

Logos 5: 17 May 2006
The Scientific and Industrial Revolution
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The Scientific and Industrial Revolution

The first inventions
Medieval machines
The Scientific Revolution
The Industrial Revolution
China, India, Islam
The Age of the Literal

What happened in
Italy, Spain and Poland
between 4 Oct and 15 Oct 1582,
France between 9 Dec 1582
and 20 Dec 1582
Hungary between 21 Oct 1587
and 1 Nov 1587
Prussia between 22 Aug 1610
and 2 Sept 1610
Denmark between 18 Feb 1700
and 1 Mar 1700
Britain between 2 Sep 1752 and
14 Sep 1752
Russia between 31 Jan 1918₂
and 14 Feb 1918 ?



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Earliest Inventions

- **Tools (2 million years, Africa, Homo Habilis)**
- **Fire (1.9 million years, Africa, Homo Erectus)**
- **Buildings (400,000 BC, France, Homo Erectus)**
- **Burial (70,000 BC, Neanderthal)**
- **Art (28,000 BC, Austria, Homo Sapiens)**
- **Lamp (17,000 BC, France)**
- **Farming (14,000 BC, Mesopotamia)**
- **Domesticated animals (12,000 BC)**
- **Boat (8,000 BC, Holland/ Norway, but earlier in Oceania)**

Earliest Inventions

- **Weapons (bow, sling, dagger, mace) (8,000 BC)**
- **Pottery (7,900 BC, China)**
- **Weaving (6,500 BC, Palestine)**
- **Musical instruments (5,000 BC, Sumeria)**
- **Wheel (3,500 BC, Mesopotamia)**
- **Sail (3,500 BC, Egypt)**
- **Glass (3,000 BC, Phoenicia)**
- **Sundial (3,000 BC, Egypt)**

Earliest Inventions

- **Bronze (copper + tin) Age**
 - **Sumerians 3300 BC**
 - **Asia Minor 3100 BC**
 - **Greece 3000 BC**
 - **India 2500 BC**
 - **Sicily 2500 BC**
 - **Egypt 2200 BC**
 - **Thailand 2100 BC**
 - **Britain 1800 BC**
 - **China 1800 BC**
 - **Japan 0**
 - **Pre-Columbian America 1000 AD**

Earliest Inventions

- **Iron Age**
 - **Mesopotamia 3200 BC**
 - **Egypt 2600 BC**
 - **Hittites 1800 BC**
 - **Greece 1200 BC**
 - **India 1100 BC**
 - **Gaul (Celts) 800 BC**
 - **Britain 700 BC**
 - **China 600 BC**
 - **Scandinavia: 100 AD**
 - **Japan: 200 AD**
 - **Russia: 800 AD**

Phoenicia

- **Navigation**

Greece

- **Greek Philosophy**
 - **The universe makes systematic sense, and we can make sense of it (rationality and intelligibility of the world)**
 - **Problem of the nature of the world: an original substance must be the source of everything that is in the world today**
 - **Problem of change: what is it that does NOT change when we say that something “changed”? What persists so that we can say that “it” changed?**

Greece

- Thales (7th c BC)
- Anaximander (7th c BC):
 - “Apeiron” generates the world and its elements (it turns successively into wind, steam, water, earth, stone)
 - Animals **evolved** from more primitive forms of life, a primeval soup heated by the Sun (proto-evolutionary theory)
 - The earth is floating in the vacuum (first cosmological model)
- Pythagoras (6th c BC)

Greece

- **Anaxagoras (5th c BC)**
 - **Life was dispersed as seeds in the universe and eventually landed on Earth ("panspermia")**
 - **The Sun is a hot stone and the Moon is made of Earth**
- **Democritus (5th c BC)**
 - **Everything is divisible in atoms**

Greece

- **Aristotel**
 - **Syllogism**
 - **Natural state is rest**
 - **Natural state of the heavens is uniform circular motion**
 - **Heavier bodies of a given material fall faster than lighter ones**

Greece

- **Eukleides/ Euclid (b300BC, Alexandria)**
 - **Geometry**
 - **Postulates (parallel lines)**
- **Archimedes (b287BC)**
 - **Mathematics and Mechanics**
 - **Principle of the lever**
 - **Law of hydrostatics**
 - **Physics becomes a separate discipline from Philosophy**

