 Electrostatics is the field of physics and especially electrodynamics that has many examples that can be seen in real life. Out of all of them, lightning and the Van de Graaff generator are a couple, one of which is natural while the other is one of the most ingenious human inventions ever. We are going to discuss both of them in detail below, and hopefully show you the utter beauty of science, especially physics. Lightning So, we have all seen lightning. It is that spark in the sky when the weather isn't too nice. But, trust me when I say that it is not as boring as it seems! We all know from the previously discussed topics that 2 bodies which have a potential difference will always cause charges to flow from a higher potential region to a lower one. Well, that is what all lightning is! During a storm, or in a humid weather, the air between the clouds and the ground gets partially ionized, i.e. it allows the charge to flow through it, unlike the neutral air we have in hot weathers. So, this causes a potential difference to be developed between the two surfaces, which further causes a flow of charges, and hence an electric shock is produced in the form of a zig-zag projectile. This type of sudden discharge occurs because both the bodies posses a very high amount of charges, because of which they become very unstable, and hence they come to equilibrium by this process. Now, the basic question that arises is, "Why zig-zag?" The reason is simple. The path of least resistance is the path that is the motive of every single charge in the lightning strike. Moreover, the entire atmosphere varies with humidity, temperature, pressure, and what not as we move along it. This causes fluctuations in its resistance, and hence the path is never straight, but rather it is one of the millions of possibilities that a lightning surge could have taken! The Van De Graaff Generator So, the next application on our list is the amazing Van de Graaff generator. According to me, it is one of the best inventions by the human mind, but its principle is pretty simple. So, picture this: you want to create a very high potential barrier or a very high potential difference between an object and its surroundings. If you would go the traditional way of accumulating the charge from the outside of the object, it would get really harder as you go on, as you'd have to face increasing amount repulsions. To overcome this problem, and to create large potential differences, that could be used in various fields; for example, in accelerating a subatomic particle, we use this device. The working of Van de Graaff generator is pretty cool, to be honest. What happens is that we use the principle of the motion of electric charge from a higher potential to lower potential. In the above diagram, you can see a pointed object D at the bottom and a pointed object E at the top. These are known as brushes and they help in collecting or depositing charges. The brush D deposits a positive charge on an insulated and rotating sheet, which then transports this charge to the brush E, which in turn lets the charge flow through it, and deposits it on the larger sphere in the end. In this way, we can create a potential difference of millions of volts, and only stop when we reach the breakdown voltage of the environment surrounding the apparatus. Now the question arises, "Why won't we face the similar repulsions as before?" That's a perfectly logical assumption to make, but the problem is that, now, we are transporting the charge not against the charge on the bigger sphere (as all its charge is on its outer surface). Moreover, with a little more mathematical manipulation, you can clearly show that the potential of the bigger sphere will always be greater than the inner pulleys, in case of a positive charge. In the end, if you are even a teensy bit interested, I'd highly recommend you to check out this collection of electrostatic experiments and lectures by a professor at MIT, who's really good at what he does. (Trust me! :P) President Bob Henderson is President of GfG Instrumentation, Inc. in Ann Arbor, Michigan.Robert has been a member of the American Industrial Hygiene... Page 2By clicking sign up, you agree to receive emails from Safeopedia and agree to our Terms of Use & Privacy Policy. How can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today's most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors' Picks.Browse Editors' Favorites Electrostatics is the study of electric charges that are fixed. It includes an study of the forces that exist between charges as defined by Coulomb's Law. The following concepts are involved in electrostatics: Electric charge, electric field, and electrostatic force.Electrostatic forces are non contact forces that can push or pull on items without coming into contact with them. A storm cloud's internal accumulation of static electricity produces lightning.In this article, we will study in detail about electrostatics, its related definitions, formulas and examples based on them.What is Electrostatics?Electrostatics is a field of physics that studies the phenomena and behaviours of stationary or slow-moving electric charges. Coulomb's law describes