

Current, voltage and power

[Science](#), [Physics](#)



Current, Voltage and Power * Electricity is the flow of electric charge. We can describe the flow of electric charge in several ways. These include the quantities Current, Voltage and Power. Current * Current (I) is the rate of flow of Charge Carriers, such as electrons. Current is usually thought of as moving in the direction of positive charge, so from the positive power supply to the negative. However, since in metals it is electrons that carry electric charge, the actual flow is opposite to the way in which we think of it. * Current is the amount of Charge, Q that passes a point in a set time, t. It is measured in Amps (A), and charge is measured in Coulombs (C). Since Amps are SI base units, Coulombs are defined as $A \cdot s$, As. Voltage * Voltage (V) or Potential Difference (p. d.) is a measure of the Energy transferred per Charge Carrier between two points. * Voltage is the Energy, E per Charge, Q. Voltage is measured in Volts (V), which is defined as one Joule per Coulomb. Voltage can be defined in base units as $Kg m^2 s^{-3} A^{-1}$. Power * Power (P) is the rate of Energy transfer. It is measured in watts (W), where one watt is defined as one Joule per Second. Hence watts can be expressed in base units as $Kg m^2 s^{-3}$ * From this definition of Power, we can substitute the algebraic definitions above to produce a variety of other formulae, including 'Power = Current \times Voltage' * Ohm's Law states that 'Voltage = Current \times Resistance'. We can use this to produce two more definitions of Power. Resistance and Resistivity * Resistance is the opposition to the passage of current within a component. The Resistance of a component decides how much voltage will be dropped across it for a particular current. * Resistance is measured in Ohms (Ω). According to Ohm's Law, voltage is the product of current and resistance. Therefore

Ohms can be expressed in base units as $\text{Kg}^{-1}\text{m}^{-2}\text{s}^3\text{A}^{-2}$. * Everything has Resistance, because everything has some opposition to the flow of Electric Charge. Components whose sole purpose is to provide a Resistance of a certain value are called Resistors. * When Resistors are connected in Series, the total Resistance across them will be equal to the sum of each Resistor value. The total voltage will be equal to the sum of the voltages across each Resistor. This rule will also apply for other components. * When Resistors are connected in Series, the reciprocal of the total resistance will be equal the sum of the reciprocals of each Resistor Resistance. The total voltage dropped will be the same as the voltages dropped across all the individual Resistors. Resistivity * Resistance is a Sample Constant, so is specific to individual components. However, there is a Material Constant that can be used to find the Resistance of any component of a specific material. This is Resistivity. Together with the length and cross-sectional area of a sample, it can calculate its resistance. * Resistivity is given the symbol ρ and is measured in Ohm Meters (Ωm , or $\text{Kg}^{-1}\text{m}^3\text{s}^{-3}\text{A}^{-2}$ in base units). * For example, copper has a Resistivity of $1.68 \times 10^{-8} \Omega\text{m}$, and Germanium $4.6 \times 10^{-1} \Omega\text{m}$. * The Resistance of a material of Resistivity ρ , length l and cross-sectional area A is calculated by the formula: $R = \frac{\rho l}{A}$ * Compounds are formed when two or more atoms join together, forming Bonds. There are different types of bonds that occur between atoms which give rise to different properties. Ionic Bonds * Ionic Bonds form when electrons are transferred from one atom to another, forming charged Ions which are attracted to each other by Electrostatic Forces. Elements tend to lose or gain electrons, forming

Ions, to get a 'full outer shell'. * Ionically bonded substances, such as Sodium Chloride, can form crystals known as Giant Ionic Lattices with bonds forming a network of connections between atoms. * Giant Ionic Lattices have high melting and boiling points since atoms are held together by strong forces. * Ionic substances can conduct electricity through the movement of charged ions. However, they may only do so if the ions are free to move around. Therefore ionic substances conduct electricity when molten or dissolved, but not when in a solid state. * Many ionic compounds dissolve in water. This is because the polar water molecules cluster around ions, and so separate them from each other. Covalent Bonds * Covalent bonds involve the sharing of electrons so that all atoms have 'full outer shells'. * Sometimes in a covalent bond, both shared electrons come from the same atom. This is known as a dative covalent bond. This often results in the formation of charged molecules. Simple Molecular Structures * Substances composed of relatively small covalently bonded structures are called simple molecular structures. * Simple molecular structures tend to have low melting and boiling points since the forces between molecules (intermolecular forces, which are van der Waals forces) are quite weak. * They don't tend to conduct electricity, since there are no free charge carriers. * They tend to be quite insoluble in water, but this depends on how polarised the molecule is. The more polar the molecules, the more water molecules will be attracted to them. Giant Covalent Structures * Sometimes, as is the case with carbon, covalently bonded structures can form giant networks, known as giant covalent structures. In these structures, each atom is connected to all the atoms to each other. * These structures are usually very

