Introduction

This is a learning as well as an exam preparation video.

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Chapter 1: Electric Charges and Feilds

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Introduction

Study of static charges is called electrostatics and this complete electrostatic will be discussed in two chapters. In this chapter we begin with a discussion of electric charge, some properties of charged bodies, and fundamental electric force between two charged bodies.

Chapter 1: Electric Charges and Feilds

What is Electric Charge?

Electric Charge is a fundamental property of a matter which is responsible for electric forces between the bodies. Two electrons placed at small separation are found to repeal each other, this repulsive force (Electric force) is only because of electric charge on electrons.

When a glass rod is rubbed with silk, the rod acquires one kind of charge, and the silk acquires the second kind of charge. This is true for any pair of objects that are rubbed to be electrified. Now if the electrified glass rod is brought in contact with silk, with which it was rubbed, they nolonger attract each other.

Chapter 1: Electric Charges and Feilds

What is Electric Charge?

Types of Electric Charge:

There are two types of charge exist in our nature.

- Positive Charge
- Negative Charge

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What is Electric Charge?

If any object loses their electrons then they get positive charge. It is denoted by (+q) sign. If any object gain electrons from another object, then they get negative charge. It is denoted by (-q) sign. The charges were named as positive and negative by the American scientist Benjamin Franklin. If an object possesses an electric charge, it is said to be electrified or charged. When it has no charge it is said to be neutral.

Chapter 1: Electric Charges and Feilds

Basic Properties of Electric Charge:

The important properties and characteristic of electric charge are given below.

Attraction and Repulsion: Like charges repel each other while unlike charges attract each other.

Electric Induction: When a charged object brings to contact with another uncharged, it gets opposite charge of charged object. It is called charging by induction.

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Basic Properties of Electric Charge:

Charge is Quantized: An object that is electrically charged has an excess or deficiency of some whole number of electrons. Since, electrons cannot be divided into fraction of electrons, it means that the charge of an object is a whole-number multiple of the charge of an electron. For example, it cannot have a charge equal to the charge of 0.5 or 1000.5 electrons.

Mathematically $q = \pm ne$, here $n = 1, 2, 3$ and $e = 1.6 \times 10–19$ coulomb.

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Basic Properties of Electric Charge:

Electric Charge is Conserved: According to this property, "An electric charge neither can be

created nor can be destroyed" i.e., total net charge of an isolated system is always conserved.

Thus, when a glass rod rubbed with silk cloth, both glass rod and silk cloth acquire opposite

charge in same quantity. Thus, total amount of charge remains same before rubbing as well as

after rubbing.

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Conductors and Insulators:

Some substances easily allow passage of electricity through them while others do not.

Substances which allow electricity to pass through them easily are called ‘conductors. They have electrons that are free to move inside the material. Metals, human and animal bodies, earth etc. are example of conductors. Non-metals e.g., glass, plastic, wood are ‘insulators’ because they do not easily allow passage of electricity through them.

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Conductors and Insulators:

Most substances are either conductors or insulators. There is a third category called

'semiconductors' which are intermediate between conductors and insulators because they partially allow movement of charges through them.

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Charging by Induction:

Now as we know that two oppositely charged bodies attract each other. But it also has been our observation that a charged body attracts a neutral body as well. This is explained on the basis of charging by induction. In induction process two bodies (at least one body must be charged) are brought very close, but they never touch each other.

