with respect to all directions at right angles to its direction of propagation, whereas a ray obtained by double refraction must be supposed to have *sides*, or properties related to special directions at right angles to its own direction. The refraction of such a ray at the surface of a crystal depends on the relation of its sides to the principal plane of the crystal.”
  + “The correct law of gravitation… was published in 1687 in Newton’s *Principia*”
  + “Newton claimed nothing more for his discovery than that it provided the necessary instrument for mathematical prediction, and he pointed out that it did not touch on the question of the mechanism of gravity.”
  + “that one body may act upon another at a distance through a vacuum, without the mediation of anything else,… is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty for thinking, can ever fall into.”
  + Newton’s *Principia* competed with practitioners of the Cartesian philosophy. “Long after the publication… the textbook of natural philosophy used at Cambridge continued to be a translation (into Latin from French) of the *Physics* of Rohault, a work entirely Cartesian. Whiston has recorded that, having returned to Cambridge after his ordination in 1693, he resumed his studies there, ‘particularly the Mathematicks and the Cartesian Philosophy, which was alone in Vogue with us at that Time. But it was not long before I, with immense Pains, but no Assistance, set myself with the utmost Zeal to the study of Sir Isaac Newton’s wonderful Discoveries.’ The change in the character of the official teaching was brought about in a very curious manner. Dr. Samuel Clarke, a zealous Newtonian, published about the year 1718 a new translation of Rohault, with a running commentary of notes which, while avoiding the language and appearance of controversy, actually constituted a complete refutation of the text. This edition superseded the older one in current use, and the younger generation peacefully adopted the new knowledge.”
  + “The first British university to incorporate Newtonianism into its formal instruction seems to have been Edinburgh, where David Gregory, a friend of Newton, was a professor from 1683-90. To quote Whiston again, ‘He caused several of his Scholars to keep Acts, as we call them, upon several Branches of the Newtonian Philosophy; while we at Cambridge, poor Wretches, were ignominiously studying the fictitious Hypotheses of the Cartesian.’”
  + “’A Frenchman who arrives in London,’ wrote Voltaire in 1730 ‘will find Philosophy, like everything else, very much changed there. He had left the world a *plenum*, and now he finds it a *vacuum*.’ ‘It is,’ he said, ‘the language used, and not the thing in itself, that irritates the human mind. If Newton had not used the word *attraction* in his admirable philosophy, everyone in our Academy would have opened his eyes to the light; but unfortunately he used in London a word to which an idea of ridicule was attached in Paris; and on that alone he was judged adversely, with a rashness which will some day be regarded as doing very little to honor his opponents.’”
  + “In Germany, Leibnitz described the Newtonian formula as a return to the discredited scholastic concept of *occult qualities*; and as late as the middle of the eighteenth century Euler and two of the Bernoullis based the explanation of magnetism on the hypothesis of vortices.”
  + “The rejection of the inverse-square law of gravitation by the French Cartesians antagonized the younger disciples of Newton to such an extent that the latter hardened into an opposition not only to the vortices but to the whole body of Cartesian notions, including the aether.”
  + “In the second edition (1713) of the *Principia*, there is a preface written by Roger Cotes (1682-1716), in which the Newtonian law of action at a distance is championed as being the only formulation of the facts of experience which does not introduce unverifiable and useless suppositions.”
* **Olaf Roemer** (25 September 1644 – 19 September 1710)
  + Danish
  + Resident professor of mathematics in Paris to the Dauphin of France
  + “Observed that the eclipses of the first satellite of Jupiter were apparently affected by an unknown disturbing cause; the time of occurrence of the phenomenon was retarded when the earth and Jupiter, in the course of their orbital motions, happened to be most remote from each other, and was accelerated in the contrary case. Roemer explained this by supposing that light requires a finite time for its propagation from the satellite to the earth; and by observations of eclipses, he calculated the interval required for its passage from the sun to the earth (the *light equation* as it is called) to be 11 minutes.
* **Daniel Bernoulli**
* **Benjamin Franklin** (January 17, 1706 – April 17, 1790)
* **Leonhard Euler** (15 April 1707 – 18 September 1783)
  + Astronomer, Engineer, Geographer, Logician, Mathematician, Physicist
    - Euler’s equation –
    - Euler’s formula –
* **Jean-Baptiste d’Alembert** (16 November 1717 – 29 October 1783)
  + Mathematician
  + Mechanician
  + Music Theorist
  + Philosopher
  + Physicist
    - d’Alembert’s generalized wave equation
    - d’Alembert’s principle
* **Georges-Louis Le Sage** (13 June 1724 – 9 November 1803)
  + Genevan physicist
  + Developed an early electric telegraph in 1774
  + “Cartesianise Newtonianism”
  + “proposed to account for gravitation by means of an aether of Descartes’ original type, that is to say, a cloud of excessively minute particle, *ultra-mundane corpuscles* as he called them. These, which resembled the neutrinos of the modern atomic physicist, he supposed to exist in great numbers in all parts of space, and to be moving with great speed in all direction; their diameters were further assumed to be so small in comparison with their distances apart that collisions between them were exceedingly rare. Then two particles of ordinary matter would to some extent screen each other from bombardment by the corpuscles, each particle receiving fewer impacts on the side facing the other than on the reverse side; and Le Sage showed that this effect would be equivalent to a force of attraction between them, varying inversely as the square of their mutual distance; which force he identified with that discovered by Newton.”
