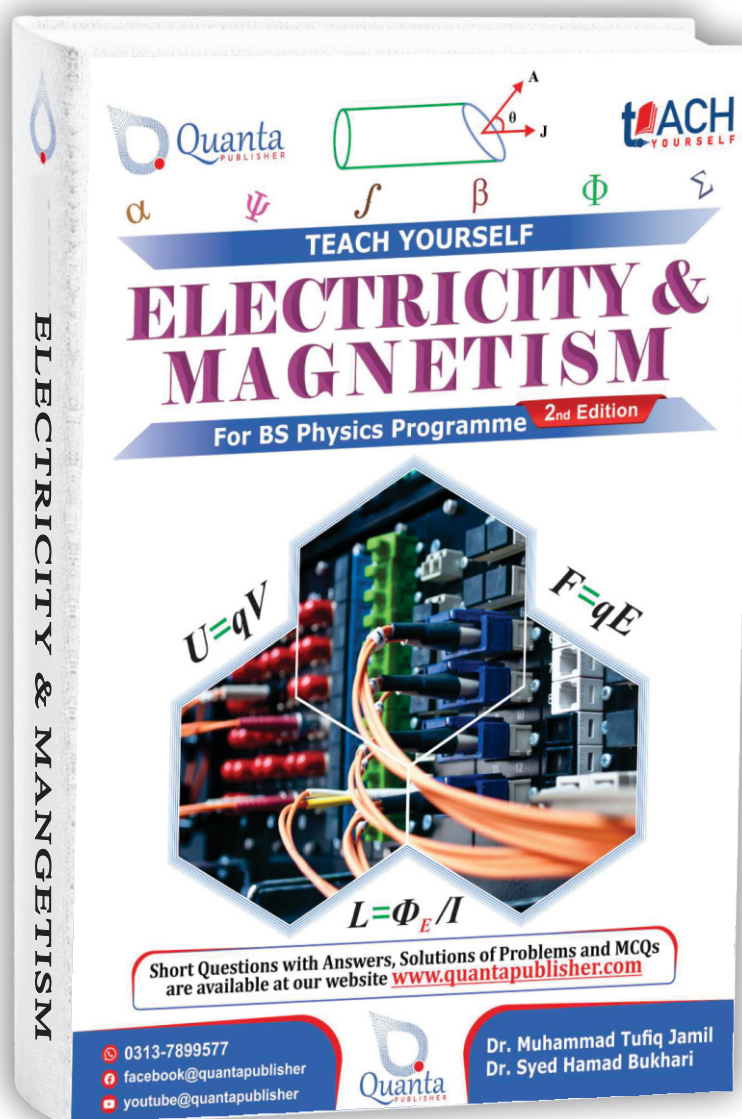




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**ELECTRICITY &**

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2nd Edition

For BS/ADS Physics/Chemistry/Mathematics students

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# Contents

<b>1</b>	<b>Electric Field</b> .....	<b>2</b>
1.1	Electric Charge .....	2
1.2	Applications of Electrical Force .....	4
1.3	Coulombs Law .....	5
1.4	Electric Field Intensity ( $E$ ) .....	8
1.4.1	Electric Field Intensity Due to Point Charge .....	8
1.4.2	Electric Field Due to Continuous Charge Distribution .....	9
1.5	The Electric Dipole .....	11
1.6	Electric Field for Continuous Charge Distributions .....	12
1.7	Electric Field Due to Ring of Charge .....	14
1.8	Electric Field Due to Charged Disk .....	15
1.9	Torque on a Dipole in an Electric Field .....	17
1.10	Potential Energy of an Electric Dipole .....	18
1.11	Electric Flux .....	19
1.12	Gauss Law .....	20
1.13	Deduction of Coulombs Law from Gauss Law .....	22
1.14	Applications of Gauss Law .....	22
1.14.1	Electric Field Due to Infinite Line of Charge .....	22
1.14.2	Electric Field Due to Infinite Sheet of Charge .....	24
1.14.3	Electric Field due to Spherical Charge Distribution .....	26
1.15	Gauss Law (Spherical Symmetry) .....	28
1.16	Charged Isolated Conductor .....	30
1.17	Review Questions and Problems .....	32
<b>2</b>	<b>Electric Potential</b> .....	<b>38</b>
2.1	Electric Potential Energy Difference .....	38
2.2	Absolute Electric Potential Energy .....	39
2.3	Electric Potential Due to Point Charge .....	39
2.4	Potential Due to Electric Dipole .....	41
2.5	Potential Due to Continuous Charge Distribution .....	42
2.6	Potential Due to Charged Disk .....	43
2.7	Calculating Field from the Potential .....	44
2.8	Poissons and Laplaces Equations .....	45
2.9	Potential and Field Inside and Outside of an Isolated Conductor .....	45
2.10	Conductor in External Electric Field .....	47