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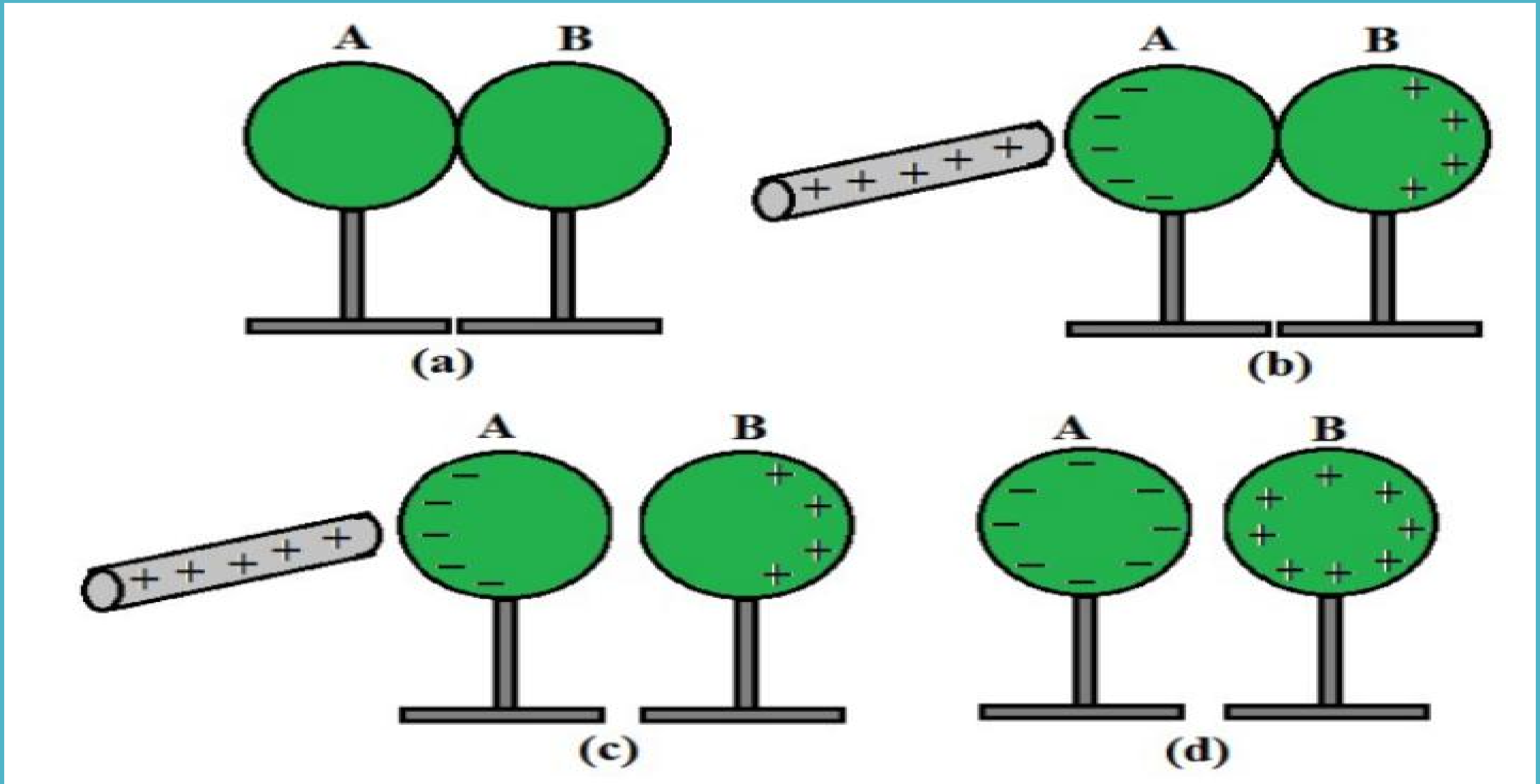
Charging by Induction:



Chapter 1: Electric Charges and Feilds

Coulomb's Law:

- In 1785 Charles Coulomb (1736-1806) experimentally established the fundamental law of electric force between two stationary charged particles. He observed that An electric force between two charge particles has the following properties:
- It is directed along a line joining the two particles and is inversely proportional to the square of the separation distance r, between them.

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Coulomb’s Law:

- It is proportional to the product of the magnitudes of the charges, |q1| and |q2|, of the two particles.
- It is attractive if the charges are of opposite sign and repulsive if the charges have the same sign.

