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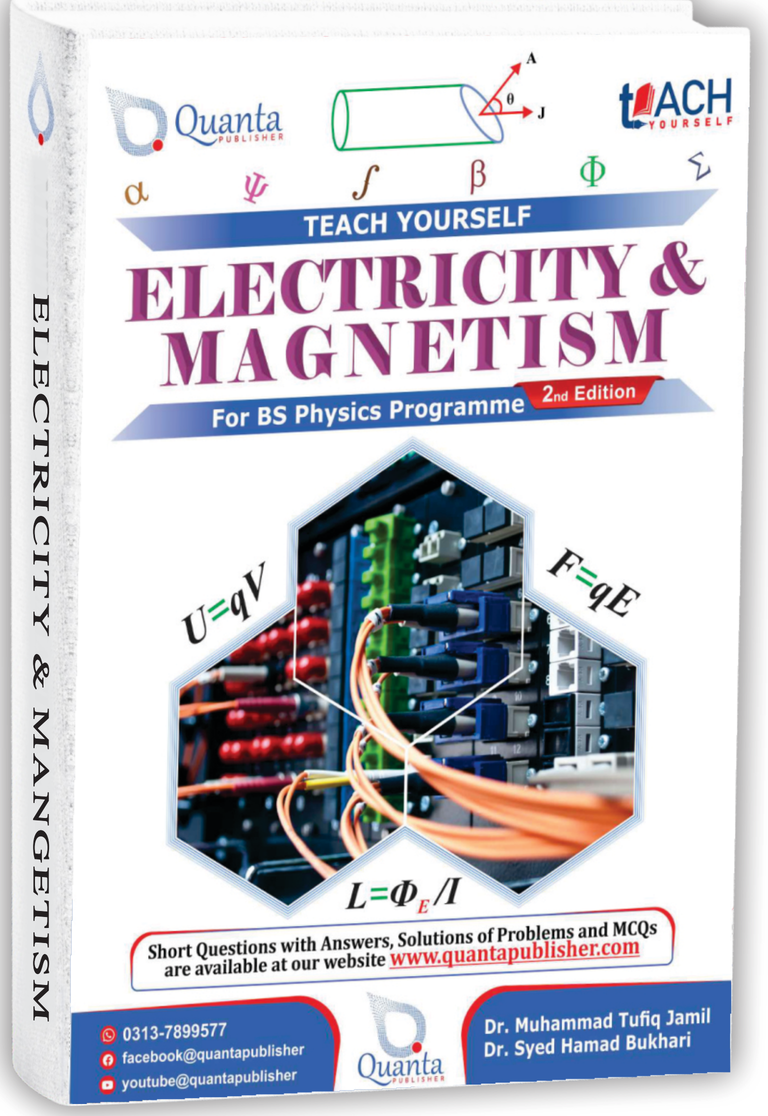

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# ELECTRICITY & MAGNETISM

2nd Edition

For **BS/ADS Physics/Chemistry/Mathematics** students

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Quanta Publisher, Raza Abad, Shah Shamas, Multan 03137899577.

# Contents

# Chapter 1

# Electric Field

The electromagnetic force is one of the basic forces in the nature and responsible for the structure of atoms and for the binding of atoms in molecules and solids. Many properties of materials that we have studied so far are electromagnetic in their nature, such as the elasticity of solids and the surface tension of liquids. The spring force, friction, and the normal force all originate with the electromagnetic force between atoms. In open words all the shapes of objects in nature are stable due to electromagnetic force. In this chapter, we begin with a discussion of electric charge, their electric field, some properties of charged bodies, and the fundamental electric force between two charged bodies.