2.11	Surface Charge Density for an Isolated Charged Conductor .....	48
2.12	Review Questions and Problems .....	49
<b>3</b>	<b>Capacitance</b> .....	<b>53</b>
3.1	Capacitor .....	53
3.2	Capacitance .....	54
3.3	Capacitance of a Parallel-Plate Capacitor .....	55
3.4	Capacitance of Spherical Capacitor .....	56
3.5	Capacitance of a Cylindrical Capacitor .....	58
3.6	Capacitor with Dielectric .....	60
3.7	Energy Stored in Electric Field .....	63
3.8	Gauss Law in Dielectrics .....	64
3.9	Review Questions and Problems .....	70
<b>4</b>	<b>DC Circuits</b> .....	<b>73</b>
4.1	Electric Current .....	73
4.2	Drift Velocity .....	74
4.3	Electrical Resistance .....	76
4.4	Ohms Law .....	78
4.5	Energy Transfer in Electric Circuit .....	80
4.6	Equation of Continuity .....	81
4.7	Kirchhoffs Rules .....	83
4.8	Calculating Current in a Single Loop Circuit .....	84
4.9	Superposition, Thevenin and Norton Theorems .....	85
4.10	Growth of Current in RC Series Circuit .....	91
4.11	Decay of Current in RC Series Circuit .....	93
4.12	Review Questions and Problems .....	95
<b>5</b>	<b>Magnetic Field</b> .....	<b>99</b>
5.1	Magnetic Field .....	99
5.2	Force on a Current Carrying Conductor in Magnetic Field .....	100
5.3	Force On Moving Charged Particle In Magnetic Field .....	102
5.4	Motion of Charged Particle in an Electric and Magnetic Field .....	104
5.5	Torque on a Current Loop .....	105
5.6	The Magnetic Dipole Moment .....	106
5.7	Determination of the Electron $e/m$ Ratio .....	108
5.8	Biot-Savart Law .....	109
5.9	Application of Biot-Savart Law .....	111
5.10	Amperes Law .....	113
5.11	Application of Amperes Law .....	115
5.12	Gauss Law for Magnetism .....	117
5.13	Atomic Magnetism .....	118
5.14	Nuclear Magnetism .....	120
5.15	Magnetization .....	121
5.16	Magnetic Materials .....	122
5.17	Hysteresis Loop .....	125
5.18	Review Questions and Problems .....	127

<b>6</b>	<b>INDUCTION</b> .....	131
6.1	Magnetic Flux .....	131
6.2	Faradays Law of Electromagnetic Induction .....	131
6.3	Lenz law .....	133
6.4	Lenz Law and Conservation of Energy .....	134
6.5	Motional Induction and Motional <i>emf</i> .....	134
6.6	Induced Electric Field .....	136
6.7	Eddy Current .....	137
6.8	Inductance .....	137
6.8.1	Inductance of a Solenoid .....	138
6.8.2	Inductance of a Toroid .....	139
6.9	Growth of Current in <i>LR</i> Circuit .....	141
6.10	Decay of Current in <i>RL</i> Circuit .....	142
6.11	Energy Density .....	145
6.12	Electromagnetic Oscillations (Qualitative Analysis) .....	145
6.13	LC Circuit: Electromagnetic Oscillations (Quantitative analysis) .....	146
6.14	Damped Oscillations .....	150
6.15	Forced Oscillations and Resonance .....	152
6.16	Growth of Current in <i>RC</i> Series Circuit .....	154
6.17	Review Questions and Problems .....	156
<b>7</b>	<b>Alternating Current Circuits</b> .....	158
7.1	AC Voltage Across Resistor .....	158
7.1.1	Phaser Method .....	158
7.2	Alternating Voltage Across an Inductor .....	159
7.3	Alternating Voltage Across a Capacitor .....	160
7.4	Single Loop RLC Series Circuit (Analytical treatment) .....	162
7.5	R.L.C Series Circuit (Graphical Analysis) .....	164
7.6	Power in Alternating Circuit .....	166
7.7	Power Dissipated in RLC Series Alternating Circuit .....	167
7.7.1	Power Factor .....	168
7.8	Review Questions and Problems .....	169
<b>8</b>	<b>Maxwells Equations and Electromagnetic Waves</b> .....	171
8.1	Summarizing the Electromagnetic Equations .....	171
8.2	Induced Magnetic Fields And The Displacement Current .....	172
8.3	Maxwells Equations .....	174
8.4	Generating An Electromagnetic Wave .....	174
8.5	Traveling Waves and Speed of Light from Maxwells Equations .....	176
8.6	Energy Transport And The Poynting Vector .....	180
8.7	Review Questions and Problems .....	181

