CHAPTER 03

CURRENT ELECTRICITY

"Electricity is really just organized lightning"

"GEORGE CARLIN"

INTRODUCTION

In electrostatics, our discussion of electric phenomena has been focused on charges at rest. In the previous chapter, we treated the concept of electric potential, which is measured in volt. Now we will see that this voltage acts like an "electrical pressure" that can produces a flow of charge or current, which is measured in ampere (or simply, amp and abbreviated as A) and that the resistance that restrains this flow is measured in ohm (Ω).

Example of electric currents about and involve many professions. Meteorologists are concerned with lightning and with the less dramatic slow flow of charge through the atmosphere. Biologists, physiologists, and engineers working in medical technology are concerned with the nerve currents that control muscles and especially with how those currents can be reestablished after spinal cord injuries. Electrical engineers are concerned with countless electrical systems, such as power systems, lightning protection systems, information storage systems, and music systems. Space engineers monitor and study the flow of charged particles from our Sun because that flow can wipe out telecommunication systems in orbit and even power transmission systems on the ground.

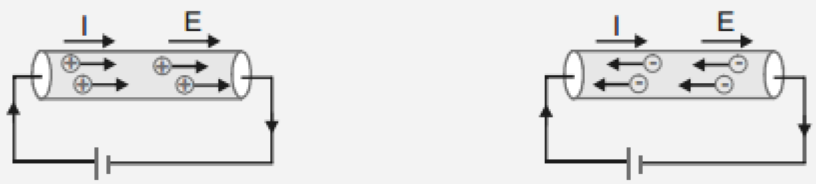
ETOOS KEY POINTS

(i) Current is a fundamental quantity with dimension $[M^0L^0T^0A^1]$

(ii) Current is a scalar quantity with its SI unit **ampere.**

Ampere : The current through a conductor is said to be one ampere if one coulomb of charge is flowing per second through a cross–section of wire.

(iii) The conventional direction of current is the direction of flow of positive charge or applied field. It is opposite to direction of flow of negatively charged electrons.



(iv) The conductor remains uncharged when current flows through it because the charge entering at one end per second is equal to charge leaving the other end per second.

(v) For a given conductor current does not change with change in its cross–section because current is simply rate of flow of charge.

(vi) If n particles each having a charge q pass per second per unit area then current associated with cross–sectional area A is $I = \frac{\Delta q}{\Delta t} = nqA$.

(vii) If there are n particles per unit volume each having a charge q and moving with velocity v then current through cross–sectional area A is $I = \frac{\Delta q}{\Delta t} = nqvA$

(viii) If a charge q is moving in a circle of radius r with speed v then its time period is $T = 2\pi r/v$. The equivalent current $I = \frac{q}{T} = \frac{qv}{2\pi r}$.

Behavior of conductor in absence of applied potential difference :

In absence of applied potential difference electrons have random motion. The average displacement and average velocity is zero. There is no flow of current due to thermal motion of free electrons in a conductor.

The free electrons present in a conductor gain energy from temperature of surrounding and move randomly in the conductor.

The speed gained by virtue of temperature is called as thermal speed of an electron $\frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$

So thermal speed $v_{rms} = \sqrt{\frac{3kT}{m}}$ where m is mass of electron

At room temperature T = 300 K, $v_{rms} = 10^5$ m/s

Etoos Tips & Formulas

1. Electric Current :

Electric charges in motion constitute an electric current.Any medium having practically free electric charges, free to migrate is a conductor of electricity. The electric charge flows from higher potential energy state to lower potential energy state. Positive charge flows from higer to lower potential and negative charge flows from lower to higher. Metals such as gold, copper, aluminium etc. are good conductors.

2. Electric Current in a Conductor :

In absence of potential difference across a conductor, no net current flows through a cross section. When a potential difference is applied across a conductor the charge carries (electrons in case of metallic conductors) flow in a definite direction which constitutes a net current in it. These electrons are accelerated by electric field in the conductor produced by potential difference across the conductor. They move with a constant drift velocity. The direction of current is along the flow of positive charge (or opposite to flow of negative charge). $i = nv_d eA$, where v_d = drift velocity.