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Coulomb's Law:

From these observations, Coulomb proposed the following mathematical form for the electric force between two charges. The magnitude of the electric force F between charges q1 and q2 separated by a distance r is given by

$$F = k\frac{|q_1||q_1|}{r^2}$$

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Coulomb's Law:

where k is a constant called the Coulomb constant. The proportionality constant k in Coulomb's

law is similar to G in Newton's law of gravitation. Instead of being a very small number like G

(6.67 × 10–11), the electrical proportionality constant k is a very large number. It is approximately.

$$k = 8.9875 \times 10^{9}\ N\text{-}m^{2}C^{-2}$$

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Coulomb's Law:

The constant k is often written in terms of another constant, ε0, called the permittivity of free

space. It is related to k by

$$k = \frac{1}{4\pi\varepsilon_0}$$

$$\therefore F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_1|}{r^2}$$

$$\varepsilon_0 = \frac{1}{4\pi k} = 8.85 \times \frac{10^{-12}C^2}{Nm^2}$$

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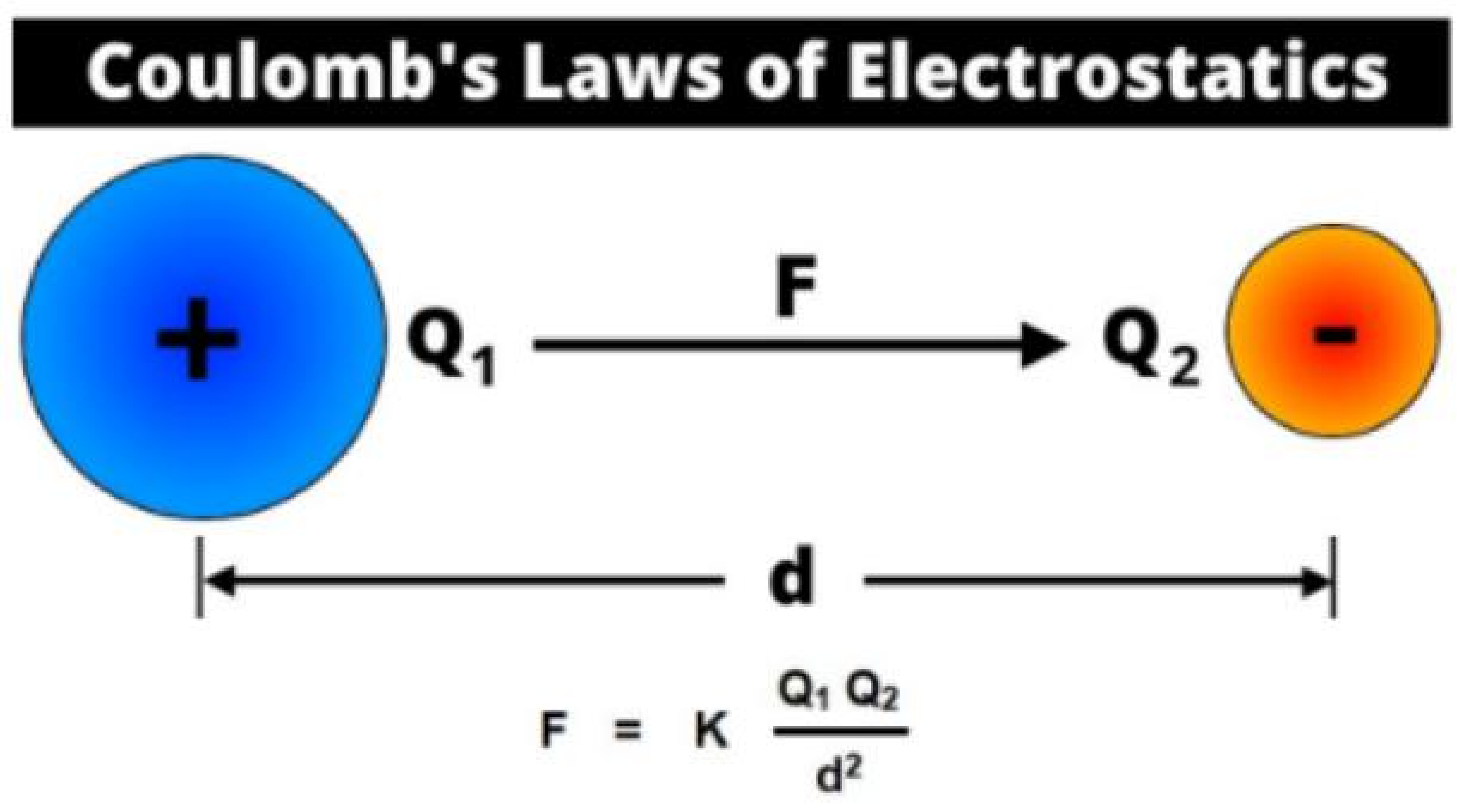
Coulomb’s Law:



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Electric Field:

A charge produces something called an electric field in the space around it and this electric field exerts a force on any charge (except the source charge itself) placed in it. The electric field has its own existence and is present even if there is no additional charge to experience the force.

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Intensity of Electric Field:

Intensity of electric field due to a charge configuration at a point is defined as the force acting on a unit positive charge at this point. Hence if a charge q experiences an electric force F at a point then intensity of electric field at this point is given as

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

It has S.I. units of newtons per coulomb (N/C).

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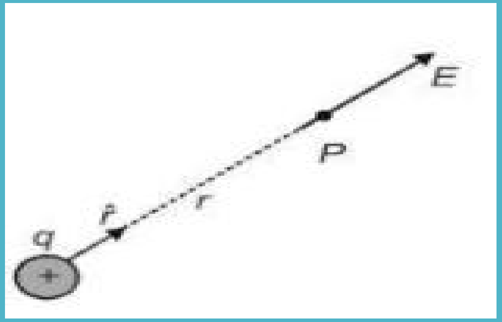
Electric Field due to a Point Charge:



To determine the direction of an electric field, consider a point charge q as a source charge. This charge creates an electric field at all points in space surrounding it. A test charge q0 is placed at point P, a distance r from the source charge. According to Coulomb's law, the force exerted by q on the test charge is.

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

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Electric Field due to a Point Charge:

This force is directed away from the source charge q, since the electric field at P, the position of

the test charge, is defined by

$$E = \frac{F}{q_0}$$

we find that at P, the electric field created by q is

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

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Electric Field Lines:

Electric field lines are a way of pictorially mapping the electric field around a configuration of charges. An electric field line is, in general, a curve drawn in such a way that the tangent to it at each point is in the direction of the net field at that point.

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Electric Field Lines:

The field lines follow some important general properties:

- The tangent to electric field lines at any point gives the direction of electric field at that point.
- In free space, they are continuous curves which emerge from positive charge and terminate at negative charge

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Electric Field Lines:

- They do not intersect each other. If they do so, then it would mean two directions of electric field at the point of intersection, which is not possible.

- Electrostatic field lines do not form any closed loops. This follows from the conservative nature of electric field.