# 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

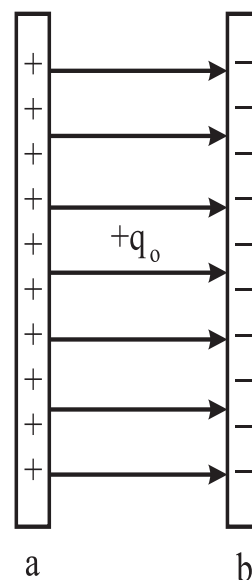
The potential energy difference between two points is equal to negative of work done by electrostatic force (conservative) in moving charge  $q$  between two points, in an electric field, with constant velocity. Change in electrostatic P.E.

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

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)

$$\begin{aligned}
 U &= \int_a^b F \, dr \\
 U_b - U_a &= q \int_a^b E \, dr \\
 U_b - U_a &= q \int E \, dr \tag{2.2}
 \end{aligned}$$



**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)

$$\begin{aligned}
 U_b - U_a &= q \int_{r_a}^{r_b} \frac{1}{4} \frac{q}{r^2} r \, r dr = \frac{1}{4} qq \int_{r_a}^{r_b} r^{-2} dr = \frac{qq}{4} \left[ \frac{1}{r} \right]_{r_a}^{r_b} \\
 U_b - U_a &= \frac{qq}{4} \left[ \frac{1}{r_b} - \frac{1}{r_a} \right] \tag{2.3}
 \end{aligned}$$

## 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) through the bulb.

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

Capacitors are also used to produce electric fields, such as the parallel-plate device that gives the very nearly uniform electric field that deflects a beam of 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.

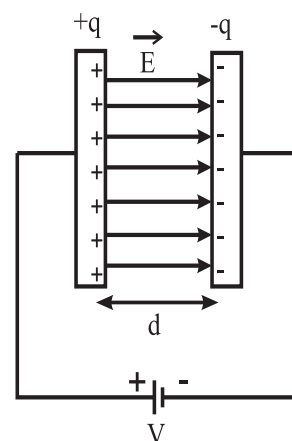


Fig. 3.1. Parallel plate capacitor.

### 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.  $Q \propto V$  or  $Q = CV$ . 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

$$dq = Idt$$

$$\int dq = \int Idt \quad \text{Taking integral on both sides}$$

$$\int dq = I \int dt \quad \text{If current is constant}$$

$$q = It$$

or  $I = \frac{q}{t}$

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 though 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.

#### 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.

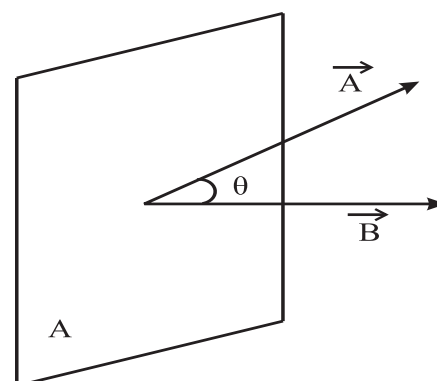


Fig. 5.1. The schematic picture of magnetic flux.

