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Conductors and insulators examples

What makes a material an electrical conductor or insulator? Simply put, electrical conductors are materials that carry (or conduct) electrical currents well, such as iron and steel, and insulators are materials that do not, like glass and plastic. Whether a substance conducts electricity is determined by how easily electrons move through it. Electrical conductivity depends on electron movement because protons and neutrons don't move—they are bound to other protons and neutrons in atomic nuclei. In addition to different types of materials, factors such as the size and temperature of materials also affect conductivity. Valence electrons are like outer planets orbiting a star. They're attracted to their atoms enough to stay in position, but it doesn't always take a lot of energy to knock them out of place. Valence electrons easily carry electric currents. Inorganic substances like metals and plasmas that readily lose and gain electrons top the list of conductors. On the other hand, organic molecules are typically insulators because their structure is primarily held together by strong covalent bonds, and the presence of hydrogen bonding further contributes to their stability. This molecular structure doesn't easily allow electrons to move, which is necessary for electrical conductivity. Some materials in pure form are insulators but will conduct if they are doped with small quantities of another element or if they contain impurities. For example, most ceramics are excellent insulators but if you dope them, you can create a superconductor. Pure water is an insulator, dirty water conducts weakly, and saltwater, with its free-floating ions, conducts well. However, most materials are neither good conductors nor good insulators but somewhere in the middle. The best electrical conductor, under conditions of ordinary temperature and pressure, is the metallic element silver. Silver is not always an ideal choice as a material, however, because it is expensive and susceptible to tarnishing, and the oxide layer known as tarnish is not conductive. Similarly, rust, verdigris, and other oxide layers reduce conductivity even in the strongest conductors. The most effective electrical conductors are: SilverGoldCopperAluminumMercurySteelIronSeawaterConcreteMercury Other strong conductors include: PlatinumBrassBronzeGraphiteDirty waterLemon juice Electric charges do not flow freely through insulators. This is an ideal quality in many cases—strong insulators are often used to coat or provide a barrier between conductors to keep electric currents under control. This can be seen in rubber-coated wires and cables. The most effective electrical insulators are: RubberGlassPure waterOilAirDiamondDry woodDry cottonPlasticAsphalt Other strong insulators include: FiberglassDry paperPorcelainCeramicsQuartz The shape and size of a material affect its conductivity. For example, a thick piece of matter will conduct better than a thin piece of the same size and length. If you have two pieces of a material of the same thickness, but one is shorter than the other, the shorter one will conduct better because the shorter piece has less resistance, in much the same way that it's easier to force water through a short pipe than a long one. Temperature also affects conductivity. As temperature increases, atoms and their electrons gain energy. Some insulators like glass are poor conductors when cool but good conductors when hot; most metals are better conductors when cool and less efficient conductors when hot. Some good conductors become superconductors at extremely low temperatures. Sometimes conduction itself changes the temperature of a material. Electrons flow through conductors without damaging the atoms or causing wear. Moving electrons do experience resistance, though. Because of this, the flow of electrical currents can heat conductive materials. Metals and plasmas readily conduct electricity because their valence electrons can move easily.Insulators, often organic molecules, are primarily held together by strong covalent bonds, impeding electron movement and hindering electrical conductivity.Material factors like doping or impurities can also affect conductivity; for example, pure water is an insulator, but saltwater conducts due to free-floating ions. Some materials let electricity pass through them easily. These materials are known as electrical conductors.Many metals, such as copper, iron and steel, are good electrical conductors. That is why the parts of electrical objects that need to let electricity pass through are always made of metal.Metal is used in plugs to allow electricity to transfer from the wall socket, through the plug, and into a device such as a radio or TV.In a light bulb, the metal filament conducts electricity and causes the light bulb to light up. Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Object or material which allows the flow of electric charge with little energy loss Overhead conductors carry electric power from generating stations to customers. Articles aboutElectromagnetism Electricity Magnetism Optics History Computational Textbooks Phenomena Electrostatics Charge density Conductor Coulomb law Electret Electric charge Electric dipole Electric field Electric flux Electric potential Electrostatic discharge Electrostatic induction Gauss's law Insulator Permittivity Polarization Potential energy Static electricity Triboelectricity Magnetostatics Ampère's law Biot–Savart law Gauss's law for magnetism Magnetic dipole Magnetic field Magnetic flux Magnetic scalar potential Magnetic vector potential Magnetization Permeability Right-hand rule Electrodynamics Bremsstrahlung Cyclotron radiation Displacement current Eddy current Electromagnetic field Electromagnetic induction Electromagnetic pulse Electromagnetic radiation Faraday's law Jefimenko equations Larmor formula Lenz's law Liénard–Wiechert potential London equations Lorentz force Maxwell's equations Maxwell tensor Poynting vector Synchrotron radiation Electrical network Alternating current Capacitance Current density Direct current Electric current Electric power Electrolysis Electromotive force Impedance Inductance Joule heating Kirchhoff's laws Network analysis Ohm's law Parallel circuit Resistance Resonant cavities Series circuit Voltage Watt Waveguides Magnetic circuit AC motor DC motor Electric machine Electric motor Gyrator–capacitor Induction motor Linear motor Magnetomotive force Permeance Reluctance (complex) Reluctance (real) Rotor Stator Transformer Covariant formulation Electromagnetic tensor Electromagnetism and special relativity Four-current Four-potential Mathematical descriptions Maxwell equations in curved spacetime Relativistic electromagnetism Stress–energy tensor Scientists Ampère Biot Coulomb Davy Einstein Faraday Fizeau Gauss Heaviside Helmholtz Henry Hertz Hopkinson Jefimenko Joule Kelvin Kirchhoff Larmor Lenz Liénard Lorentz Maxwell Neumann Ohm Ørsted Poisson Poynting Ritchie Savart Singer Steinmetz Tesla Thomson Volta Weber Wiechert vte In physics and electrical engineering, a conductor is an object or type of material that allows the flow of charge (electric current) in one or more directions. Materials made of metal are common electrical conductors. The flow of negatively charged electrons generates electric current, positively charged holes, and positive or negative ions in some cases. In order for current to flow within a closed electrical circuit, one charged particle does not need to travel from the component producing the current (the current source) to those consuming it (the loads). Instead, the charged particle simply needs to nudge its neighbor a finite amount, who will nudge its neighbor, and on and on until a particle is nudged into the consumer, thus powering it. Essentially what is occurring is a long chain of momentum transfer between mobile charge carriers; the Drude model of conduction describes this process more rigorously. This momentum transfer model makes metal an ideal choice for a conductor; metals, characteristically, possess a delocalized sea of electrons which gives the electrons enough mobility to collide and thus affect a momentum transfer. As discussed above, electrons are the primary mover in metals; however, other devices such as the cationic electrolyte(s) of a battery, or the mobile protons of the proton conductor of a fuel cell rely on positive charge carriers. Insulators are non-conducting materials with few mobile charges that support only insignificant electric currents. A piece of resistive material with electrical contacts on both ends Main article: Electrical resistance and conductance The resistance of a given conductor depends on the material it is made of, and on its dimensions. For a given material, the resistance is inversely proportional to the cross-sectional area.[1] For example, a thick copper wire has lower resistance than an otherwise-identical thin copper wire. Also, for a given material, the resistance is proportional to the length; for example, a long copper wire has higher resistance than an otherwise-identical short copper wire. The resistance R and conductance G of a conductor of uniform cross section, therefore, can be computed as[1] $R = \rho \frac{\ell}{A}, G = \sigma \frac{A}{\ell}$. {\displaystyle {\begin{aligned}R&=\rho {\frac {\ell }{A}},\\[6pt]G&=\sigma {\frac {A}{\ell }}.