3. Charge Current and Current Density

The strength of the current i is the rate at which the electir charges are flowing. If a charge Q coulomb passes through a given cross section of the conductor in t second the current I through the conductor is given by

$$I = \frac{Q \text{ coulomb}}{t \text{ second}} = \text{ampere}$$

Ampere is the unit of current. If i is not constant then $i = \frac{dq}{dt}$, where dq is net charge transported at a section in time dt. In a current carrying conductor we can define a vector which gives the direction as current per unit normal, cross sectional area & is known as current density.

Thus $\vec{J} = \frac{I}{S}\hat{n}$ or $I = \vec{J}.\vec{S}$

Where $\hat{n}$ is the unit vector in the direction of the flow of current.

For random J or S, we use $I = \int \vec{J}.\vec{ds}$

4. Relation in J, E and V_D :

In conductors drift velocity of electrons is proportional to the electric field inside the conductor as; $V_d = \mu E$ where μ is the mobility of electrons

current density is given as $J = \frac{I}{A}$ ne $V_d = ne(\mu E) = \sigma E$

where $\sigma = ne\mu$ is called conductivity of material and we can also write

$\rho = \frac{1}{\sigma} \rightarrow$ resistivity of material.

Thus $E = \rho . J$. It is called as differential form of Ohm`s Law.

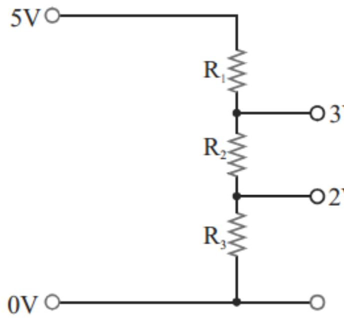
5. Sources of Potential Difference & Electromotive Force :

Dry cells, secondary cells, generator and thermo couple are the devices used for producing potential difference in an electric circuit. The potential difference between the **"Electromotive force"** or **"EMF"** of the source. The unit of potential difference is volt.

$$1 \text{ volt} = 1 \text{ Ampere} \times 1 \text{ Ohm.}$$

SOLVED EXAMPLE

Ex. 1 A potential divider is used to give outputs of 2V and 3V from a 5V source, as shown in figure. Which combination of resistances, R_1, R_2 and R_3 gives the correct voltages?



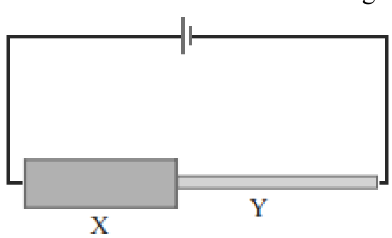
	R_1	R_2	R_3
(A)	1 kΩ	1 kΩ	2 kΩ
(B)	2 kΩ	1 kΩ	2 kΩ
(C)	3 kΩ	2 kΩ	2 kΩ
(D)	3 kΩ	2 kΩ	3 kΩ

Sol. For resistors in series connection, current (I) is the same through the resistors. In other words, ratio of the voltage drop across each resistor with its resistance is the same.

That is $I = \frac{5-3}{R_1} = \frac{3-2}{R_2} = \frac{2}{R_3}$

i.e., $R_1 : R_2 : R_3 = 2 : 1 : 2$.

Ex. 2 Figure shows a thick copper rod X and a thin copper wire Y, joined in series. They carry a current which is sufficient to make Y much hotter than X. Which one of the following is correct?



Density of conduction electrons	Mean time between collisions of the electrons
(A) Same in X and Y	Less in X than Y
(B) Same in X and Y	Same in X and Y
(C) Same in X and Y	More in X than Y
(D) More in X than Y	less in X than Y

Sol. The number density n of conduction electrons in the copper is a characteristic of the copper and is about 10^{29} at room temperature for both the copper rod X and the thin copper wire Y.