## 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  $\Phi_B$ . 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  $d\Phi_B$  through  $dA$  is given by:

$$d\Phi_B = B dA \cos \theta$$

Total flux of whole surface  $S$  is

$$\Phi_B = \int_S B dA \cos \theta = \int_S B dA \cos \theta \quad (6.1)$$

Where  $\theta$  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.

$$\mathcal{E} = -N \frac{d\Phi_B}{dt} \quad (6.2)$$

### 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)

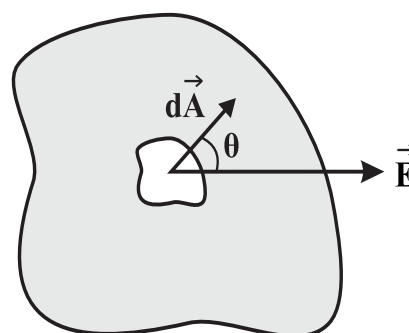


Fig. 6.1. Magnetic flux through surface area  $dA$ .

# Chapter 7

## Alternating Current Circuits

### 7.1 AC Voltage Across Resistor

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

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

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

and  $\phi$  = Initial Phase and  $\omega$  is angular frequency.

#### Voltage Across Resistor ( $V_R$ )

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

$$V_R = iR = i_m R \sin(t + \phi) \tag{7.2}$$

$$V_R = V_m \sin(t + \phi) \quad V_m = i_m R$$

$V_m$  = 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,

$$\phi = t \tag{7.3}$$

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

#### 7.1.1 Phasor Method

Phasor is a rotating vector in anti clock wise direction. The Length of the phasor gives maximum or peak value of alternating quantity and, angle made by the phasor with  $x$ -axis at any instant gives the phase of alternating quantity. Phasor  $OP$  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 phasor  $OP = V_m$  and  $OQ = i_m$  lie along

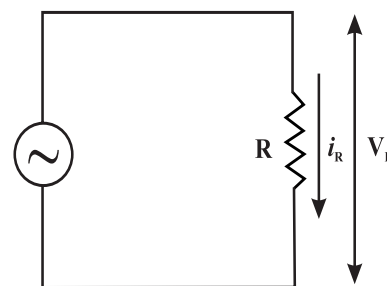


Fig. 7.1. AC through resistor

## 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 exist 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 Gauss's law for both electric and magnetic fields:

$$\oint E \, dA = 0 \quad (8.1)$$

$$\oint B \, dA = 0 \quad (8.2)$$

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 Faraday's law and Ampere's law:

$$\oint E \, dS = \frac{d}{dt} B \quad (8.3)$$

$$\oint B \, dS = 0 \quad (8.4)$$

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). Faraday's law tells us that in this region a varying magnetic