## 1.1 Electric Charge

*The physical entity which is responsible for all the electromagnetic properties of the matter and also experiences a force when placed in electromagnetic field is known as charge.* After you pass a plastic comb through your hair a few times, you will find that the comb can exert a force on individual strands of your hair. You may also observe that, once the strands of hair are attracted to the comb and come into contact with it, they may no longer be attracted to it. It seems reasonable to conclude that the attraction between the comb and the hair is a result of some physical entity being transferred from one to the other then they rub together, with the same physical entity being transferred back again to neutralize the attraction when they come into contact. This physical entity is called electric charge, and today we understand this transfer on the basis of electrons that can be removed from the atoms of one object and attached to the atoms of the other object. Note the net electric charge of an object is usually represented by the symbol $q$. The charge is a scalar quantity. It can be positive or negative, depending on whether the object has a net positive or negative charge. Electric charge is measured in units of coulombs ($C$).

# Chapter 2

# Electric Potential

## 2.1 Electric Potential Energy Difference

*The potential energy difference between two points is equal to negative of work done by electrostatic force (conservative) in moving charge $q$ between two points, in an electric field, with constant velocity.* Change in electrostatic P.E.

$$U = W \tag{2.1}$$

If test charge $q$ moves in electric field $E$ from point $a$ to $b$ under the action of electrostatic force $F = q\ E$ then by Eq. (2.1)

$$U = \int_a^b F\ dr$$

$$U_b \quad U_a = q\int_a^b E\ dr$$

$$U_b \quad U_a = q\int E\ dr \tag{2.2}$$

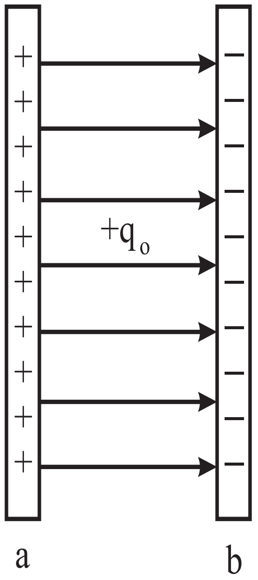

**Fig. 2.1.** A positive test charge is placed between two oppositely charged plates.

Because electric force is conservative, the integral is independent of path and depends only on initial position $a$ and final position $b$. If electric field is produced due to positive point charge $q$, then by Eq.(2.2)

$$U_b \quad U_a = q\int_{r_a}^{r_b} \frac{1}{4}\frac{q}{r^2} r\ rdr = \frac{1}{4} qq\int_{r_a}^{r_b} r\ ^2 dr = \frac{qq}{4}\Big| \quad \frac{1}{r}\Big|_{r_a}^{r_b}$$

$$U_b \quad U_a = \frac{qq}{4}\left[\frac{1}{r_b} \quad \frac{1}{r_a}\right] \tag{2.3}$$

# Chapter 3

# Capacitance

## 3.1 Capacitor

*A capacitor is the device that stores energy in an electrostatic field. A capacitor can draw energy relative slowly (over several seconds) from the battery and it then can release the energy rapidly (within milliseconds) thought the blub .*

The capacitor allows to pass AC signal but blocks DC signal.

A capacitor are also used to produced electric fields, such as the parallel-plate device that gives the very nearly uniform electric field that deflects beam of the electrons in the TV or oscilloscope tube.

In another application, the tuning of the radio TV receiver is usually done by varying the capacitance of the circuit.

That is why study of the capacitance is very important in the physics and technology.

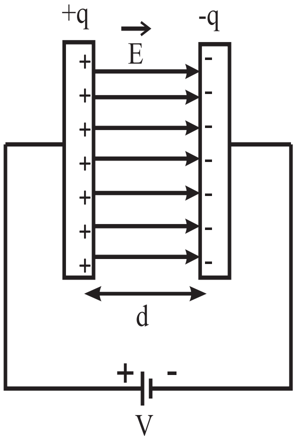

**Fig. 3.1.** Parallel plate capacitor.

### Mathematical Treatment

Consider a parallel plate capacitor connected with a battery of potential difference $V$ as shown in Fig.(3.1). It is experimentally observed that:

with more charging voltage, the electric field between the plates is stronger, hence more charge is stored.

The amount of charge $Q$ stored in the capacitor is directly proportional to potential difference $V$ of battery i.e. $Q$ $V$ $Q = CV$. Where $C$ is constant of proportionality called capacity or capacitance of capacitor.