Alexandria

- **Eratosthenes (Alexandria, b276BC)**
 - **Calculates the circumference of the Earth**
- **Aristarchus (Alexandria, b270BC)**
 - **The Earth is a planet**
 - **Planets revolve in circles around the Sun (heliocentric world)**
 - **Calculates the distance between the Earth and the Moon**
- **Klaudios Ptolemaios/ Ptolemy of Alexandria (145 AD)**
 - **Earth at the center of the universe (“geocentric theory”)**
 - **Uniform circular motion of the planets in their orbits and of their orbits around the Earth**

Alexandria

- **Mathematics accounts systematically for the motion of the universe**

Between Athens and Rome

- **Time-keeping**
 - **Egyptian “outflow” water clocks (325 BC)**
 - **Ctesibius of Alexandria (3rd C BC): the inflow water clock**
 - **Large-scale water automata**
 - **Athens' "Horologion" by Andronikos (1st C BC), comprising both sundials and 24-hour water clocks, indicators for the eight winds and the seasons, and astrological data**

Roman Empire

- **Engineering**
- **Roads**
- **Water automata**

China

- **Han (206 BC - 220 AD)**
 - **Paper (105 AD)**
 - **Waterwheel (waterpower for grinding grain and casting iron)**
 - **Compass**
- **Tang (618 - 907)**
 - **World's first escapement (Xian, 725)**
 - **Porcelain (7th c)**
 - **Gunpowder (9th c)**

China

- **Printing**
 - **Woodblock printing (7th c)**
 - **First printed book in 770 (one million copies of a Buddhist text)**
 - **Tang government's official gazette**
 - **Complete 130-volume edition of Confucian classics (953)**

Islam

- **Averroes: two truths, one the approximation of the other**

Islam

- **Astronomy**
 - Thabit ibn Qurra (836)
 - Abd al-Rahman al-Sufi (903)
 - Abu al-Hasan Ali ibn Yunus (950)
 - al-Biruni (973)
- **Mathematics**
 - Al-Khwarizmi (780): algebra (from India)
 - Habash al-Hasib (825): sine, cosine, tangent
 - Umar al-Khayyam (1048): algebraic equations
 - Sharaf al-Din al-Tusi (1135): algebraic geometry

Medieval Europe

- **Scholasticism**
 - Reason can prove the Christian revelation
 - Science must be consistent with religion
 - Averroes: two truths, one the approximation of the other
 - Scholastics: only one truth
 - Philosophy and science of Aristotle

Medieval Europe

- **Age of machines/ The Mill**
 - **Horizontal water mill (Egypt, 2nd c. BC)**
 - **Vertical water mill (Vetruvius, 1st c. BC)**
 - **10th c. AD: mills pervasive for grinding grain, fulling clothes, pressing olives and tanning (especially in the Islamic world)**
 - **Monasteries improve waterpower and millpower technology**
 - **The Cistercian monks pioneer water-powered iron mills**
 - **William the Conqueror's "Domesday Book" (1086) lists 5,624 mills**
 - **End of 12th c: windmill (England, North Sea)**
 - **First water-powered paper mill: Fabriano, 1276**