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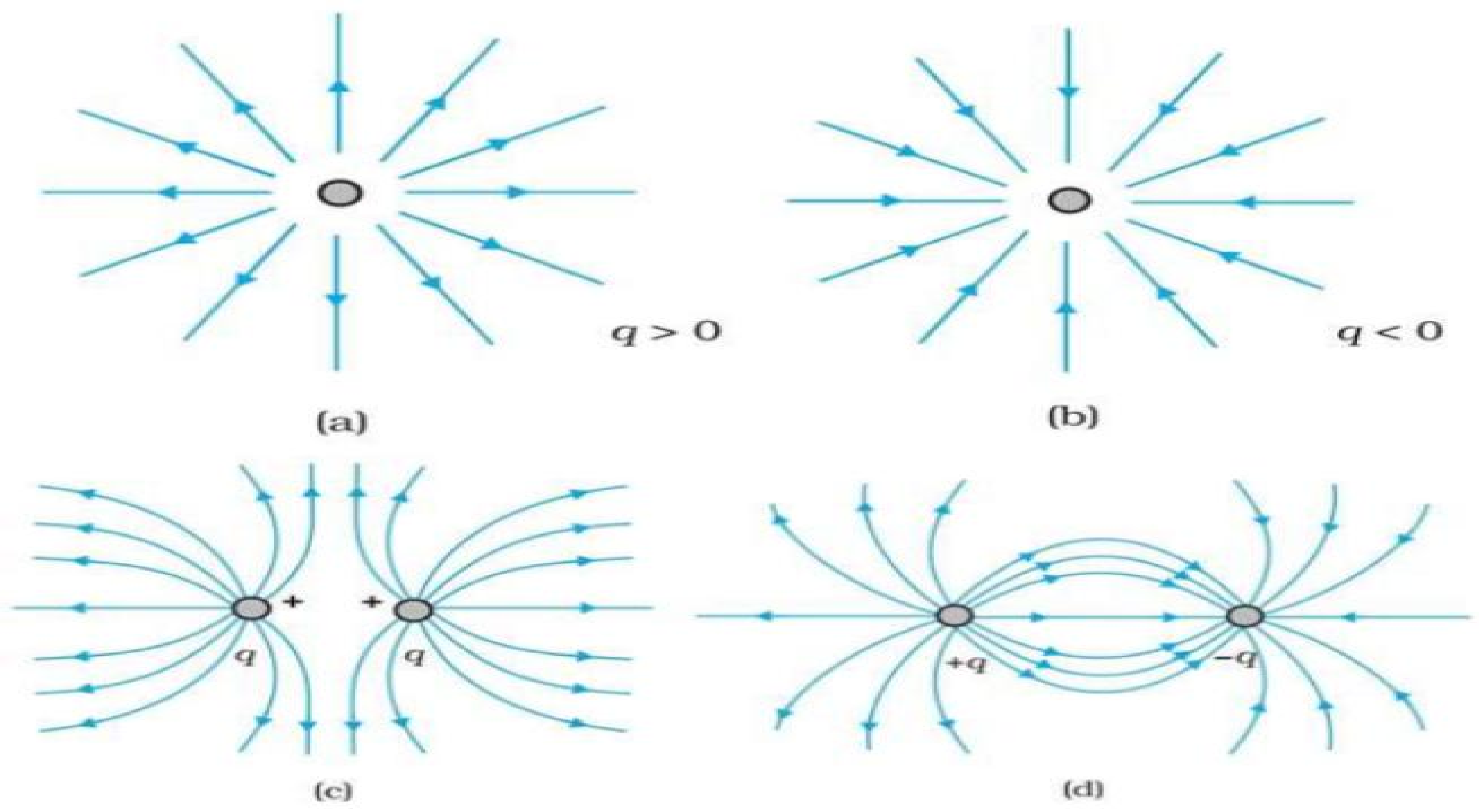
Electric Field Lines:



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Electric Dipole:

A configuration of two charges of same magnitude q, but of opposite sign, separated by a small distance (say 2a) is called an electric dipole.

Dipole moment for an electric dipole is a vector quantity directed from the negative charge to the positive charge and its magnitude is $p = q \times 2a$ (charge × separation). The SI unit of dipole moment is C-m (coulombmeter).

