Electricity

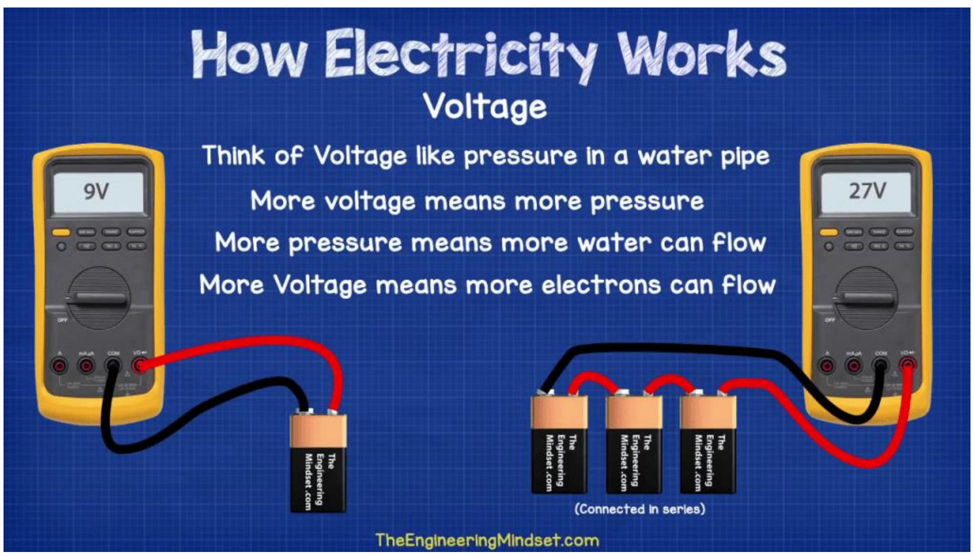
Electricity:

Electricity is the set of physics phenomena associated with the presence and motion of matter that has a property of electric charge. Various common phenomena related to electricity including lighting, static electricity, electric heating, electric discharge and many others.

Electricity is at the heart of many modern technologies, being used for:

Electric power where electric current is used to energize equipment;

Electronics which deals with electrical circuits that involve active electrical components such as vacuum tubes, transistors, diodes and integrated circuits, and associated passive interconnection technologies.

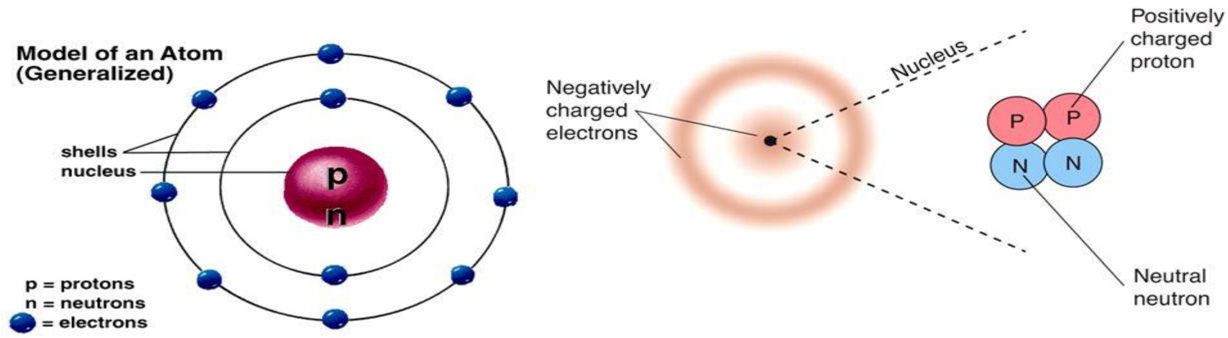


Electric Charge:

Charge is a fundamental and characteristic property of the elementary particles of which the matter is composed. These particles are electron, proton and neutron. Electrons are negatively charged particle, protons positively charged and neutrons are neutral. Like any other physical entities charge cannot be created or destroyed, that means, the total charge of an isolated system cannot change. The individual charges can be combined or regrouped in different ways. This is known as the principle of conservation of charge. Example of charge conservation is radioactivity decay.