Medieval Europe

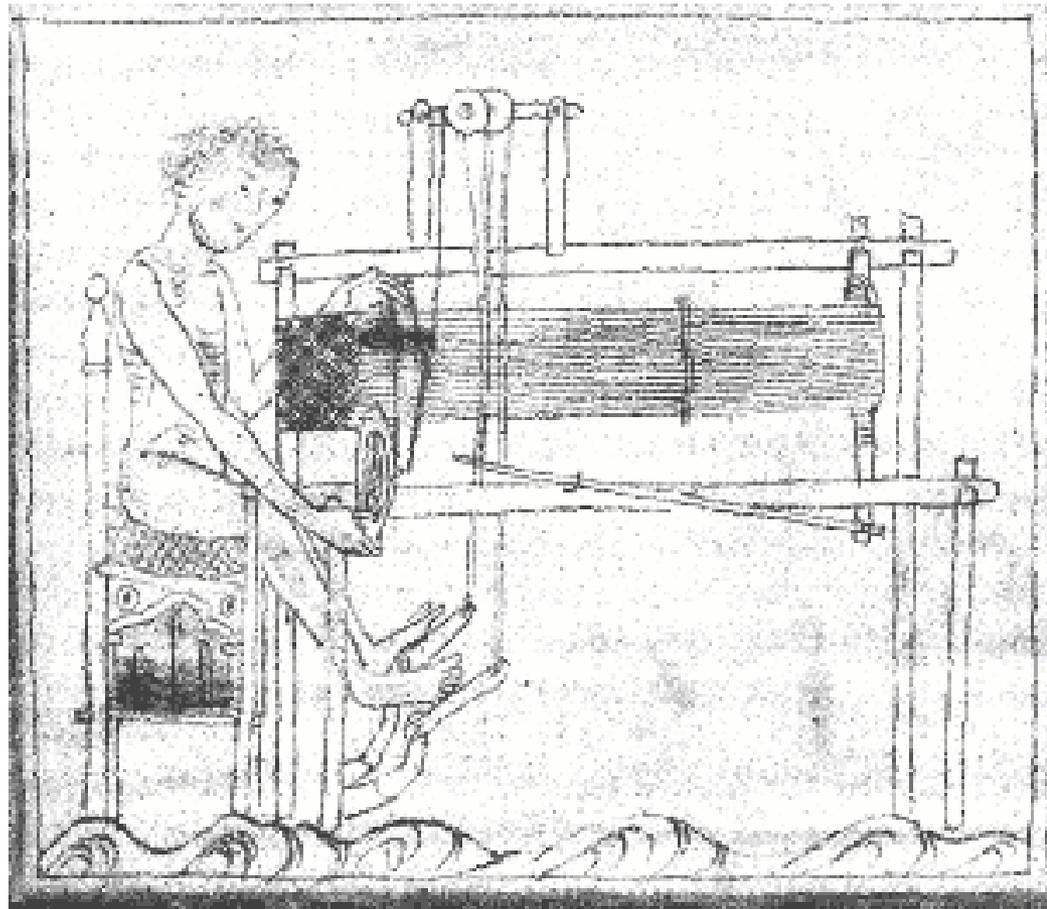
- **Age of machines**
 - **1126: artesian well (invented by the Carthusians in Artois)**
 - **12th c. AD: trebuchet (catapult)**
 - **12th c. AD: paper (Spain)**
 - **13th c. AD: mechanical clock and planetarium**
 - **13th c. AD: spinning wheel (first instance of belt transmission of power)**
 - **1285: spectacles (Italy)**
 - **12th c: blast furnace (Sweden)**



“Dominican” Frescoes (1352) by Tomaso da Modena in San Nicolo, Treviso (Italy): spectacles of Cardinal Ugo, lens of Niccolò da Rouen, sandglass of Cardinal William

Medieval Europe

- **Age of machines**
 - **Horizontal loom of 1250 (manuscript at Trinity College, Cambridge)**



Medieval Europe

- **Age of machines/ Weapons**
 - **Milano (12th c) center of military technology (weapons, armors)**
 - **Cannon (late 13th c)**
 - **Handguns (end of 14th c)**

Medieval Europe

- **Age of machines/ Clocks**
 - **Escapement (end of 13th c)**
 - **Mechanical clock (13th c - 14th c)**
 - **First machine made entirely of metal**
 - **Initially to serve the need of astrologers (astronomical clocks) and made by blacksmiths**
 - **St Eustorgio (Milano, 1309)**
 - **First clockmakers (Jacopo di Dondi, who built the clock for the tower of the Carrara palace at Padua, 1344)**
 - **First household clocks: end of 13th c, made by goldsmiths/silversmiths, not by blacksmiths**