# Chapter 4

# DC Circuits

## 4.1 Electric Current

*The rate of flow of charge through any area of cross-section of a conductor or wire is called electric current* . If net charge $dq$ passes through any area of cross-section of conductor in time $dt$, then electric current $I$ is,

$$I = \frac{dq}{dt}$$

Net charge that passes through the conductor in any time interval is given by

$$\begin{aligned}
dq &= I dt \\
\int dq &= \int I dt && \text{Taking integral on both sides} \\
\int dq &= I \int dt && \text{If current is constant} \\
q &= It \\
\text{or} \quad I &= \frac{q}{t}
\end{aligned}$$

Where $q$ is charge that flows in time $t$. The electric current $I$ is same for all area of cross-section of a conductor even through the cross-sectional areas may be different at different points.

### Direction of Current

The free electrons are in continuous random motion in metallic conductors. The current is not established without external electric field whether conductor is charged or uncharged. When external electric field is applied, electrons move from low potential terminal (-ve) to high potential terminal (+ve) of battery. The direction of conventional current in a circuit is from high potential to low potential terminal of battery.

# Chapter 5

# Magnetic Field

## 5.1 Magnetic Field

*The space around a permanent magnet or current carrying conductor or moving charge where another magnet experience a magnetic force is called magnetic field* . A moving electric charge or an electric current sets up a magnetic field $B$ which can then exert a magnetic force on other moving charges or current.

### Magnetic Field Lines

*The line or path along which isolated north-pole moves in magnetic field is called line of magnetic force* .

It is directed away from north-pole and is directed towards south-pole.

The tangent to the magnetic line at any point gives direction of magnetic induction $B$ at that point.

The inter spacing between magnetic field lines at any point gives an idea about strength of magnetic field at that point.

If magnetic field lines are close, field will be strong and if lines are apart, field will be weak.

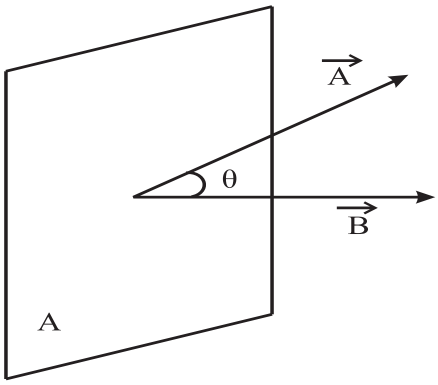

**Fig. 5.1.** The schematic picture of magnetic flux.

### Magnetic Flux Density or Magnetic Induction

Total number of magnetic lines passing perpendicularly through unit area is called magnetic flux density $B$ at that point.

# Chapter 6

# INDUCTION

## 6.1 Magnetic Flux

The number of magnetic lines of force passing normally through certain area is called magnetic flux. It is denoted by $_B$. It is a scalar quantity and its SI unit is weber ($Wb$). It is measured by the product of magnetic field strength and the component of vector area parallel to magnetic field. If $dA$ is the vector area element of the surface placed in uniform magnetic field of magnetic field strength $B$ as shown in the Figure (6.1). The magnetic flux $d\ _B$ through $dA$ is given by:

$$d\ _B = B\ dA = BdA\cos$$

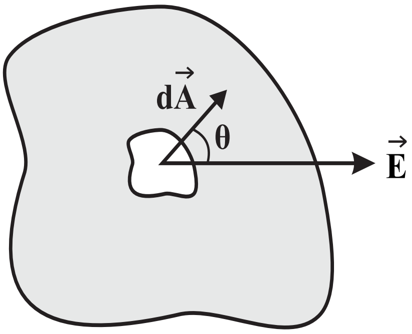

**Fig. 6.1.** Magnetic flux through surface area $dA$.

Total flux of whole surface S is

$$_B = \int_S B\ dA = \int_S BdA\cos \tag{6.1}$$

Where is the angle between magnetic field strength and vector area element.