Electric Charge

- Atom is made up of **electrons and nucleus**
- **Nucleus contains the protons and neutrons**
- **Electrons are outside the nucleus like a cloud surrounding the nucleus**



Coulomb is the unit of electric charge.
Coulomb is defined as the amount of charge that flows through a given cross section of a wire in one second if there is a steady current of one ampere in the wire.
In symbol, **q=it**, where, q is in coulomb, I is in ampere and t is in second.

particle	charge (C)	mass (Kg)
proton p^+	$+1.602 \times 10^{-19}$	1.67×10^{-27}
neutron n^0	0	1.67×10^{-27}
electron e^-	-1.602×10^{-19}	9.11×10^{-31}

Quantization of charge:

The electric field is not continuous one but it is made up of certain minimum electric charge. This fundamental charge is the charge of an electron or proton and has the magnitude 1.6×10^{-19} coulomb. If this charge is given by the symbol 'e', then any physically existing charge q can be written as, **q=ne**, where **n is a positive or negative integer**. So that, the charge can exists in discrete packets rather than in continuous amount. This is refereed as the **quantization of charge.**

Charge Quantization & Conservation

1. Electric charge is <u>quantized</u>
   a. The elementary unit of charge: $e = 1.602 \times 10^{-19}$ C
   b. The magnitude of net charge for any matter is

   $$|q_{net}| = Ne$$

   where N is the number of elementary charges
2. Electric charge is <u>conserved</u>
   a. There is no known process that can change the charge of something, *in any process the total net charge must remain constant*

Example: *During "beta" decay, a neutron splits into a proton & an electron:*

$$^{14}_{6}C \rightarrow \, ^{14}_{7}N^{+} + e^{-}$$

$$^{3}_{1}H \rightarrow \, ^{3}_{2}He^{+} + e^{-}$$

Coulomb's law:

The electrostatic force of attraction or repulsion between the two charges was first measured by Charles Augustine de Coulomb.

The electrostatic force exerted on one charge by another charge depends directly on the product of the magnitude of the two charges and inversely on the square of their separation. Let us consider two point charges q_1 and q_2 separated by a distance r, then according to Coulombs law,

$$F \propto \frac{q1q2}{r^2}$$

$$F=k\frac{q1q2}{r^2}$$

Applications:

- Laser Jet printer
- Photocopiers
- Dust particle separators
- Painting metal surfaces

The above equation is called Coulombs law and generally holds for point charges. In

SI system, the constant K can be expressed in the following form,

$$K = \frac{1}{4\pi\varepsilon 0}$$

Where, ϵ_0 =Permittivity constant of free space.
= 8.854×10^{-12} $Coul^2/N\text{-}m^2$

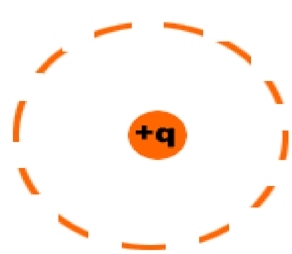
The constant Ka has the corresponding value,
K=9×10^{9} $N\text{-}m^2/Coul^2$

The Coulomb's law can be written as,

$$F=\frac{1}{4\pi\varepsilon 0}\frac{q1q2}{r^2}$$

Electric Field

Space and region surrounding an electric charge or a charged body within which another charge experiences some electrostatic force of attraction or repulsion, when placed at a point is called electric field. The force experienced by a charge in an electric field is given, F=qE



Electric Field

The concept of an electric field was introduced by Michael Faraday. An electric field is a physical quantity which has different values at different points in space. The electric field is a vector field with SI units of Newton per coulomb ($N C^{-1}$)

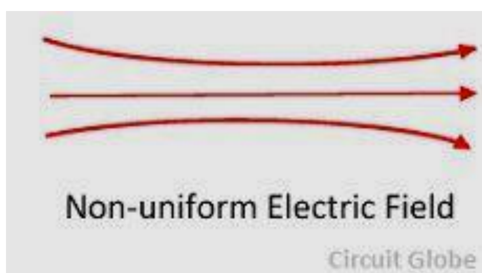
The electric field is mainly classified into two types. They are the uniform electric field and the non uniform electric field.