Medieval Europe

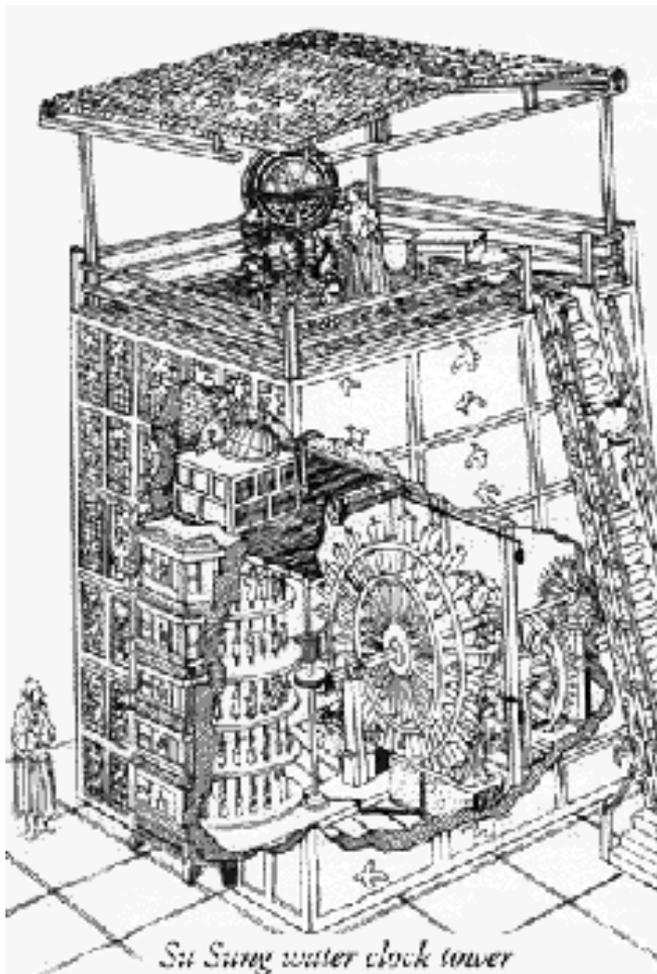
- **Clocks**
 - **Boom of public clocks in Italy (early 14th c)**
 - **Mechanical clock in the San Gottardo tower of Milano (1336): first tower clock**
 - **Parallel development: the sandglass**
 - **Pope Urban V's "portable clock" of 1365: first portable clock, but requires a "clock carrier"**
 - **Regulation of working time (Cologne, 1374), town-hall meetings, markets, schools, preaching**
 - **Small portable clocks (15th c)**

Medieval Europe

- **Clocks**
 - **The clock replaces the natural flow of time (the flow of individual experiences) with an abstract flow of time (the universal flow of clocks)**
 - **The clock begins a process of alienation of the individual from its natural environment**
 - **Before the invention of the clock, only monasteries valued routine daily behavior**

Medieval Europe

- **Clocks**



Miniature from 1250 Bible 31
Oxford Bodleian Library

Medieval Europe

- **Age of machines**
 - **Theophilus Presbyter: “De Diversis Artibus” (13th c), Europe’s first technical manual**
 - **The art of the painter**
 - **The art of the glass worker**
 - **The art of the metal worker**
 - **Each village acquires its own carpenter and smith**

Medieval Europe

- **Printing press**
 - **12xx: paper is “invented” in Spain**
 - **124x: movable type metal printing press is invented in Korea**
 - **1276: paper mill in Fabriano**
 - **1423: Laurens-Janszoon Koster (Netherlands) introduces movable type in Europe**
 - **1450: newsletters begin circulating in Europe**
 - **1456: Gutenberg “invents” the printing press**
 - **By 1501 there are 1000 printing shops in Europe**

Medieval Europe

- **Printing press**
 - **After the press**
 - **1534: first Frankfurt Book Fair**
 - **1545: Venezia introduces author's copyrights**
 - **1566: the first newspaper, Notizie Scritte, in Venezia**
 - **1571: Pope Paul IV issues Index of Forbidden Books**
 - **1599: 10,000,000 books in Europe**
 - **End of the Church's monopoly on books (and knowledge)**

Medieval Europe

- **Printing press**
 - **First revolution in information technology (first in the chain that would lead to the telegraph, telephone, computer, Internet)**

Medieval Europe

- **The standard model of science**
 - **The Earth is at the center of the universe**
 - **The heavens are organized around the Earth in concentric revolving spheres**
 - **The planets are located in the first sphere**
 - **The stars are in the second sphere**
 - **The other spheres are for angels**
 - **The last sphere is God**

Medieval Europe

- **The standard model of science/ Problems:**
 - **Motion of Mars**
 - **Why does the arrow keep flying?**
 - **Why does the arrow stops flying?**

The Scientific Revolution

- **The age of exploration**
- **The reformation (1517)**

The Scientific Revolution

- **What happened in...?**
 - **Italy, Spain and Poland between 4 Oct 1582 and 15 Oct 1582,**
 - **France between 9 Dec 1582 and 20 Dec 1582**
 - **Hungary between 21 Oct 1587 and 1 Nov 1587**
 - **Prussia between 22 Aug 1610 and 2 Sept 1610**
 - **Denmark between 18 Feb 1700 and 1 Mar 1700**
 - **Britain between 2 Sep 1752 and 14 Sep 1752**
 - **Greece between 9 Mar 1924 and 23 Mar 1924**
 - **Russia between 31 Jan 1918 and 14 Feb 1918**
 - **Turkey between 18 Dec 1926 and 1 Jan 1927**