## 6.2 Faradays Law of Electromagnetic Induction

### Statement

*The induced emf in a circuit is equal to the negative of rate at which the magnetic flux through the circuit is changing with time. Or* The magnitude of induced $emf$ in a circuit is directly proportional to the rate of change of magnetic flux.

$$= \quad N\frac{d\ _B}{dt} \tag{6.2}$$

### Explanation

When a magnet is moved toward the loop, the ammeter needle deflects in one direction, as shown in the Fig.(6.2) (a). When the magnet is brought to rest and held stationary relative to the loop Fig.(6.2)(b), no deflection is observed. When the magnet is moved away from the loop, the needle deflects in the opposite direction, as shown in Fig.(6.2)

# Chapter 7

# Alternating Current Circuits

## 7.1 AC Voltage Across Resistor

Suppose a time varying alternating voltage is applied across a resister $R$. The instantaneous value of alternating current $i$ produced in resistor $R$ due to alternating voltage is,

$$i = i_m \sin(t \qquad ) \tag{7.1}$$

$i_m$ = Peak value or maximum value of alternating current

and = Initial Phase and is angular frequency.

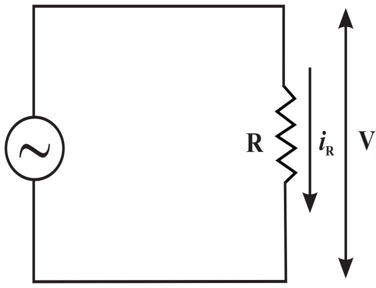

**Fig. 7.1.** AC through resistor

### Voltage Across Resistor ($V_R$)

The alternating voltage across resistor $R$ is given by,

$$V_R = iR = i_m R \sin(t \qquad )$$

$$V_R = V_m \sin(t \qquad ) \qquad V_m = i_m R \tag{7.2}$$

$V_m$ = Peak value or maximum value of alternating voltage.

Now the Eq.(7.1) and Eq.(7.2) show that both the voltage and current have same phase angle,

$$= t \tag{7.3}$$

Both reach their maximum value at same time. It means current and voltage have same phase.

## 7.1.1 Phaser Method

Phaser is a rotating vector in anti clock wise direction. The Length of the phaser gives maximum or peak value of alternating quantity and, angle made by the phaser with $x$-axis at any instant gives the phase of alternating quantity. Phaser $OP$ and $OQ$ gives the maximum or peak values $V_m$ and $i_m$ of alternating voltage and alternating current where as their projection $OM$ and $ON$ on vertical axis gives instantaneous values $V_R$ and $i_R$ of alternating voltage and alternating current. As phaser $OP = V_m$ and $OQ = i_m$ lie along

# Chapter 8

# Maxwells Equations and Electromagnetic Waves

## 8.1 Summarizing the Electromagnetic Equations

Although there are many differences in the physical properties of electric and magnetic fields, there are many similarities on their mathematical properties. To see these similarities, let us write the basic equations of electromagnetism to apply to a region of space in which electric and magnetic fields exits but there are no charge or current(the fields may be caused by charges and currents in other regions of space). If we choose any closed surface in this region, we can apply Gausss law for both electric and magnetic fields:

$$\oint E \;\; dA = 0 \tag{8.1}$$

$$\oint B \;\; dA = 0 \tag{8.2}$$

Over any closed surface, the surface integrals of the electric and magnetic fields are both zero, because the surface encloses no electric charge or magnetic poles. These two equations have exactly the same form, which represents an important symmetry between electric and magnetic fields. We now choose any closed path in this region and apply Faradays law and Amperes law:

$$\oint E \;\; dS = \quad \frac{d \quad _B}{dt} \tag{8.3}$$

$$\oint B \;\; dS = 0 \tag{8.4}$$

The symmetry between $E$ and $B$ that was present in Eqs.(8.1) and (8.2) seems to be missing in Eqs.(8.3) and (8.4). Faradays law tells us that in this region a varying magnetic


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