Uniform Electric Field:

When the electric field is constant at every point, then the field is called the uniform electric field. The constant field is obtained by placing the two conductors parallel to each other, and the potential difference between them remains same at every point.

Non Uniform Electric Field:

The field which is irregular at every point is called the non-uniform electric field. The non-uniform field has a different magnitude and directions.



Electric field intensity

Electric field intensity at a point is defined as the force experienced per unit positive charge at a point placed in the electric field.

$E = \frac{F}{q}$ (Newton/ Coulomb)

Where E is the electric field intensity, F is the force and q is the test charge.

Let a test charge q_0 be placed at a distance r from a point charge +q (Fig. below). The magnitude of the force acting on the teat charge q_0 is given by (Coulomb's Law)

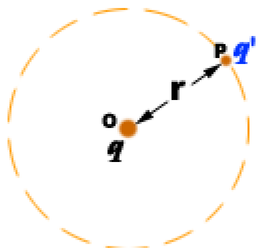


Fig. Electric field due to a point charge

The electric field strength at the site of the test charge is given by

$$E=\frac{F}{q}$$

$$E=\frac{1}{q_0}\ \frac{q q_0}{4\pi\varepsilon_0 r^2}$$

$$E= \frac{q}{4\pi\varepsilon_0 r^2}$$

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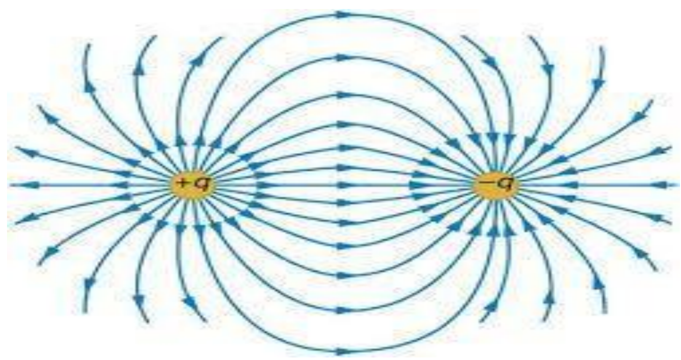
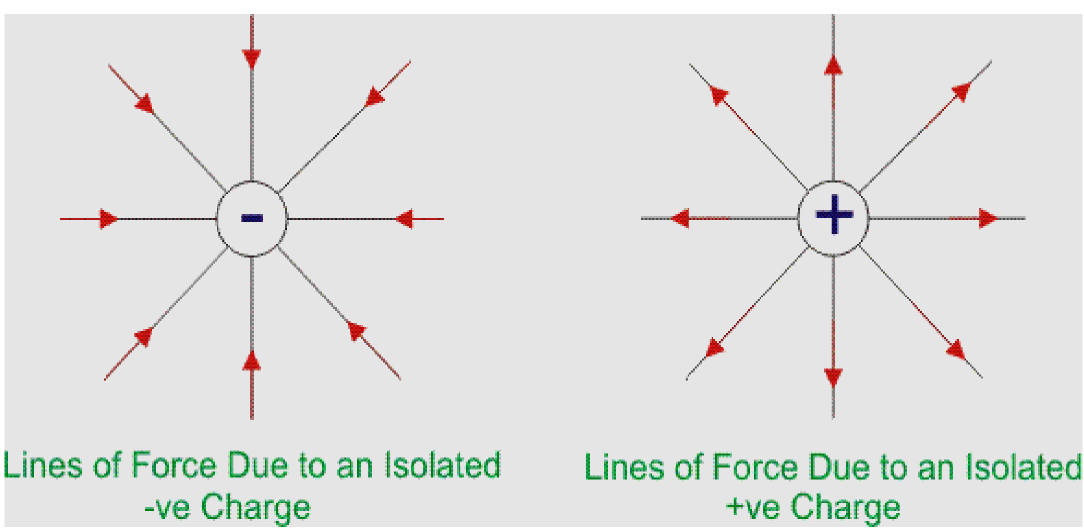
Electric lines of force:

Michael Faraday introduced the concept of lines of force. The lines of force are supposed to originate from the positive charges and terminate in the negative charges. These lines may be straight or curved depending on the system of charge creating them.