The Scientific Revolution

- **Science**
 - **Main center of scientific research: Italy**
 - **Leonardo, Copernicus, Galileo**
 - **Accademia dei Lincei, Roma (1603)**
 - **Royal Society of Science, London (1662)**
 - **French Academy of Science (1666)**

The Scientific Revolution

- **Mikolaj Kopernik/ Nicolaus Copernicus (1530, Poland)**
 - **Heliocentric theory**
 - **The sun is at rest at the center of the universe**
 - **The earth, spinning on its axis once daily, revolves annually around the sun**
 - **The planets also circle the sun**
 - **The Earth is one of the planets**
 - **The greater the radius of a planet's orbit, the greater the time the planet takes to revolve around the sun**

The Scientific Revolution

- **Tycho Brahe (1573, Sweden)**
 - **Discovered a nova (a new star)**
 - **Aristotelian/Christian view:**
 - **The world below the moon is imperfect and dynamic**
 - **The world above the moon is perfect and static**
 - **Brahe's view:**
 - **The world below the moon is not as imperfect as we think**
 - **The world above the moon is not as perfect as we think**

The Scientific Revolution

- **Johannes Kepler (1619, Germany)**
 - **Laws of planetary motion**
 - **Planets move in ellipses (motion is not uniformly circular)**
 - **Planets describe equal areas in equal times**
 - **The square of a planet's periodic time is proportional to the cube of its mean distance from the sun**
 - **Ellipses not circles for astral bodies**
 - **The heavens are a machine**

The Scientific Revolution

- **Renaissance Inventions**
 - **Microscope (1590s, Dutch)**
 - **Telescope (1608, Dutch/Italian)**
 - **Thermometer (1611, Italian)**
 - **Barometer (1644, Italian)**
 - **Pendulum clock (1657, Dutch)**

The Scientific Revolution

- **Science**
 - **Very fast: Olaus Roemer determines the speed of light (1678)**
 - **Very small: Anton van Leeuwenhock proves the existence of microorganisms**
 - **Very far and very big: Galileo (1610) documents the mountains of the Moon and the moons of other planets (Jupiter)**

The Scientific Revolution

- **Francis Bacon (1620)**
 - Truth must be found via **objective, unbiased, empirical** observation
 - **Induction**
 - **Goal of science is to control the world (“how to command nature itself”), i.e. technology**

The Scientific Revolution

- **Galileo Galilei (1632)**
 - A body in free motion does not need any force to continue moving
 - If a force is applied, then what will change is the **acceleration**, not the velocity
 - Linear uniform motion as the natural motion of all objects
 - Acceleration is due to forces
 - Acceleration is the same for all falling objects
 - How to unify horizontal and vertical motion
 - Relativity: All physical laws are the same for all observers in linear uniform motion relative to each other

The Scientific Revolution

- **Blaise Pascal (1632)**
 - **First mechanical adding machine (1642)**
 - **Mathematical theory of probability (1654)**

The Scientific Revolution

- **René Descartes (1637)**
 - **Mathematics is certain knowledge (what cannot be doubted), from which other certain knowledge can be derived**
 - **The scientific method**
 - **Rationalism**
 - **Mechanicism**

The Scientific Revolution

- **Robert Boyle (1661)**
 - **Founding father of Chemistry**
 - **Under conditions of constant temperature, the pressure and volume of a gas are inversely proportional.**
 - **Atomic theory of matter: matter is made of innumerable elementary particles**

The Scientific Revolution

- **Jacques Guttin: Epigone, histoire du siècle futur (1659)**
 - **First futuristic book**

The Scientific Revolution

- **Isaac Newton (1687)**
 - **The same physical laws apply to the entire universe**
 - **Unification of terrestrial and celestial mechanics**
 - **Every event is controlled by such physical laws**
 - **Such physical laws can be formulated in terms of mathematical equations**
 - **Mathematical description of the motion of bodies in space and over time**

The Scientific Revolution

- **Isaac Newton (1687)**
 - **Absolute time and space made of ordered instants and points**
 - **Force as cause of change of motion (acceleration)**
 - **Conservation of energy**
 - **Principle of universal gravitation: every particle of matter in the universe attracts every other particle with a force varying inversely as the square of the distance between them and directly proportional to the product of their masses**
 - **Action at distance**
 - **Force is proportional to mass and acceleration**

The Scientific Revolution

- **Isaac Newton (1687)**
 - **Galileo's inertia: the property of a material object to either remain at rest or in a uniform motion in the absence of external forces**
 - **Newton's inertia: a fundamental quantitative property of matter (mass)**
 - **What is "mass"? Where does it come from? Why is it related to acceleration?**