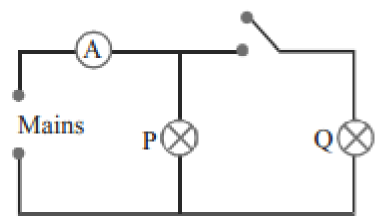
Both X and Y carry the same current I since they are joined in series.

From $I = neAv_d$

We may conclude that rod X has a lower drift velocity of electrons compared to wire Y since rod X has larger cross-sectional area. This is so because the electrons in X collide more often with one another and with the copper ions when drifting towards the positive end. Thus, the mean time between collisions of the electrons is more in X and than in Y.

Ex. 3 How will the reading in the ammeter A of figure be affected if another identical bulb Q is connected in parallel to P as shown. The voltage in the mains is maintained at a constant value.

(A) The reading will be reduced to one-half



(B) The reading will not be affected

(C) The reading will be doubled of the previous one

(D) The reading will be increased four-fold

Sol. Resistance is halved . Current is doubled.

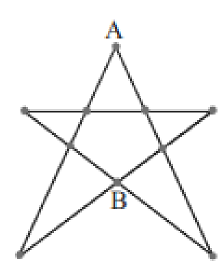
Ex. 4 The resistance of all the wires between any two adjacent dots is R. The equivalent resistance between A and B as shown in figure is

(A) $\frac{7}{3}R$

(B) $\frac{7}{6}R$

(C) $\frac{14}{8}R$

(D) None of these



Exercise # 1

SINGLE OBJECTIVE | NEET LEVEL

1. Current of 4.8 amperes is flowing through a conductor. The number of electrons per second will be

(A) 3×10^{19} (B) 7.68×10^{21}
(C) 7.68×10^{20} (D) 3×10^{20}

2. When the current i is flowing through a conductor, the drift velocity is v. If $2i$ current is flowed through the same metal but having double the area of cross-section, then the drift velocity will be

(A) $v/4$ (B) $v/2$
(C) v (D) $4v$

3. When current flows through a conductor, then the order of drift velocity of electrons will be

(A) 10^{10} m / sec (B) 10^{-2} cm / sec
(C) 10^{4} cm / sec (D) 10^{-1} cm / sec

4. Every atom makes one free electron in copper. If 1.1 ampere current is flowing in the wire of copper having 1 mm diameter, then the drift velocity (approx.) will be (Density of copper $= 9 \times 10^3$ kg m^{-3} and atomic weight = 63)

(A) 0.3 mm / sec (B) 0.1 mm / sec
(C) 0.2 mm / sec (D) 0.2 cm / sec

5. Which one is not the correct statement

(A) 1 volt × 1 coulomb = 1 joule
(B) 1 volt × 1 ampere = 1 joule / second
(C) 1 volt × 1 watt = 1 H.P.
(D) Watt-hour can be expressed in eV

6. If a 0.1 % increase in length due to stretching, the percentage increase in its resistance will be

(A) 0.2 % (B) 2 %
(C) 1 % (D) 0.1 %

7. The specific resistance of manganin is 50×10^{-8} ohm × m. The resistance of a cube of length 50 cm will be

(A) 10^{-6} ohm (B) 2.5×10^{-5} ohm
(C) 10^{-8} ohm (D) 5×10^{-4} ohm

8. The resistivity of iron is 1×10^{-7} $ohm - m$. The resistance of a iron wire of particular length and thickness is 1 *ohm*. If the length and the diameter of wire both are doubled, then the resistivity in $ohm - m$ will be

(A) 1×10^{-7} (B) 2×10^{-7}
(C) 4×10^{-7} (D) 8×10^{-7}

9. The temperature coefficient of resistance for a wire is $0.00125\ /°C$. At 300K its resistance is 1 *ohm*. The temperature at which the resistance becomes 2 *ohm* is

(A) 1154 K (B) 1100 K
(C) 1400 K (D) 1127 K

10. When the length and area of cross-section both are doubled, then its resistance

(A) Will become half
(B) Will be doubled
(C) Will remain the same
(D) Will become four times