**1 Electric Field ..... 02**

1.1 Electric Charge ..... 02

1.2 Applications of Electrical Force ..... 04

1.3 Coulomb's Law ..... 05

1.4 Electric Field Intensity (E) ..... 08

    1.4.1 Electric Field Intensity Due to Point ..... 08

    1.4.2 Electric Field Due to Continuous ..... 09

1.5 The Electric Dipole ..... 11

1.6 Electric Field for Continuous Charge ..... 12

1.7 Electric Field Due to Ring of Charge ..... 14

1.8 Electric Field Due to Charged Disk ..... 15

1.9 Torque on a Dipole in an Electric Field ..... 17

1.10 Potential Energy of an Electric Dipole ..... 18

1.11 Electric Flux ..... 19

1.12 Gauss's Law ..... 20

1.13 Deduction of Coulomb's Law from ..... 22

1.14 Applications of Gauss's Law ..... 22

    1.14.1 Electric Field Due to Infinite Line ..... 22

    1.14.2 Electric Field Due to Infinite ..... 24

    1.14.3 Electric Field due to Spherical ..... 26

1.15 Gauss's Law (Spherical Symmetry) ..... 28

1.16 Charged Isolated Conductor ..... 30

1.17 Review Questions and Problems ..... 32

**2 Electric Potential ..... 37**

2.1 Electric Potential Energy Difference ..... 37

2.2 Absolute Electric Potential Energy ..... 38

2.3 Electric Potential Due to Point Charge ..... 38

2.4 Potential Due to Electric Dipole ..... 40

2.5 Potential Due to Continuous Charge ..... 41

2.6 Potential Due to Charged Disk ..... 42

2.7 Calculating Field from the Potential ..... 43

2.8 Poisson's and Laplace's Equations ..... 44

2.9 Potential and Field Inside and Outside of ..... 44

2.10 Conductor in External Electric Field ..... 46

2.11 Surface Charge Density for an ..... 47

2.12 Review Questions and Problems ..... 48

**3 Capacitance ..... 51**

3.1 Capacitor ..... 51

3.2 Capacitance ..... 52

3.3 Capacitance of a Parallel-Plate Capacitor ..... 53

3.4 Capacitance of Spherical Capacitor ..... 54

3.5 Capacitance of a Cylindrical Capacitor ..... 56

3.6 Capacitor with Dielectric ..... 58

3.7 Energy Stored in Electric Field ..... 61

3.8 Gauss's Law in Dielectrics ..... 62

3.9 Review Questions and Problems ..... 68

**4 DC Circuits ..... 71**

4.1 Electric Current ..... 71

4.2 Drift Velocity ..... 72

4.3 Electrical Resistance ..... 74

4.4 Ohm's Law ..... 76

4.5 Energy Transfer in Electric Circuit ..... 78

4.6 Equation of Continuity ..... 79

4.7 Kirchhoff's Rules ..... 81

4.8 Calculating Current in a Single Loop Circuit... 82

4.9 Superposition, Thevenin and Norton ..... 83

4.10 Growth of Current in RC Series Circuit ..... 89

4.11 Decay of Current in RC Series Circuit ..... 91

4.12 Review Questions and Problems ..... 93

**5 Magnetic Field ..... 97**

5.1 Magnetic Field ..... 97

5.2 Force on a Current Carrying Conductor ..... 98

5.3 Force On Moving Charged Particle In ..... 100

5.4 Motion of Charged Particle in an ..... 102

5.5 Torque on a Current Loop ..... 103

5.6 The Magnetic Dipole Moment ..... 104

5.7 Determination of the Electron e/m Ratio ... 106

5.8 Biot-Savart Law ..... 107

5.9 Application of Biot-Savart Law ..... 109

5.10 Ampere's Law ..... 111

5.11 Application of Ampere's Law ..... 113

5.12 Gauss's Law for Magnetism ..... 115

5.13 Atomic Magnetism ..... 116

5.14 Nuclear Magnetism ..... 118

5.15 Magnetization ..... 119

5.16 Magnetic Materials ..... 120

5.17 Hysteresis Loop ..... 123

5.18 Review Questions and Problems ..... 125

**6 Induction and Inductance ..... 129**

6.1 Magnetic Flux ..... 129

6.2 Faraday's Law of Electromagnetic ..... 129

6.3 Lenz law ..... 131

6.4 Lenz Law and Conservation of Energy ..... 132

6.5 Motional Induction and Motional emf ..... 132

6.6 Induced Electric Field ..... 134

6.7 Eddy Current ..... 135

6.8 Inductance ..... 135

    6.8.1 Inductance of a Solenoid ..... 136

**7 Alternating Current Circuits ..... 156**

7.1 AC Voltage Across Resistor ..... 156

    7.1.1 Phaser Method ..... 156

7.2 Alternating Voltage Across an Inductor ..... 157

<b>7.3</b> Alternating Voltage Across a Capacitor ..... 158	<b>8</b> <b>Maxwell's Equations and Electromagnetic..... 169</b>
<b>7.4</b> Single Loop RLC Series Circuit (Analytical treatment) ..... 160	<b>8.1</b> Summarizing the Electromagnetic..... 169
<b>7.5</b> R.L.O Series Circuit (Graphical Analysis) ..... 162	<b>8.2</b> Induced Magnetic Fields And The ..... 170
<b>7.6</b> Power in Alternating Circuit ..... 164	<b>8.3</b> Maxwell's Equations ..... 172
<b>7.7</b> Power Dissipated in RLC Series Alternating Circuit ..... 165	<b>8.4</b> Generating An Electromagnetic Wave ..... 172
<b>7.7.1</b> Power Factor ..... 166	<b>8.5</b> Traveling Waves and Speed of Light from.... 174
<b>7.8</b> Review Questions and Problems..... 167	<b>8.6</b> Energy Transport And The Poynting Vector.. 178
	<b>8.7</b> Review Questions and Problems..... 179

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$\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$   
 $\mathbf{v} = \frac{d\mathbf{r}}{dt}$   
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 $\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$

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 $\mathbf{B} = \nabla \times \mathbf{A}$

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 $T = E/k$   
 $E_p = C/r^2$

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 $h\nu = E_2 - E_1$   
 $P = W/N \cdot \Delta t$

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 $F = qE$   
 $f_{net} = \dot{h} - \dot{h}_i$

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$A + A = A$   
 $A + \bar{A} = 1$

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