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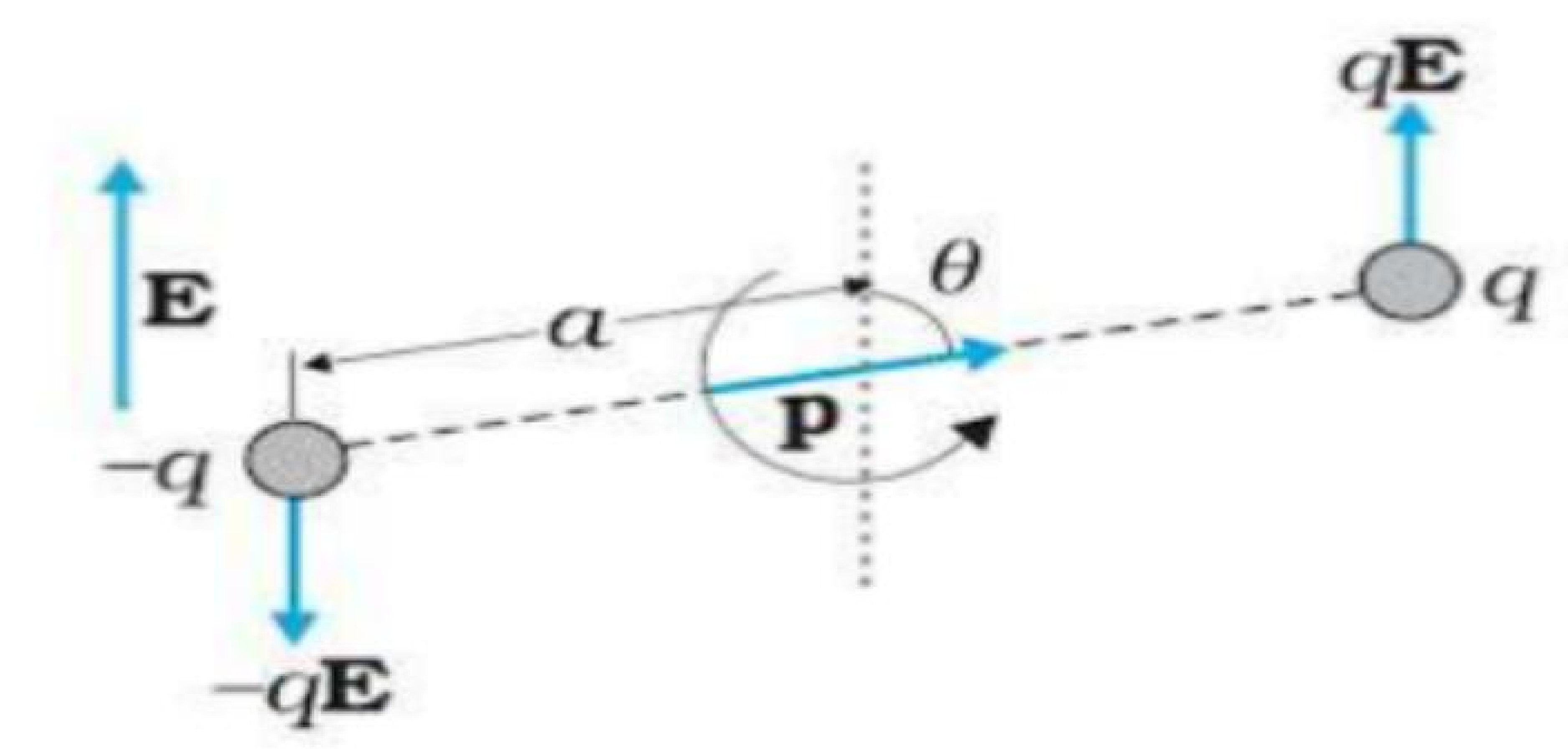
Electric Dipole:



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Gauss’s Law:

- The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the
- Total charge enclosed by S.
- Electric field outside the charged shell is as though the total charge is concentrated at the center. The same result is true for a solid sphere of uniform volume charge density.
- The electric field is zero at all points inside a charged shell.

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Deduction of Coulomb’s law from Gauss' Law:

Consider a charge +q in place at origin in a vacuum. We want to calculate the electric field due to this charge at a distance r from the charge. Imagine that the charge is surrounded by an imaginary sphere of radius r as shown in the figure below. This sphere is called the Gaussian sphere.