The Industrial Revolution

- **Coal economy**
 - **16th-17th century London**
 - **Coal heats homes better than wood**
 - **Wood scarce, coal plenty**
 - **18th century England**
 - **Coal wealth**
 - **Shipbuilding technology improved to transport coal to London**
 - **Canals built to transport coal**
 - **Railroads invented for coal (1825)**

The Industrial Revolution

Textiles

1721: Thomas Lombe builds the first factory in the world (for silk)

1733: John Kay invents the flying shuttle (for the manufacture of wool)

1741: Lewis Paul, having invented a mechanical system to spin cotton, opens the first cotton mill

1757: James Watt improves the steam engine

1765: James Hargreaves invents the spinning jenny (for the cotton industry)

1771: Richard Arkwright opens the first factory powered by water power

1779: Samuel Crompton invents the "mule" for the cotton industry, which reduces the cost of spinning by 95% in 20 years

1785: Edmund Cartwright mechanizes weaving (the "power loom")

1787: Robert Peel builds an integrated spinning, weaving and printing factory

The Industrial Revolution

Transportation

1804: Richard Trevithick builds the world's first locomotive

1812: Henry Bell starts the first commercial steamboat service in Glasgow

1819: The "Savannah" completes the first transatlantic crossing by a steamboat

1820: the first iron steamship is built

1830: the world's first commercial railroad opens (George Stephenson's Liverpool-Manchester)

1844: the telegraph

1869: the Suez canal (impassable by sail boats) boosts sales of steamboats

1879: the first steel steamboat crosses the Atlantic

1892: Britain tonnage and seatriade exceeds the rest of the world together

The Industrial Revolution

- **Britain**
 - **Joint-stock company ubiquitous**
 - **Glorious revolution (1689)**
 - **Stabilizing role of the Bank of England (1694)**
 - **Efficient and honest government**
 - **Weak hold of the guild system**

The Industrial Revolution

- **Manchester**
 - **Water mills + coal mines + Liverpool's port + technology**
 - **Middle class ran most of the enterprises**
 - **200 years of clock-making (cotton mechanics were clock-makers)**
 - **First polytechnic schools**

The Industrial Revolution

- **Steam engine**
 - **Boom of factories caused high demand for iron**
 - **Iron had to be smelt with coal**
 - **The demand of coke increased exponentially to smelt iron**
 - **Problem: pumping water out of coal mines**

The Industrial Revolution

- **Steam engine**
 - **Before the steam engine:**
 - **water wheels (need water)**
 - **windmills (need wind)**
 - **draft animals (need food, vulnerable to disease and exhaustion)**
 - **people (need food, vulnerable to disease and exhaustion)**
 - **The steam engine: independent of location, time, weather, people**
 - **First major innovation in transformation of energy since the windmill**
 - **Biggest impact on daily life since the printing press**

The Industrial Revolution

- **Steam engine**
 - **Consequence: high demand for iron to build steam engines**

The Industrial Revolution

- **Transportation**
 - **Railways**
 - **Steamships**
 - **National postal systems**
 - **1855: Panama railway**
 - **1869: Suez canal**

The Industrial Revolution

- **Transportation**
 - **The Railway**
 - **Conductors, drivers, engine fireman**
 - **Railway stations**
 - **Signalmen**
 - **Maintenance crews**
 - **Telegraph**
 - **Engineers**

What the Industrial Age knew

- **International Standards**
 - **1582: Gregorian calendar**
 - **1744: Celsius degrees**
 - **1800: Metric system**
 - **1884: Greenwich time**

The Chemical Revolution

- **Joseph Black (1755): carbon dioxide**
- **Henry Cavendish (1766): hydrogen**
- **Joseph Priestly (1774): oxygen**
- **Henry Cavendish (1785): water and air are not elements but compounds (oxygen+hydrogen, oxygen+nitrogen)**
- **Antoine Lavoisier (1777): combustion is a form of oxidation (combination with oxygen)**
- **Antoine Lavoisier (1789): conservation of mass (the quantity of matter is the same at the end as at the beginning of every chemical reaction)**
- **John Dalton (1803): matter is composed of atoms of differing weights**

The Chemical Revolution

- **Daniel Bernoulli (1738)**
 - **Macroscopic properties of objects are due to and can be explained by the motion of the particles that constitute them**
 - **First kinetic theory of gases**
 - **Expressed in probabilistic terms**
- **Sadi Carnot (1824)**
 - **Study of heat**
 - **Perpetual motion is impossible**
- **1850: Rudolf Clausius discovers entropy**