Properties of Electric Lines of Force

1. Each electric line of force is conceptually imagined it does not have any physical existence.
2. Each electric line of force is originated from positive charge and terminated to the negative charge.
3. A tangent drawn at any point on an electric line of force indicates the direction electric field at that point in the field.
4. Each electric line of force emanates normally from the surface of the charge body.
5. Electric lines of force can expand laterally.
6. No two electric lines of force cross each other.
7. The electric lines of force in same direction repel each other.
8. The electric lines of force in opposite direction attract each other.

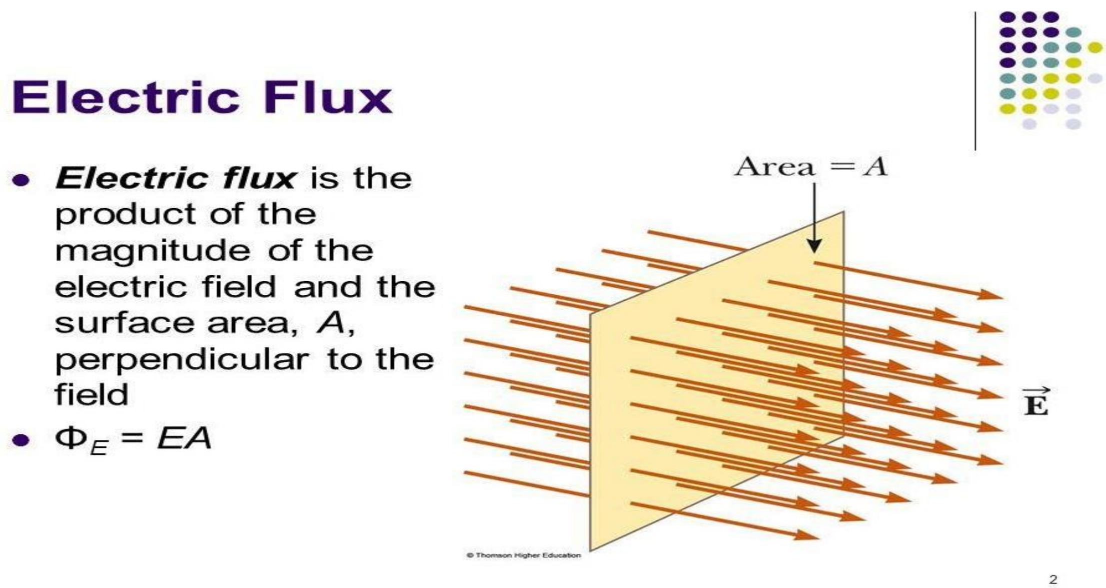


The relationship between the lines of force and the electric field intensity vector is given below.

(1) The tangent to the line of force at any point gives the direction of E at that point.
(2) The density of the lines of force is proportional to the magnitude of E where the lines are close together, E is large and where they are far apart, E is small.

Electric Flux:

Flux is the property of any vector field; it refers to a hypothetical surface in the field which may close or open. For an electric field, the flux Φ_E is measured by the number of lines of force that cut through such a surface.



The product of the electric field strength and the area, through which the lines are passing, is called electric flux. It is denoted by $\Phi_E = EA$

For closed surfaces, the flux Φ_E is considered positive if the lines of force point outward everywhere and negative if they point inward.

Gauss's law:

A hypothetical closed surface of any shape drawn in an electric field for the purpose of solving problems concerning electric flux is called Gaussian surface.