electrostatic processes, which result from the forces that electric charges apply to one another. even if forces generated by electrostatics appear to be rather little.Electrostatics Phenomena ExamplesExamples of Electrostatic Phenomena are as follows:A balloon rubbing hairThe shock of touching a doorknob after crossing a carpetAn electric balloon adhering to a wallA charged comb that gathers tiny bits of paperrubbing nylon clothing against flesh or other materialsUsing a towel to rub a rodUtilising a TV screenPutting on winter clothingMaking use of a photocopierWhat is Electric Charge? Electric charge is a fundamental property of matter that determines how it interacts with electromagnetic fields. When charges are stationary, they produce an electric field around them, and when in motion, they produce a magnetic field as well. Electric charge comes in two types: positive and negative. Like charges repel whereas unlike charges attract.Basic Properties of Electric ChargeElectric charge possesses three fundamental properties:Quantization: Electric charge is quantized, meaning charges are always found in integer multiples of the elementary charge(e), i.e., q=ne where n I. Elementary charge is the charge of an electron, approximately -1.602 x 10-19coulombs (C).Conservation: The total electric charge in an isolated system remains constant over time. Charge cannot be created or destroyed, only transferred from one object to another. This principle is known as the conservation of electric charge.Additivity: The total charge of a system is the algebraic sum(considering the correct sign) of the individual charges within it.Types of Charged ParticlesThere are primarily two types of charged particles which are discussed below:Positively Charged ParticlesProtons are the positively charged particles that are found in the nucleus of an atom. Protons have a mass of about 1 u. A particle gain positive charge when it lose electrons.Negatively Charged ParticlesElectrons are Negatively charged subatomic particles that surround the nucleus of an atom. Electrons have a much smaller mass of about 0.0005u. Electrons are located outside the nucleus in the outermost regions of the atom, called electron shells. A particle gain negative charge when its gains electron from other particleAfter from positive and negatively charged particles, there are neutral particles which are discussed below:Neutral ParticlesNeutrons are Neutral subatomic particles that are also found in the nucleus of an atom. Neutrons have a mass of about 1 u.Coulomb's law Coulomb's law states that the magnitude of the electrostatic force F between two point charges q1 and q2 is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between their centers. Mathematically, Coulomb's law is expressed as:F = k q1q2/r2 where r is the distance between two chargesk is the proportionality constant.k = 1/4π?0 = 9 × 109 Nm2C-2Superposition PrincipleTotal force exerted on a charged particle by multiple charged particles is the vector sum of the forces exerted by each individual particle. This principle holds true because the electrostatic force obeys Coulomb's law, which is a linear relationship.What is Electric Field?The electric field at a given point is defined as the force per unit charge experienced by a small positive test charge q0 placed at that point. Mathematically, the electric field E due to a point charge q is given by:E = F/q0 = q/4π?0r2 rThe electric field emanates radially outward when q is positive, and conversely, it converges radially inward when q is negative.Electric Field LinesThese are imaginary lines drawn in a way that the tangent at any given point on the line represents the direction of the electric field at that point. Some key characteristics of field lines include: They form continuous unbroken curves.They never intersect.They extend from positive to negative charges, there can be no closed loops.Electric FluxElectric flux quantifies the number of electric field lines passing through a surface. Mathematically, electric flux through a surface S is defined as the surface integral of the electric field E over the surface:ΦE = ∫S E.dAThe dot product indicates the projection of the electric field vector onto the area vector.The SI unit of electric flux is Nm2 C-1.What is an Electric Dipole?An electric dipole consists of two equal and opposite electric charges separated by a distance. These charges create an electric field around the dipole. The magnitude of the electric dipole moment, denoted by p, is the product of the magnitude of either charge q and the separation distance 2a between them: p = 2qaElectric Field Along Equator of DipoleThe derivation of electric field along equator of dipole is shown below:Resolving E into horizontal and vertical components. The vertical components (E sin θ) strike off each other. Therefore the electric field at A is 2 E cos θ.Where E = q/4π?0(a2+r2)EA = 2q/4π?0(a2+r2) cos θFrom figure ,cos θ = a/√(a2+r2)EA = 2qa / 4π?0(a2+r2)3/2We know Dipole moment p = 2qaEA = (-p/4π?0) (1/(a2+r2)3/2For r >> aE = -p/4π?0r3Electric Field Along Axis of DipoleThe derivation of electric field along axis of dipole is discussed below:AB is electric dipole of two point