The Electrical Revolution

- **William Gilbert (1600):** coins the term "electricity" (from "elektron", the Greek word for amber: amber becomes charged by rubbing)
- **Otto von Guericke (1660):** the first machine for producing static electricity
- **Robert Boyle (1675):** electric force is transmitted through a vacuum
- **Stephen Gray (1729):** conductors and nonconductors, positive and negative charge
- **Pieter van Musschenbroek (1745):** invents the Leyden jar, a "condenser" that can store static electricity but discharge it only all at once
- **Benjamin Franklin (1752):** lightning is a form of electricity

The Electrical Revolution

- **Charles Coulomb (1791): law of attraction and repulsion**

$$F_{\text{elec}} = K \frac{Q_1 Q_2}{r^2}$$

- **Alessandro Volta (1800): battery that transforms chemical energy into electricity**

The Electrical Revolution

- **Hans Christian Oersted (1819):** a magnetic field surrounds a current-carrying wire
- **AndreMarie Ampere (1820):** electromagnetic reaction (two parallel conductors carrying currents traveling in the same direction attract each other; if traveling in opposite directions, repel each other)
- **Michael Faraday (1831):** electromagnetic induction
- **Michael Faraday (1830s):** dynamo (that converts mechanical energy into electrical energy), electric motor, electric generator
- **Georg Simon Ohm (1827):** the relationship among voltage, current, and resistance $V=R*I$

The Electrical Revolution

- **Michael Faraday (1831)**
 - **Interaction between bodies is transmitted through a field**
 - **Electricity is transmitted through an electrical fields**
 - **Magnetism is transmitted through a magnetic field (first observed by Hans Christian Oersted in 1819)**
 - **Identity of electricity and magnetism**

The Electrical Revolution

- **Gustav Robert Kirchhoff (1845):** laws for the distribution of current in electric circuits (e.g., the sum of the currents into a given node equals the sum of the currents out of that node)
- **William Weber (1855):** the ratio between the electrodynamic and electrostatic units of charge is the same number as the speed of light

The Electrical Revolution



- **James Maxwell (1873)**
 - **Electricity and magnetism are the same phenomenon**
 - **Electric bodies radiate invisible waves of energy through space (fields)**
 - **The number of coordinates needed to determine a wave is infinite**
 - **Mathematical relation between electric and magnetic fields (field equations)**
 - **Light is made up of electromagnetic waves**

The Electrical Revolution

- **James Maxwell (1873)**
 - **The story of “c”**
 - **The ratio between electrostatic and electrodynamic units of charge: a constant c with the dimensions of a speed**
 - **c is exactly the vacuum speed of light**
 - **Maxwell’s conclusion: light must be an electromagnetic wave**

The Electrical Revolution

- **Germany**
 - **1847: Werner Von Siemens founds a company to exploit the telegraph**
 - **1866: the first practical dynamo is developed by Siemens**
 - **1879: Siemens demonstrates the first electric railway**
 - **1881: Siemens demonstrates the first electric tram system**
 - **1887: Emil Rathenau founds the Allgemeine Elektrizitäts Gesellschaft, specializing in electrical engineering, whereas Siemens specializes in communication and information**
 - **1890: AEG develops the AC motor and generator (first power plants) and alternating current makes it easy to transmit electricity over long distances**

The USA

- **Boom of cotton**
 - **Samuel Slater's cotton spinning mill of 1790 in Rhode Island turns cotton into thread**
 - **Eli Whitney's cotton gin of 1793 helps the USA become the producer of 70% of the world's cotton by 1850**
 - **Francis Cabot Lowell's integrated cotton factory (spinning + weaving) of 1814 in Massachusetts**
 - **The USA becomes the second industrial power in the world (two million people employed in manufacturing in 1824)**

The USA

- **Transportation**
 - **1790: First turnpike (Philadelphia-Lancaster)**
 - **Capital intensive (private investors)**
 - **1803-1848: Turnpike from Maryland to Illinois (Congress funded)**
 - **1807: First steamboat (Robert Fulton's North River Boat from New York to Albany)**
 - **Capital intensive (private investors)**
 - **1817: First scheduled passenger ship from New York to Liverpool (Black Ball Line)**
 - **Capital intensive (private investors)**