\end{aligned}}} where ℓ {\displaystyle \ell } is the length of the conductor, measured in metres [m], A is the cross-section area of the conductor measured in square metres [m2], σ (sigma) is the electrical conductivity measured in siemens per meter ($S \cdot m^{-1}$), and ρ (rho) is the electrical resistivity (also called specific electrical resistance) of the material, measured in ohm-metres (Ω·m). The resistivity and conductivity are proportionality constants, and therefore depend only on the material the wire is made of, not the geometry of the wire. Resistivity and conductivity are reciprocals: $\rho = 1 / \sigma$ {\displaystyle \rho =1/\sigma } . Resistivity is a measure of the material's ability to oppose electric current. This formula is not exact: It assumes the current density is totally uniform in the conductor, which is not always true in practical situation. However, this formula still provides a good approximation for long thin conductors such as wires. Another situation this formula is not exact for is with alternating current (AC), because the skin effect inhibits current flow near the center of the conductor. Then, the geometrical cross-section is different from the effective cross-section in which current actually flows, so the resistance is higher than expected. Similarly, if two conductors are near each other carrying AC current, their resistances increase due to the proximity effect. At commercial power frequency, these effects are significant for large conductors carrying large currents, such as busbars in an electrical substation,[2] or large power cables carrying more than a few hundred amperes. Aside from the geometry of the wire, temperature also has a significant effect on the efficacy of conductors. Temperature affects conductors in two main ways, the first is that materials may expand under the application of heat. The amount that the material will expand is governed by the thermal expansion coefficient specific to the material. Such an expansion (or contraction) will change the geometry of the conductor and therefore its characteristic resistance. However, this effect is generally small, on the order of 10^{-6}. An increase in temperature will also increase the number of phonons generated within the material. A phonon is essentially a lattice vibration, or rather a small, harmonic kinetic movement of the atoms of the material. Much like the shaking of a pinball machine, phonons serve to disrupt the path of electrons, causing them to scatter. This electron scattering will decrease the number of electron collisions and therefore will decrease the total amount of current transferred. Main article: Electrical resistivity and conductivity Further information: Copper conductor and Aluminum building wiring Material ρ [Ω·m] at 20 °C σ [S/m] at 20 °C Silver, Ag 1.59×10^{-8} 6.30×10^{7} Copper, Cu 1.68×10^{-8} 5.96×10^{7} Aluminum, Al 2.82×10^{-8} 3.50×10^{7} Conduction materials include metals, electrolytes, superconductors, semiconductors, plasmas and some nonmetallic conductors such as graphite and conductive polymers. Copper has a high conductivity. Annealed copper is the international standard to which all other electrical conductors are compared; the International Annealed Copper Standard conductivity is 58 MS/m, although ultra-pure copper can slightly exceed 101% IACS. The main grade of copper used for electrical applications, such as building wire, motor windings, cables and busbars, is electrolytic-tough pitch (ETP) copper (CW004A or ASTM designation C100140). If high conductivity copper must be welded or brazed or used in a reducing atmosphere, then oxygen-free high conductivity copper (CW008A or ASTM designation C10100) may be used.[3] Because of its ease of connection by soldering or clamping, copper is still the most common choice for most light-gauge wires. Silver is 6% more conductive than copper, but due to cost it is not practical in most cases. However, it is used in specialized equipment, such as satellites, and as a thin plating to mitigate skin effect losses at high frequencies. Famously, 14,700 short tons (13,300 t) of silver on loan from the United States Treasury were used in the making of the calutron magnets during World War II due to wartime shortages of copper.