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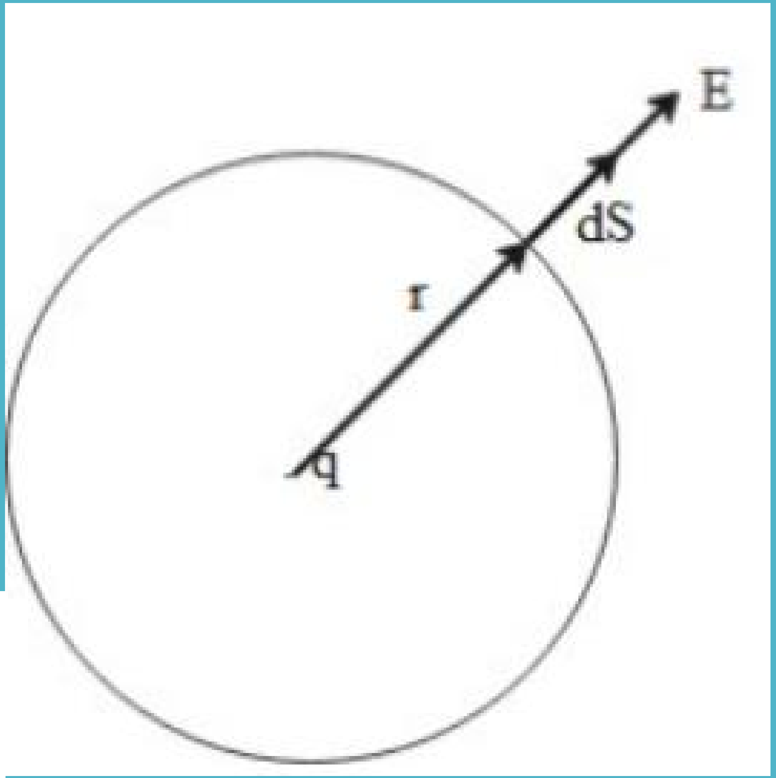
Deduction of Coulomb’s law from Gauss' Law:

Consider a small area element dS on the Gaussian sphere. We can calculate the flux through this area element due to charge as follows:



$$\oint \vec{E}.\overrightarrow{ds} = E\oint ds$$

$$\oint \vec{E}.\overrightarrow{ds} = E(4\pi r^2)$$

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Deduction of Coulomb’s law from Gauss' Law:

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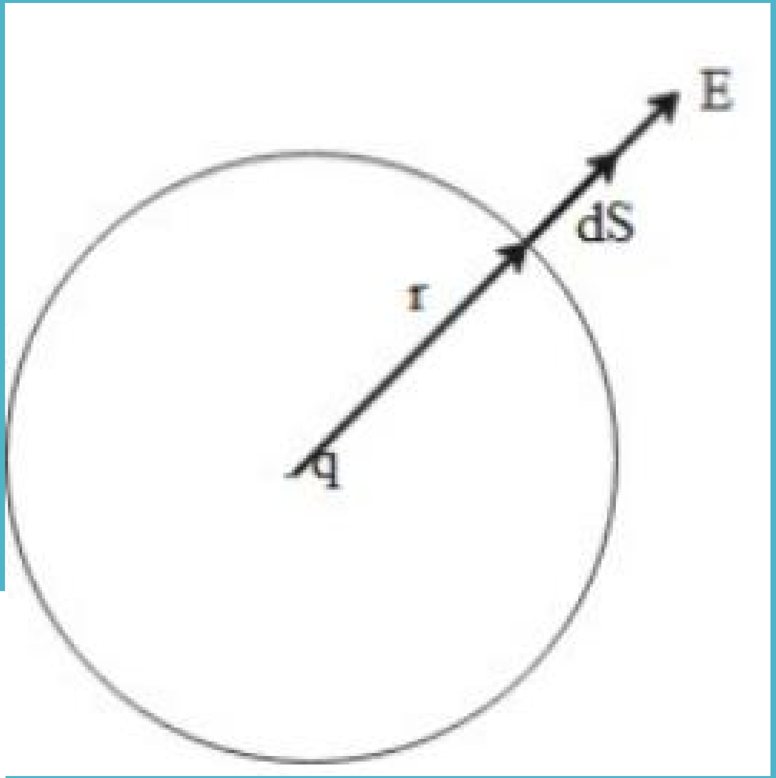

$$\oint \vec{E}.\overrightarrow{ds} = E\oint ds$$

$$\oint \vec{E}.\overrightarrow{ds} = E(4\pi r^2)$$

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Deduction of Coulomb’s law from Gauss' Law:

Using this in Gauss theorem we get

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

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

We know that

$$F = Eq_0$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r^2}$$

This is the required Coulomb’s law obtained from Gauss theorem.