hard and have high melting and boiling points. This is because of the strong covalent bonds holding each atom in place. * In general, Giant Covalent Structures cannot conduct electricity due to the fact that there are no free charge carriers. One notable exception to this is Graphite. This is a structure composed of 'sheets' of carbon atoms on top of each other. Electrons can move between the sheets and so carry electricity. Metallic Bonding * Metals form Giant Metallic Lattices. These are composed of positive metal ions surrounded by a 'sea' of Delocalised Electrons. The metal ions are attracted to the negative electrons. * Metals tend to have high melting and boiling points because of the attraction between the metal ions and the electrons. The more Delocalised Electrons are present (because of a higher valency), the greater the melting and boiling points. * Metals conduct electricity because the electrons are free to move and carry charge. * Metals do not tend to dissolve, except in liquid metals, due to the strength of the attraction between the metal ions and the electrons. * Metals are Malleable and Ductile. This is because there are no direct bonds between metal ions, so they can slide over each other. The Shapes of Molecules * Different molecules have different shapes. The shape of a molecule is dictated by the arrangement of Electron Pairs. This is because Electron Pairs repel each other. The molecule settles in a state where the Electron Pairs are furthest apart from each other. * Different types of Electron Pairs have different repulsions. There occur Lone Pair Electrons (LP) and Bonding Pair Electrons (BP). The order of repulsion between different combinations, in order of decreasing repulsion, and so decreasing angle, is: * LP - LP * LP - BP * BP - BP * Common bond angles: * 2 Electron Pairs on a single atom

form 180° bond angles. * 3 Electron Pairs on a single atom form 120° bond angles. * 4 Electron Pairs on a single atom form $109.47(1220... =)^\circ$ bond angles. * 6 Electron Pairs on a single atom form 90° bond angles. * 2 Lone Pairs and 2 Bonding Pairs on a single atom form a 104.5° bond angle. * 1 Lone Pair and 3 Bonding Pairs on a single atom form a 107° bond angle.

Mass Spectrometry * Mass Spectrometry is a process by which the atomic mass of atoms or molecules is determined. It can be used to find relative isotopic abundance, atomic and molecular mass, and the structure of a compound. * The result of a Mass Spectrometry is a graph plotting mass per charge against relative abundance. Objects (atoms or groups of atoms) of different masses may be detected due to varying atomic masses giving Isotopes and the fragmentation of molecules into smaller groups of atoms. This data can then be used to calculate relative isotopic abundance, atomic or molecular mass, or the structure of a compound. * The peak with the highest mass is called the Molecular Ion, and the peak with the greatest abundance (largest size) is called the Base Peak. Time-of-Flight Mass Spectrometer * A Time-of-Flight Mass Spectrometer works by accelerating an ionised sample and calculating mass per charge based on how long each 'object' is in flight for. Since every 'object' receives equal force, according to Newton's Second Law, the acceleration of each 'object' will be inversely proportional to its mass. * The sample is first ionised by bombarding it with electrons, which also causes fragmentation to form smaller groups of atoms. Ions tend to have +1 charge, since a bombarding electron will knock an electron out of an atom's shell, so 'mass per charge' can generally be taken as simply 'mass'. * The

ions are then accelerated by Electromagnetic Field and travel through a vacuum area called the Drift Region, before being detected by the Ion Detector. Calculations and Deductions * Given a sample of a single element, the relative atomic mass can be calculated by looking at the peaks and performing a simple mean calculation. * The relative molecular mass can be deduced by looking for the Molecular Ion peak, since this will be the peak caused by the whole molecule. * The structure of a molecule can be deduced by looking at the smaller peaks and inferring the structure of those, given the likely combinations of atoms present that could produce that mass. This is because these peaks will be caused by fragments of the whole molecule. The stronger the bond between atoms, the less likely it is to break, and so the lower the abundance of the fragments that would be formed by the breaking of that bond. * In reality, peaks will not be perfectly clear because of the varying mass of individual atoms. However, smaller peaks like this can help to determine the structure of the larger ones.