The USA

- **Transportation**
 - **1825: Erie Canal (Great Lakes to New York)**
 - **Reduced importance of the Mississippi river and of New Orleans for domestic trade**
 - **Manhattan's population increases from 123,000 in 1820 to 814,000 in 1860**
 - **Capital intensive (New York state)**
 - **1829: Cornelius Vanderbilt's first steamboat**
 - **Slashes operational costs and reduces fares to made them affordable to the masses**
 - **Capital intensive (private investors)**

The USA

- **Transportation**
 - **1828: First railroad (Baltimore-Ohio)**
 - **1840: 4,500 kms of railroad track**
 - **1860: 49,000 kms of railroad track (mostly in the North)**
 - **Capital intensive (private investors)**
 - **1869: The Union and Central Pacific railroads create the first transcontinental railroad**
 - **Capital intensive (USA government)**

The USA

- **Communication**
 - **1844: Samuel Morse’s telegraph**
 - **Used electricity to broadcast information**
 - **Shared the route of the railroads**
 - **Cut the time to send a message from months to minutes**
 - **Made Wall Street “the” stock market of the nation (no more need for others)**
 - **Capital intensive (USA government)**
 - **1866: Cyrus Field’s transatlantic cable**
 - **Capital intensive (private investors)**

The USA

- **Communication**
 - **Telegraph**
 - **Second major revolution in information technology after the printing press**
 - **The virtual movement of information replaces the physical movement of people**
 - **Transportation and communication get decoupled**

The USA

- **Communication**
 - **1835: James Bennett's New York Herald**
 - **First mass-market daily newspaper**
 - **Rotary press powered by steam (thousands of copies, low price)**
 - **Pages on business, weather, sports.**
 - **International correspondents (enabled by telegraph)**
 - **Advertising**
 - **Capital intensive (private investors)**

The USA

- **Gas**
 - **1796: Philadelphia pioneers gaslight**
 - **1830s: Street lighting in all major eastern cities**
 - **1840s: Gaslight common in homes**
 - **1840s: Central heating common in homes**
 - **People can stay up till late and read**
 - **Boom of books, magazines and newspapers**

The USA

- **Oil**
 - **1859: First oil well in the world (Edwin Drake)**
 - **Scarcity of whale oil for illumination drives search for alternatives**
 - **Technology of drilling for salt**
 - **Lighting drives the great demand for oil until gasoline-powered cars**
 - **1862: John Rockefeller's Standard Oil to refine oil**
 - **Mission: low-cost producer of oil (Samuel Andrews's process for the refinement of crude petroleum)**
 - **Internal combustion engine (1876)**
 - **Capital intensive (private investors)**

The USA

- **Steel**
 - **Iron + coke + limestone**
 - **Melting point of iron: 1535 C**
 - **Bessemer converter for mass-producing steel (1856)**

The USA

- **Agriculture**

- **Vast areas to farm for a small population of colonists**
- **Huge farms outside the village**
- **Need for mechanical tools to help in farming the land**
- **1831: Cyrus McCormick's harvesting machine**
 - **Chicago's shipment of wheat increased from 80 bushels in 1839 to 2,000,000 in 1849**
- **1837: John Deere's steel plow**
- **The percentage of agricultural workers steadily declined, while agricultural output steadily increased**
- **Capital intensive (private investors)**

The USA

- **Consumerism**
 - **1846: The “Marble Palace”, New York (first department store where customers can browse at leisure)**
 - **Sets the standard for middle-class lifestyle (furniture, carpeting, china, decoration)**
 - **Change the meaning of “necessity”**
 - **Turns Christmas into the main engine of retail business**

The USA

- **Consumerism**
 - **1816: Frederic Tudor's ice box (insulated with sawdust)**
 - **USA exports ice to Brazil, India, China and Indonesia**
 - **1851: Isaac Singer's sewing machine**
 - **The price for ready-made clothes plunges and makes them affordable for the masses**

Second Industrial Revolution

- **Steel replaces iron**
- **Electricity replaces steam**
- **Machines replace humans**
- **Scientific laboratories at the service of the industry**
- **Global business based on fast transportation and communication**
- **Imperialism**

Next Lecture

The Thermodynamic revolution

The Subatomic Revolution

The Cosmological Revolution

The Biological Revolution

The Psychological Revolution

The Digital Revolution

The Age of the Literal

- **Decline of the metaphorical/allegorical world**
- **Engineering the Future (Futuristic fiction)**
- **Rediscovering the Past (Archeology)**
- **Age of Specialization**
- **Decline of Religion**