Gauss's law states that, "the flux of electric field E through any closed surface that is the integral $\int E.\,ds$ over the closed surface is equal to $\frac{1}{\varepsilon_0}$ the total charge enclosed by the

Surface.

$$\Phi_E = \frac{q}{\varepsilon_0}$$

$\varepsilon_0 \Phi_E = q$ As $[\Phi_E = EA]$

$$\varepsilon_0 \oint E.ds = q$$

So, $\oint E.ds = \frac{q}{\varepsilon_0}$ Where q is the net charge.

$\oint E.ds = \frac{q}{\varepsilon_0}$ q inside the surface

$\oint E.ds = 0$ q outside the surface

How is electric flux related to Gauss law?

When we talk about the relation between electric flux and Gauss law, the law states that the net electric flux in a closed surface will be zero if the volume that is defined by the surface contains a net charge.

To establish the relation we will first take a look at the Gauss law.

If we take the Gauss's law it is represented as:

$\Phi_E = Q/\varepsilon_o$

Here,

- Φ_E = electric flux through a closed surface S enclosing any volume V.
- Q = total charge enclosed within V,
- ε_o = electric constant.

Meanwhile, the electric flux Φ_E can now be defined as a surface integral of the electric field. It is given as:

$\Phi_E = \iint E . dA$

Here,

- E = electric field.
- dA = vector representing an infinitesimal element of area of the surface.

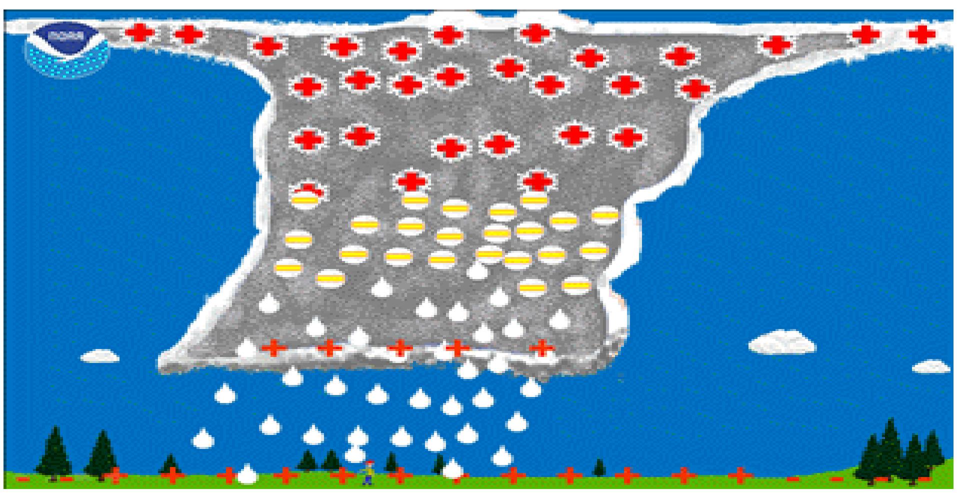
Notably, flux is considered as an integral of the electric field. This relation or form of Gauss's law is known as the integral form.

http://egyankosh.ac.in/bitstream/123456789/64861/1/Unit7.pdf

Formation of Lightning:

Lightning is a giant spark of electricity in the atmosphere or between the atmosphere and the ground. In the initial stage of development, air acts as an insulator between the positive and negative charges in the cloud and between the cloud and the ground; however, when the differences in charges becomes too great, this insulating capacity of the air breaks down and there is a rapid discharge of electricity that we know as lightning.

Lightning can occur between opposite charges within the thunderstorm cloud (Intra Cloud Lightning) or between opposite charges in the cloud and on the ground (Cloud-To-Ground Lightning). Cloud-to-ground lightning is divided into two different types of flashes depending on the charge in the cloud where the lightning originates.



Thunder:

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Thunder is the sound made by a flash of lightning. As lightning passes through the air it heats the air quickly. This causes the air to expand rapidly and creates the sound wave we hear as thunder. Normally, you can hear thunder about 10 miles from a lightning strike. Since lightning can strike outward 10 miles from a thunderstorm, if you hear thunder, you are likely within striking distance from the storm.