charges -q, +q separated by a distance 2d.Electric field at P due to +q at B,E1 = q / 4π?0 (r - d)2Electric field at P due to -q at A,E2 = q / 4π?0 (r + d)2Resultant electric field, E = E1 - E2E = q / 4π?0 [1/(r - d)2 - 1/(r + d)2]E = q / 4π?0 [4rd/ (r2 - d2)2]Since point P is far away from the dipole, then r>>dE = 4qrd / 4π?0 r4 E = 4qd / 4π?0 r3 We know Dipole moment p = 2qdE= 2p/4π?0r3Point to be noted : Electric field for dipole varies as 1/r3 not 1/r2.Gauss' lawGauss' law for electrostatics states that the total electric flux through a closed surface is proportional to the enclosed electric charge. This includes the bound charge due to polarization. The coefficient of proportionality is the reciprocal of the permittivity of free space(ε0). Mathematically, this can be expressed as ∮E.ds = Q/?0Where E is the electric field, ds is the infinitesimal area element and the closed integral of E over ds gives the electric flux. Important points to be noted: the area must be of a closed surface, the charge considered must be the charge enclosed by this surface.Conductors, Insulators, and SemiconductorsConductors: Conductors are materials with low electrical resistivity, strong electrical conductivity, and ease of electricity conductivity. Charge can flow across conductors when a voltage is supplied to them. Semiconductors: Semiconductors are materials with a conductivity value in between that of an insulator and a conductor. When required, semiconductors can function as both a conductor and an insulator. Insulators : Insulators are materials that don't conduct electricity. Current cannot flow through insulators. Insulators are used to shield ourselves from the potentially harmful effects of electricity passing via conductors. Dielectric StrengthDielectric strength refers to an insulating material's electrical strength. It is the highest electric field that a substance is capable of withstanding before degrading and turning electrically conductive. Surface Charge DensitySurface charge density refers to the amount of electric charge per unit area on a two-dimensional surface. It is a measurement of the total electric charge that has built up on a surface. Electric Potential (V)Electric potential (also known as voltage) is the difference in potential energy per unit charge between two points in an electric field. It is a scalar with the volt (V) as its unit. V = Q/(4πε0r) is the formula for electric potential. Equipotential SurfaceAn equipotential surface is a region in space where all points have the same potential. Although it is typically used in reference to scalar potentials, vector potentials can also be considered.Charged Particles in Electric FieldWhen a charged particle enters an electric field, it accelerates in the direction of the field lines. The direction of the electric field is always the force acting on the particle. The particle in the electric field will follow a straight path. However, the particle will either be attracted to or repelled by the charge depending on its polarity. A charged particle experiences force regardless of its velocity. The particle's path is bent by the field, which is perpendicular to the velocity. Combined Field Due to Two Point ChargesIf there are many source charges, each contributes to the electric field at every site in their area. The electric field at a point in space close to the source charges is the vector sum of the electric fields caused by each source charge. Assume that the set of source charges consists of two charged particles. The electric field vector resulting from the first charged particle plus the electric field vector resulting from the second charged particle equals the electric field at point P.Determining the overall electric field at place P is a vector addition since the two electric field vectors that contribute to it are vectors.Therefore, the electric field intensity at each point resulting from a system or group of charges is equal to the vector sum of the electric field intensities attributable to individual charges at the same site. The vector sum of electric field intensities is given by E=E1+E2+E3+..+En.Electric Lines of ForceElectric lines of force are imaginary lines or curves formed across an electric field. The direction that a tiny free positive charge will go along a line of force is known as its direction. Since two tangents can be traced to the two lines of force at the intersection, electric lines of force never cross. This indicates that there will be two electric field directions at the intersection, which is not feasible.Electrostatic FormulasThe important formulas required in Electrostatics are as follows:Name of formulasFormulaCoulombs force between two-point chargesF = {1/4π?0} (q1q2/r2)where,k= 1/4π?0 = 9 x 109 Nm2/C2q1 and q2 are the charges separated by a distance rElectric fieldE = {1/4π?0}(q/r2)The electric field separated from the charge q by a distance rElectric field IntensityE= F/qwhere F is the force that the electric field E exerts on the charge q.Electrostatic EnergyU = {1/4π?0}(q1q2/r) where q1 and q2 are the charges separated by a distance rElectric PotentialV = 1/4π?0(q/r) Electric Dipole Momentp = 2qaIt is calculated by multiplying