* **Henry Cavendish** (10 October 1731 – 24 February 1810)
  + Proposed electrically charged objects obey an inverse-square law (1762)
* **Joseph-Louis Lagrange** (25 January 1736 – 10 April 1813)
* **Charles-Augustin de Coulomb** (14 June 1736 – 23 August 1806)
  + Coulomb’s law (1784)
* **Alessandro Volta**
* **Pierre-Simon Laplace** (23 March 1749 – 5 March 1827)
  + Astronomer
  + Mathematician
    - *Dynamic Theory of Tides* (1775)
    - *Mécanique Céleste* (1799 – 1825)
    - Spherical Harmonics
    - One of the first to postulate black holes and gravitational collapse
    - Invented Z-transform in his work on probability theory
* **André-Marie Ampère** (20 January 1775 – 10 June 1836)
  + Formulated the angular dependence on the force between two currents (1820)
* **Hans Christian Ørsted** (14 August 1777 – 9 March 1851)
  + Discovered magnetic needles are affected by voltaic current (1820)
* **François Jean Arago** (26 February 1786 – 2 October 1853)
  + Astronomer, mathematician, physicist, freemason
  + First to observe eddy currents
  + Observed “rotatory magnetism” in 1824 and that most conductive bodies could be magnetized (to be later fully explained by Faraday)
* **Michael Faraday** (22 September 1791 – 25 August 1867)
  + Developed the modern concept of electric and magnetic fields
    - without a full mathematical description
  + Discovered induction (1831)
  + Created the Faraday disc or homopolar generator
  + *On the possible relation of gravity to electricity!?*
  + *On the Physical Character of the Lines of Magnetic Force* (1852)
    - Investigated gravity, electricity, radiation, and propagation media
* **William Rowan Hamilton** (3 August 1805 – 2 September 1865)
* **James Prescott Joule**
* **Jean Bernard Léon Foucault** (18 September 1819 – 11 February 1868)
  + Foucault pendulum
  + Named the “gyroscope”
* **Hermann von Helmholtz**
* **William Thomson, 1st Baron Kelvin, The Lord Kelvin** (26 June 1824 – 17 December 1907)
  + Engineer, Mathematical Physicist
  + Formulated 1st and 2nd Laws of Thermodynamics
  + Kelvin Temperature Scale
  + Introduced concept of vector potential (1851)
  + Knighted by Queen Victoria in 1866 for transatlantic telegraph project
* **Georg Friedrich Bernhard Riemann** (17 September 1826 – 20 July 1866)
  + Mathematician
  + Riemann integral
  + Riemann surface
  + Riemannian geometry
  + \*Suggested “in 1858 that the potentials should be calculated by the retarded formulae, but Ludwig Lorenz was the first to give a comprehensive treatment based on the retarded potentials (1867).” [Heald & Marion pg. 257]
  + \*First showed in 1858 that the retarded potentials are a solution to the inhomogeneous wave equation.
* **James Clerk Maxwell** (13 June 1831 – 5 November 1879)
  + Applied Faraday’s concept of *lines of force* to his electromagnetic theory
  + *On Faraday’s Lines of Force* (1855/56)
  + *On Physical Lines of Force* (1861)
  + *A Dynamical Theory Of The Electromagnetic Field* (1865)
  + Identified Faraday’s law as describing two separate phenomena
    - Motional EMF – generated by magnetic force on a moving wire
    - Transformer EMF – generated by electric force due to changing magnetic field
* **Oliver Heaviside** (18 May 1850 – 3 February 1925)
  + Invented modern vector notation
    - and applied it to Maxwell’s equations (reducing them from 10 to 4)
  + Fixed the mistakes made by J.J. Thomson and identified the correct force due to an external magnetic field (1885 and 1889)
  + Predicted the cogravtiational field
  + *A Gravitational and Electromagnetic Analogy* (1893)
* **Hendrik Antoon Lorentz** (18 July 1853 – 4 February 1928)
  + Abandoned Maxwellian descriptions of ether and conduction, distinguished between matter and the aluminiferous aether and applied the Maxwell-Heaviside equations at a microscopic scale using Lagrangian mechanics.
  + Completely derived the Lorentz force and identified the contribution of the electric force (1895)
* **Nikola Tesla** (10 July 1856 – 7 January 1943)
* **Joseph John Thomson** (18 December 1856 – 30 August 1940)
  + Credited with discovery of electron
  + First to attempt to derive the electromagnetic forces on a moving object in terms of its properties and external fields from Maxwell’s field equations
    - Using a cathode tube, determine the force due to external magnetic field as half of the correct value (displacement current was incomplete at the time)
* **Ernest Rutherford**
* **Albert Einstein**
* **Max Born**
* **Neils Bohr**
* **Wolfgang Pauli**
* **Enrico Fermi**
* **Paul Dirac**
* **Richard Feynman** (11 May 1918 – 15 February 1988)
* **Oleg Dmitrovich Jefimenko** (14 October 1922 – 14 May 2009)
  + Derived general solutions to Maxwell’s equations
    - “Ultimately derive from continuity equation” but can be derived from potentials [Hills]
  + Says that charge density and current density create both fields!
    - “both fields are caused by charges and currents.” [Heald & Marion pg. 262]