11. The resistance of a wire is 20 *ohm*s. It is so stretched that the length becomes three times, then the new resistance of the wire will be

(A) 6.67 *ohm*s (B) 60.0 *ohm*s
(C) 120 *ohm*s (D) 180.0 *ohm*s

12. The resistivity of a wire

(A) Increases with the length of the wire
(B) Decreases with the area of cross-section
(C) Decreases with the length and increases with the cross-section of wire
(D) None of the above statement is correct

13. *Ohm*'s law is true

(A) For metallic conductors at low temperature
(B) For metallic conductors at high temperature
(C) For electrolytes when current passes through them
(D) For diode when current flows

Exercise # 2 SINGLE OBJECTIVE AIIMS LEVEL

1. A current I flows through a uniform wire of diameter d when the mean electron drift velocity is v. The same current will flow through a wire of diameter d/2 made of the same material if the mean drift velocity of the electron is

(A) v/4 (B) v/2
(C) 2v (D) 4v

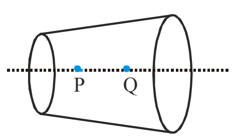
2. Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carries in the two wires are in the ratio 1:4, the drift velocity of electrons in the two wires will be in the ratio :

(A) 1:2 (B) 2:1
(C) 4:1 (D) 1:4

3. An insulating pipe of cross–section area 'A' contains an electrolyte which has two types of ions : their charges being –e and +2e. A potential difference applied between the ends of the pipe result in the drifting of the two types of ions, having drift speed = v (–ve ion) and v/4 (+ve ion). Both ions have the same number per unit volume = n. The current flowing through the pipe is

(A) nev A/2 (B) nev A/4
(C) 5nev A/2 (D) 3nev A/2

4. 45 A wire has a non–uniform cross–section as shown in figure. A steady current flows through it. The drift speed of electrons at points P and Q is v_P and v_Q



(A) $v_P = v_Q$ (B) $v_P < v_Q$
(C) $v_P > v_Q$ (D) data insufficient

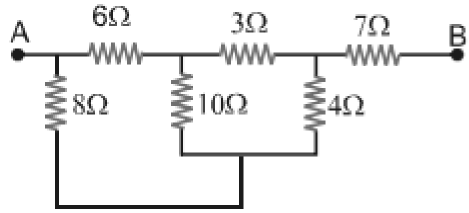
5. A wire of resistance R is stretched to double its length. Its new resistance is

(A) R (B) R/2
(C) 4R (D) R/4

6. Three copper wires have their lengths in the ratio 5 : 3 : 1 and their masses are in the ratio 1 : 3 : 5. Their electrical resistance will be in the ratio

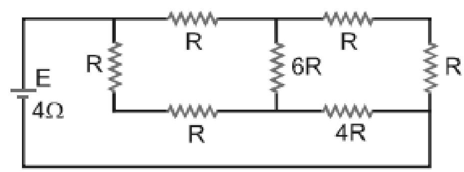
(A) 5 : 3 : 1 (B) 1 : 3 : 5
(C) 125 : 15 : 1 (D) 1 : 15 : 125.

7. The equivalent resistance between the points A and B is –



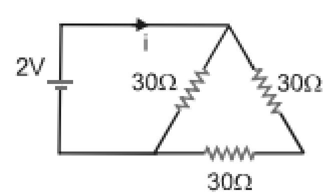
(A) $\frac{36}{7}\ \Omega$ (B) 10 Ω
(C) $\frac{85}{7}\ \Omega$ (D) none of these

8. A battery of internal resistance 4Ω is connected to the network of resistance as shown. In order that the maximum power can be delivered to the network, the value of R in Ω should be :–



(A) $\frac{4}{9}$ (B) 2
(C) $\frac{8}{3}$ (D) 18

9. The current i in the circuit (see figure) is :



(A) $\frac{1}{45}$ A (B) $\frac{1}{15}$ A
(C) $\frac{1}{10}$ A (D) $\frac{1}{5}$ A