a charge (q) by the separation distance (2a)Electric Field Along Equator of DipoleE= -p/4π?0r3where p is electric dipole moment, r denotes the distance Electric Field Along Axis of DipoleE= 2p/4π?0r3where p is electric dipole moment, r denotes the distanceConclusion: ElectrostaticsElectric charge governs interactions with electromagnetic fields. Charges exist as positive and negative forms, with like charges repelling and unlike ones attracting. Important properties include quantization, conservation, and additivity. Coulomb's law describes force between charges, while the superposition principle states the total force on a charged particle is the sum of forces exerted by each charge. Electric field lines illustrate field direction, and Gauss' law relates total electric flux through a closed surface to enclosed charge.Solved Examples on ElectrostaticsExample 1: Consider a sphere of radius R with a total charge Q uniformly distributed throughout its volume. Find the electric field inside the sphere.Solution:We'll use Gauss's law to find the electric field. Consider a Gaussian surface in the form of a sphere with radius r, where r < R . According to Gauss's law, the electric flux through this surface is:Φ = E.4πr2The total charge enclosed by this Gaussian surface is density of charge times the volume inside sphere with radius rq = Q/(4/3πR3) × 4/3 πr3=Qr3/R3Therefore, Gauss's law gives us:E.4πr2 = q/?0 = Qr3/?0R3The electric field becomesE = Q r/4π?0R3Example 2: Two point charges, q1 = +3C and q2 = -6C, are placed 10 cm apart in air. Calculate the magnitude of the electric force between them. Solution:Given:q1 = +3C and q2 = -6Cr = 10 cm = 0.1 mUsing Coulomb's lawF = k |q1q2|/r2 Substituting the given values:F = 9 × 109 × 18 × 10-12/ (0.1)2 = 16200 NTherefore, the magnitude of the electric force between the two charges is 16200 N.Example 3: An electric dipole consists of q=4 C, separated by a distance of 10 cm. Calculate the electric dipole moment and the electric field at a point 2 m away from the centre of the dipole along its axis.Solution: Given:q = +4C and -q = -4C2a = 10 cm = 0.1 mThe electric dipole moment isp = 4 × 10-7 C.mFor the electric field at a point along the axis of the dipole, we can use the case r>>a E=2p/4π?0r3= 9 × 109 × 8 × 10-7 /8 = 900 N/CExample 4: For the above problem, calculate the electric field at a point 2 m away from the centre of the dipole along its equator. Solution: For this we use the formula : E= -p/ 4π?0r3= -450 N/CTherefore, the magnitude of the electric field is 450 N/C.Practice Problems on Electrostatics1. A point charge Q=+4μC is located at the centre of a spherical Gaussian surface of radius r=0.1m. Calculate the electric flux through the Gaussian surface.2. Consider a uniform electric field E=2×103 N/C directed along the positive x-axis. Determine the total charge enclosed by a cylindrical Gaussian surface of radius r=0.05m and height h=0.2m centred at the origin.3. Two point charges, q1=+4C and q2=-3C, are placed 5cm apart in air. Calculate the magnitude of the electric force between them. 4. The charges, q1=+5C, q2=-3C, q3=+7C are placed at the vertices of an equilateral triangle of side length 15 cm. Calculate the magnitude and direction of the net electric force on each. 5. An electric dipole consists of q=2C, separated by a distance of 10 cm. Calculate the electric dipole moment and the electric field at a point 20 cm away from the centre of the dipole along its axis. Electrostatic refers to electromagnetic phenomena which occur when there are no moving electrical charges on or within a given material. When electrostatic energy is built up on a given material, it is referred to as a "static charge." The amount of static charge that an object can hold depends on the physical properties of the material it is constructed with. Electrostatic charges can pose both direct and indirect safety risks. A direct risk is simply the pain that a worker can experience when experiencing an electrostatic shock. Indirect safety risks include the potential of a static discharge to create a spark, which could then cause a fire within a flammable environment. Workplace electrostatic shocks are typically not severe enough to cause injury to workers, although they may cause pain. There is a limit to the amount of charge that any single item can hold, and this limit is typically below the threshold for a direct injury. The primary safety risks posed by an electrostatic shock are that it will cause consequential damages, which are damages that are not caused by the electrostatic discharge itself, but as a consequence of an event that the discharge causes. An electrostatic discharge can cause consequential damage if a static shock interrupts an individual during a safety-sensitive task, causing an accident. Electrostatic discharges can also damage sensitive electronic equipment, which could have negative safety consequences if the equipment has a safety function. The most significant danger posed by electrostatic discharge is probably the danger that the discharge will generate a spark that causes a fire or explosion. Any workplace that involves an explosive atmosphere, such as environments with high levels