[4] Aluminum wire is the most common metal in electric power transmission and distribution. Although only 61% of the conductivity of copper by cross-sectional area, its lower density makes it twice as conductive by mass. As aluminum is roughly one-third the cost of copper by weight, the economic advantages are considerable when large conductors are required. The disadvantages of aluminum wiring lie in its mechanical and chemical properties. It readily forms an insulating oxide, making connections heat up. Its larger coefficient of thermal expansion than the brass materials used for connectors causes connections to loosen. Aluminum can also "creep", slowly deforming under load, which also loosens connections. These effects can be mitigated with suitably designed connectors and extra care in installation, but they have made aluminum building wiring unpopular past the service drop. Organic compounds such as octane, which has 8 carbon atoms and 18 hydrogen atoms, cannot conduct electricity. Oils are hydrocarbons, since carbon has the property of tetracovalency and forms covalent bonds with other elements such as hydrogen, since it does not lose or gain electrons, thus does not form ions. Covalent bonds are simply the sharing of electrons. Hence, there is no separation of ions when electricity is passed through it. Liquids made of compounds with only covalent bonds cannot conduct electricity. Certain organic ionic liquids, by contrast, can conduct an electric current. While pure water is not an electrical conductor, even a small portion of ionic impurities, such as salt, can rapidly transform it into a conductor. Wires are measured by their cross sectional area. In many countries, the size is expressed in square millimetres. In North America, conductors are measured by American wire gauge for smaller ones, and circular mils for larger ones. The ampacity of a conductor, that is, the amount of current it can carry, is related to its electrical resistance: a lower-resistance conductor can carry a larger value of current. The resistance, in turn, is determined by the material the conductor is made from (as described above) and the conductor's size. For a given material, conductors with a larger cross-sectional area have less resistance than conductors with a smaller cross-sectional area. For bare conductors, the ultimate limit is the point at which power lost to resistance causes the conductor to melt. Aside from fuses, most conductors in the real world are operated far below this limit, however. For example, household wiring is usually insulated with PVC insulation that is only rated to operate to about 60 °C, therefore, the current in such wires must be limited so that it never heats the copper conductor above 60 °C, causing a risk of fire. Other, more expensive insulation such as Teflon or fiberglass may allow operation at much higher temperatures. If an electric field is applied to a material, and the resulting induced electric current is in the same direction, the material is said to be an isotropic electrical conductor. If the resulting electric current is in a different direction from the applied electric field, the material is said to be an anisotropic electrical conductor. Classification of materials based on permittivity εr″/εr′ Current conduction Field propagation 0 perfect dielectriclossless medium $\ll 1$ {\displaystyle \ll 1} low-conductivity materialpoor conductor low-loss mediumgood dielectric ≈ 1 {\displaystyle \approx 1} lossy conducting material lossy propagation medium $\gg 1$ {\displaystyle \gg 1} high-conductivity materialgood conductor high-loss mediumpoor dielectric ∞ {\displaystyle \infty } perfect conductor Bundle conductor Charge transfer complex Electrical cable Electrical resistivity and conductivity Fourth rail Overhead line Stephen Gray, first to identify electrical conductors and insulators Superconductivity Third rail ^ a b "Wire Sizes and Resistance" (PDF). Retrieved 2018-01-14. ^ Fink and Beaty, Standard Handbook for Electrical Engineers 11th Edition, pages 17–19 ^ "High conductivity coppers (electrical)". Copper Development Association (U.K.). Archived from the original on 2013-07-20. Retrieved 2013-06-01. ^ "From Treasury Vault to the Manhattan Project" (PDF). American Scientist. Retrieved 2022-10-27. William Henry Preece. On Electrical Conductors. 1883. Oliver Heaviside. Electrical Papers. Macmillan, 1894. Annual Book of ASTM Standards: Electrical Conductors. American Society for Testing and Materials. (every year) IET Wiring Regulations. Institution for Engineering and Technology. wiringregulations.net Archived 2021-04-02 at the Wayback Machine BBC: Key Stage 2 Bitesize: Electrical Conductors The discovery of conductors and insulators by Gray, Dufay and Franklin. Wikimedia Commons has media related to Electrical conductors. Retrieved from " What makes a material an electrical conductor or insulator? Simply put, electrical conductors are materials that carry (or conduct) electrical currents well, such as iron and steel, and insulators are materials that do not, like glass and plastic. 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