Exercise # 3 PART - 1 MATRIX MATCH COLUMN

1. Match the statements in Column I with the current element in Column II

	Column - I		Column - II
(A)	Current always flows from higher potential to lower potential	(P)	A Resistor
(B)	Energy dissipated in an element is always zero	(Q)	Ideal cell/Battery
(C)	Current flow through the element is always zero	(R)	Non-Ideal cell/Battery
(D)	Potential difference may/will be zero	(S)	Short-circuited resistor

2. **Match the following :**

The following table gives the lengths of four copper rods at the same temperature, their diameters, and the potential differences between their ends.

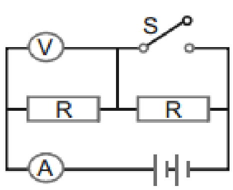
Rod	Length	Diameter	Potential Difference
1	L	3d	V
2	2L	d	3V
3	3L	2d	2V
4	3L	d	V

Correctly match the physical quantities mentioned in the left column with the rods as marked.

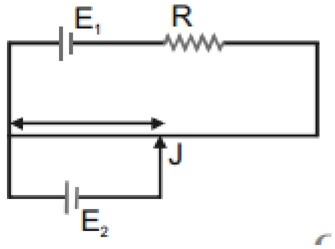
(A)	Greatest Drift speed of the electrons.	(P)	Rod 1
(B)	Greatest Current	(Q)	Rod 2
(C)	Greatest rate of thermal energy produced	(R)	Rod 3
(D)	Greatest Electric field	(S)	Rod 4

3. The diagram shows a circuit with two identical resistors. The battery has a negligible internal resistance.What will the effect on the ammeter and voltmeter be if the switch S is closed ?

	Column I		Column II
(A)	Ammeter reading	(P)	Increases
(B)	Voltmeter reading	(Q)	Decreases
(C)	Equivalent resistance of circuit	(R)	Does not change
(D)	Power dissipated across R in right branch	(S)	Becomes zero



4. In the potentiometer arrangement shown in figure, null point is obtained at length l.

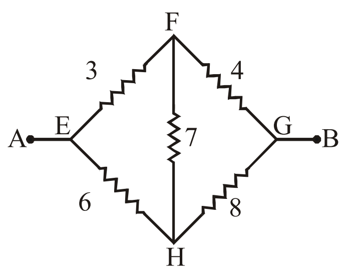


Exercise # 4

PART - 1

PREVIOUS YEAR (NEET/AIPMT)

1. A bridge circuit is shown in figure. The equivalent resistance btween A and B will be **[CBSE AIPMT 2000]**



(A) 21 Ω (B) 7 Ω

(C) $\frac{252}{85}\Omega$ (D) $\frac{14}{3}\Omega$

2. Potentiometer measures the potential difference more accurately than a voltmeter, because **[CBSE AIPMT 2000]**

(A) it has a wire of high resistance

(B) it has a wire of low resistance

(C) it does not draw current from external circuit

(D) it draws a heavy current from external circuit

3. A cell has an emf 1.5 V. When connected across an external resistance of 2 Ω , the terminal potential difference falls to 1.0 V. The internal resistance of the cell is **[CBSE AIPMT 2000]**

(A) 2 Ω (B) 1.5 Ω

(C) 1.0 Ω (D) 0.5 Ω

4. In a Wheatstone bridge resistance of each of the four sides is 10 Ω. If the resistance of the galvanometer is also 10 Ω , then effective resistance of the bridge will be **[CBSE AIPMT 2001]**

(A) 10 Ω (B) 5 Ω

(C) 20 Ω (D) 40 Ω

5. Resistivity of potentiometer wire is 10^{-7} Ω-m and its area of cross-section is 10^{-6} m^2. When a current i = 0.1 A flows through the wire, its potential gradient is **[CBSE AIPMT 2001]**