of petrochemical fumes or high levels of airborne dusts, needs to be protected against electrostatic discharges. Flammable environments require similar protection. Because friction between two materials can create enough static charge to cause a spark, workers may be required to wear anti-static gloves when working in flammable environments. Depending on the workplace, the fire and explosion dangers posed by electrostatic shocks can be very significant. The National Fire Protection Association's (NFPA's) static electricity standard, NFPA 77, is specifically concerned with fire and explosion prevention. Electrostatic shocks and other unwanted discharges are usually prevented through the use of a grounding instrument; the use of a ground prevents the buildup of a static charge, thus eliminating the risk of a potentially hazardous electrostatic discharge. SUMMARY · Like charges repel and unlike charges attract · The total charge in the universe is conserved · Charge is quantized. Total charge in an object q = ne where n = 0,1,2,3... and e is electron charge. · Coulomb's law in vector form: (r ^ is unit vector along joining q1, q2) · For continuous charge distributions, integration methods can be used. · Electrostatic force obeys the superposition principle. · Electric field at a distance r from a point charge: · Electric field lines starts at apositive charge and end at a negative charge or at infinity · Electric field due to electric dipole at points on the axial line : · Electric field due to electric dipole at points on the equatorial line: · Torque experienced by a dipole in a uniform electric field: · Electrostatic potential at a distance r from the point charge: · Electrostatic potential due to an electric dipole: · The electrostatic potential is the same at all points on an equipotential surface. · The relation between electric field and electrostatic potential: · Electrostatic potential energy for system of charges is equal to the work done to arrange the charges in the given configuration. · Electrostatic potential energy stored in a dipole system in a uniform electric field: · The total electric flux through a closed surface : ΦE = Q/ε0 where Q is the net charge enclosed by the surface · Electric field due to a charged infinite wire : · Electric field due to a charged infinite plane : · Electric field inside a charged spherical shell is zero. For points outside: · Electric field inside a conductor is zero. The electric field at the surface of the conductor is normal to the surface and has magnitude E = σ/ε0 . · The surface of the conductor has the same potential, at all points on the surface. · Conductor can be charged using the process of induction. · A dielectric or insulator has no free electrons. When an electric field is applied, the dielectric is polarised. · Capacitance is given by C = Q/V . · Capacitance of a parallel plate capacitor: C = εA / d · Electrostatic energy stored in a capacitor: U = 1/2 CV2 · The equivalent capacitance for parallel combination is equal to the sum of individual capacitance of capacitors. · For a series combination: The inverse of equivalent capacitance is equal to sum of inverse of individual capacitances of capacitors. · The distribution of charges in the conductors depends on the shape of conductor. For sharper edge, the surface charge density is greater. This principle is used in the lightning arrestor · To create a large potential difference, a Van de Graaff generator is used Page 2Multiple choice questions1. Two identical point charges of magnitude –q are fixed as shown in the figure below. A third charge +q is placed midway between the two charges at the point P. Suppose this charge +q is displaced a small distance from the point P in the directions indicated by the arrows, in which direction(s) will +q be stable with respect to the displacement?(a) A1 and A2 (b) B1 and B2(c) both directions (d) No stableHint: Since V=0 along equatorial line2.Which charge configuration produces a uniform electric field?(a) point Charge (b) infinite uniform line charge (c) uniformly charged infinite plane(d) uniformly charged spherical shell3. What is the ratio of the charges |q1/q2| for the following electric field line pattern?(a) 1/5(b) 25/11(c) 5(d) 11/254.An electric dipole is placed at an alignment angle of 30º with an electric field of 2 × 105 N C-1. It experiences a torque equal to 8 N m. The charge on the dipole if the dipole length is 1 cm is(a) 4 mC(b) 8 mC(c) 5 mC(d) 7 mC5. Four Gaussian surfaces are given below with charges inside each Gaussian surface. Rank the electric flux through each Gaussian surface in increasing order.a. D < C < B < Ab. A < B = C < Dc. C < A = B < Dd. D > C > B > A6.The total electric flux for the following closed surface which is kept inside water(a)80q/ε(b)q/40ε(c)q/80ε(d)q/160ε7. Two identical conducting balls having positive charges q1 and q2 are separated by a center to center distance r. If they are made to touch each other and then separated to the same distance, the force between them will bea. less than beforeb. same as beforec. more than befored. zero8.Rank the electrostatic potential energies for the given system of charges in increasing order.(a) 1 = 4