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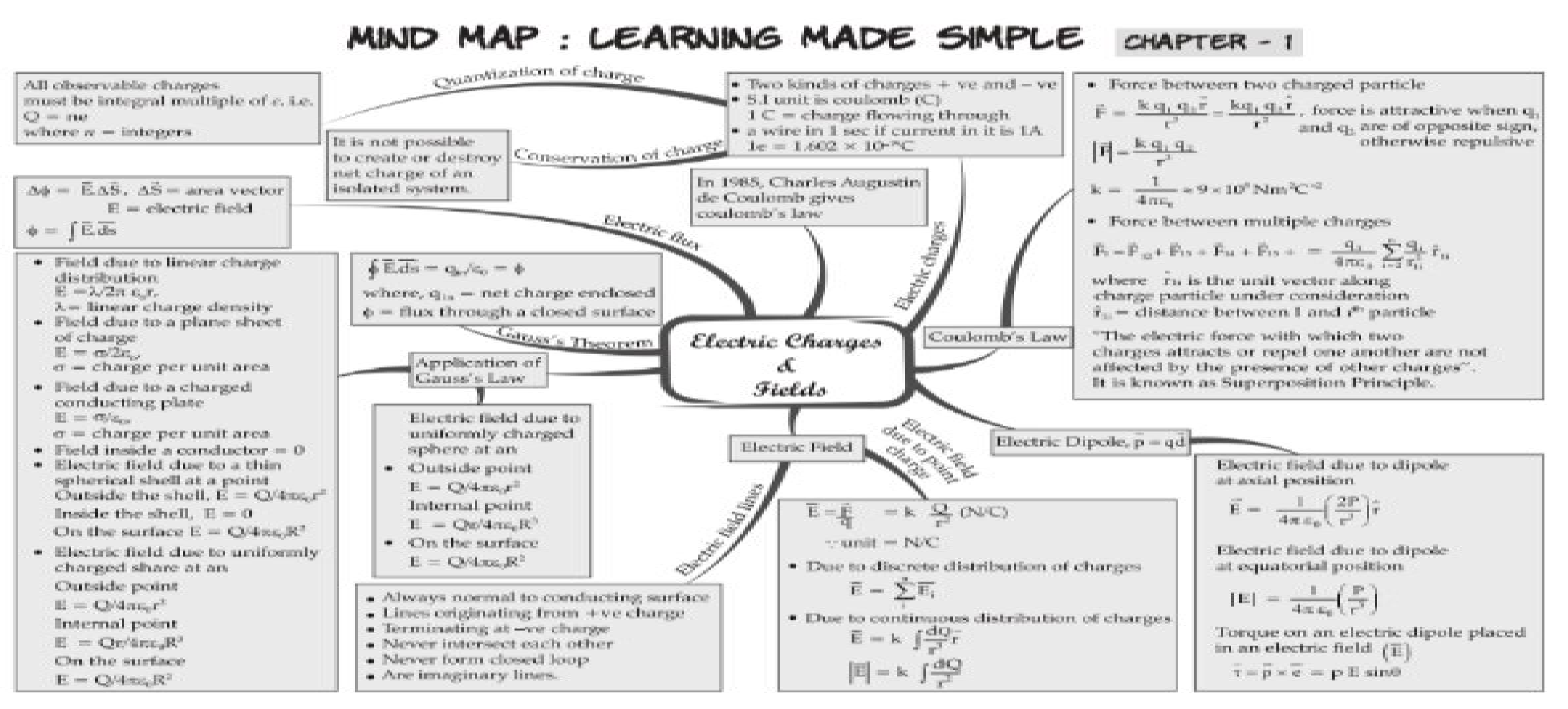

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