(A) 10^{-2} V/m (B) 10^{-4} V/m

(C) 0.1 V/m (D) 10 V/m

6. The specific resistance of a conductor increases with **[CBSE AIPMT 2002]**

(A) increase in temperature

(B) increase in cross-sectional area

(C) decrease in length

(D) decrease in cross-sedctional area

7. For a cell, the terminal potential difference is 2.2 V when circuit is open and reduces to 1.8 V when cell is connected to a resistance R = 5 Ω, the internal resistance (r) of cell is **[CBSE AIPMT 2002]**

(A) $\frac{10}{9}\Omega$ (B) $\frac{9}{10}\Omega$

(C) $\frac{11}{9}\Omega$ (D) $\frac{5}{9}\Omega$

8. In a Wheatstone bridge, all the four arms have equal resistance R. If the resistance of the galvanometer arm is also R, the equivalent resistance of the combination as seen by the battery is **[CBSE AIPMT 2003]**

(A) R (B) 2 R

(C) $\frac{R}{4}$ (D) $\frac{R}{2}$

9. A battery is charged at a potential of 15 V for 8 h when the current flowing is 10 A. The battery on discharge supplies a current of 5 A for 15 h. The mean terminal voltage during discharge is 14 V. The watt-hour efficiency of the battery is **[CBSE AIPMT 2004]**

(A) 82.5% (B) 80%

(C) 90% (D) 87.5%

10. The electric resistance of a certain wire of iron is R. It its length and radius are both doubled, then **[CBSE AIPMT 2004]**

(A) the resistance will be doubled and the specific resistance will be halved

(B) the resistance will be halved and the specific resistance will remain unchanged

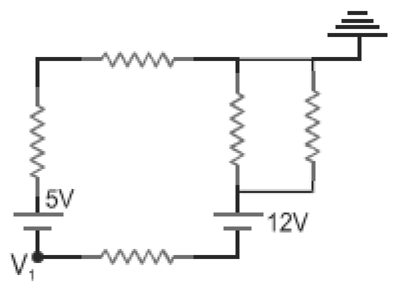
(C) the resistance will be halved and the specific resistance will be doubled

(D) the resistance and the specific resistance will both remain unchanged

MOCK TEST

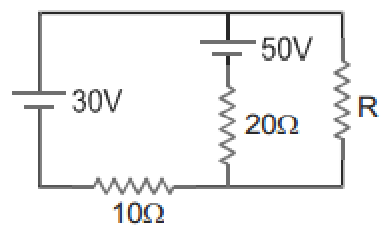
STRAIGHT OBJECTIVE TYPE

1. In the circuit shown, each resistances is 2 W. The potential V_1 as indicated in the circuit, is equal to



(A) 11 V (B) – 11V (C) 9 V (D) – 9 V

2. In the circuit shown, the value of R in ohm that will result in no current through the 30 V battery, is :

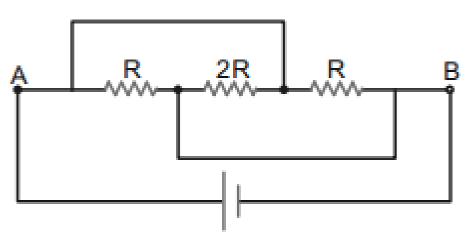


(A) 10 Ω (B) 25 Ω (C) 30 Ω (D) 40 Ω

3. The maximum current in a galvanometer can be 10 mA. It's resistance is 10Ω. To convert it into an ammeter of 1 Amp. a resistor should be connected in
(A) series, 0.1Ω (B) parallel, 0.1Ω (C) series, 100 Ω (D) parallel, 100Ω.

4. When a galvanometer is shunted with a 4Ω resistance, the deflection is reduced to one - fifth. If the galvanometer is further shunted with a 2Ω wire, the further reduction (find the ratio of decrease in current to the previous current) in the deflection will be (the main current remains the same).
(A) (8/13) of the deflection when shunted with 4Ω only
(B) (5/13) of the deflection when shunted with 4Ω only
(C) (3/4) of the deflection when shunted with 4Ω only
(D) (3/13) of the deflection when shunted with 4Ω only

5. In the figure shown the current flowing through 2 R is :
(A) from left to right
(B) from right to left
(C) no current
(D) None of these



11th Class Modules Chapter Details

Physics
5
Modules

Chemistry
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Modules

Mathematics
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Modules

PHYSICS

Module-1

1. Physical World & Measurements
2. Basic Maths & Vector
3. Kinematics

Module-2

1. Law of Motion & Friction
2. Work, Energy & Power

Module-3

1. Motion of system of particles & Rigid Body
2. Gravitation

Module-4

1. Mechanical Properties of Matter
2. Thermal Properties of Matter

Module-5

1. Oscillations
2. Waves

CHEMISTRY

Module-1(PC)

1. Some Basic Conceps of Chemistry
2. Atomic Structure
3. Chemical Equilibrium
4. Ionic Equilibrium

Module-2(PC)

1. Thermodynamics & Thermochemistry
2. Redox Reaction
3. States Of Matter (Gaseous & Liquid)

Module-3(IC)

1. Periodic Table
2. Chemical Bonding
3. Hydrogen & Its Compounds
4. S-Block

Module-4(OC)

1. Nomenclature of Organic Compounds
2. Isomerism
3. General Organic Chemistry

Module-5(OC)

1. Reaction Mechanism
2. Hydrocarbon
3. Aromatic Hydrocarbon
4. Environmental Chemistry & Analysis Of Organic Compounds

BIOLOGY

Module-1

1. Diversity in the Living World
2. Plant Kingdom
3. Animal Kingdom

Module-2

1. Morphology in Flowering Plants
2. Anatomy of Flowering Plants
3. Structural Organization in Animals

Module-3

1. Cell: The Unit of Life
2. Biomolecules
3. Cell Cycle & Cell Division
4. Transport in Plants
5. Mineral Nutrition

Module-4

1. Photosynthesis in Higher Plants
2. Respiration in Plants
3. Plant Growth and Development
4. Digestion & Absorption
5. Breathing & Exchange of Gases

Module-5

1. Body Fluids & Its Circulation
2. Excretory Products & Their Elimination
3. Locomotion & Its Movement
4. Neural Control & Coordination
5. Chemical Coordination and Integration

12th Class Modules Chapter Details

Physics
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Modules

Chemistry
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Modules

Mathematics
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Modules

PHYSICS

Module-1

1. Electrostatics
2. Capacitance

Module-2

1. Current Electricity
2. Magnetic Effect of Current and Magnetism

Module-3

1. Electromagnetic Induction
2. Alternating Current

Module-4

1. Geometrical Optics
2. Wave Optics

Module-5

1. Modern Physics
2. Nuclear Physics
3. Solids & Semiconductor Devices
4. Electromagnetic Waves

CHEMISTRY

Module-1(PC)

1. Solid State
2. Chemical Kinetics
3. Solutions and Colligative Properties

Module-2(PC)

1. Electrochemistry
2. Surface Chemistry

Module-3(IC)

1. P-Block Elements
2. Transition Elements (d & f block)
3. Co-ordination Compound
4. Metallurgy

Module-4(OC)

1. HaloAlkanes & HaloArenes
2. Alcohol, Phenol & Ether
3. Aldehyde, Ketone & Carboxylic Acid

Module-5(OC)

1. Nitrogen & Its Derivatives
2. Biomolecules & Polymers
3. Chemistry in Everyday Life

BIOLOGY

Module-1

1. Reproduction in Organisms
2. Sexual Reproduction in Flowering Plants
3. Human Reproduction
4. Reproductive Health

Module-2

1. Principles of Inheritance and Variation
2. Molecular Basis of Inheritance
3. Evolution

Module-3

1. Human Health and Disease
2. Strategies for Enhancement in Food Production
3. Microbes in Human Welfare

Module-4

1. Biotechnology: Principles and Processes
2. Biotechnology and Its Applications
3. Organisms and Populations

Module-5

1. Ecosystem
2. Biodiversity and Conservation
3. Environmental Issues