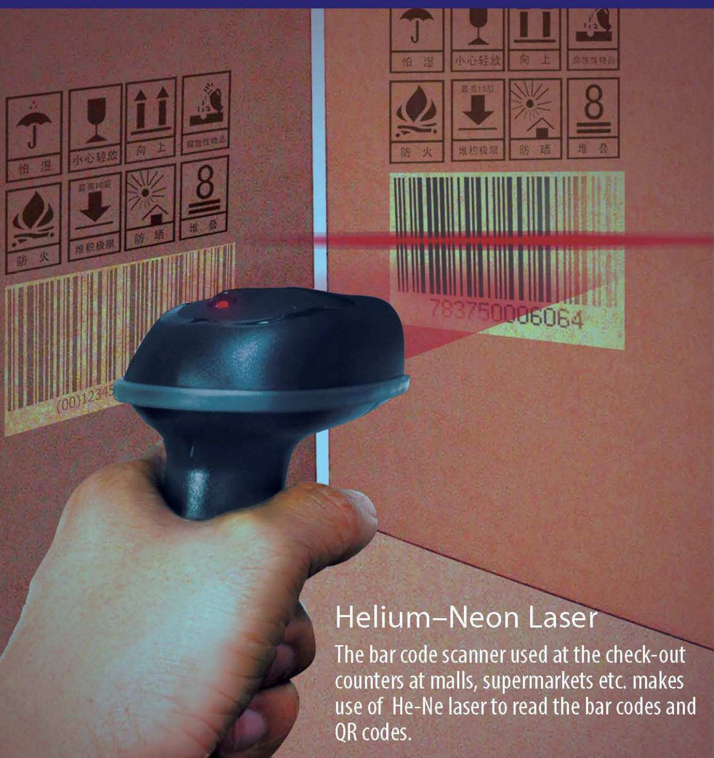
APPLIED SCIENCE

COMPUTER / ELECTRICAL / ELECTRONICS ENGINEERING GROUP

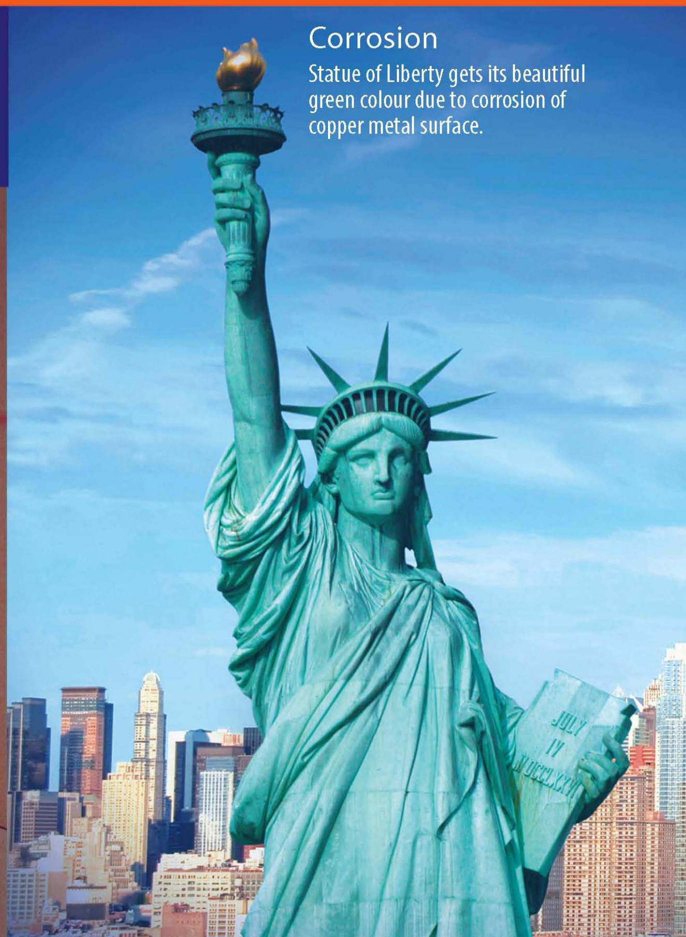
Phy. Code: 17210 | Chem. Code: 17211

FIRST YEAR DIPLOMA
SEMESTER II
MSBTE 'G' SCHEME



Helium–Neon Laser

The bar code scanner used at the check-out counters at malls, supermarkets etc. makes use of He-Ne laser to read the bar codes and QR codes.



Corrosion

Statue of Liberty gets its beautiful green colour due to corrosion of copper metal surface.

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FIRST YEAR DIPLOMA

SEMESTER - II

First Edition: December 2015

Salient Features

- Concise content with complete coverage of revised G-scheme syllabus.
- Simple and Lucid language.
- Neat, Labelled and Authentic diagrams.
- Illustrative examples showing detailed solution of numericals.
- MSBTE Theory Questions and Numericals from Summer-2007 to Winter-2015.
- MSBTE Question Papers of Summer, Winter - 2014 and 2015.
- Three Model Question Papers for practice.
- Important Inclusions: Additional Theory Questions, Problems for Practice, Knowledge Bank, Physics Behind.

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PREFACE

In the case of good books, the point is not how many of them you can get through, but rather how many can get through to you.

Target's "Applied Science: Computer/Electrical/Electronics Engineering Group" is a complete and thorough book critically analysed and extensively drafted to boost the students' confidence. Applied Science is divided into two parts: **Applied Science - Physics** and **Applied Science - Chemistry**. The book is prepared as per the revised scheme [G-scheme] of MSBTE curriculum effective from June 2012.

The **Topic-wise** classified format for each chapter of this book helps the students in easy comprehension. Each chapter includes the following features:

- **Theory** is provided in the form of pointers. Neat labelled diagrams have been provided wherever required. Definitions, statements and laws are specified with italic representation.
- **Illustrative Examples** are provided in relevant chapters in order to understand the application of different concepts and formulae.
- **Formulae** provided for quick recap.
- **MSBTE Theory Questions** covered in separate section to give a clear idea of the type of questions asked. *(Reference of answer to each question is provided.)*
- **MSBTE Numericals** till latest year are included.
- **Additional Theory Questions** to help the student gain insight on the various levels of theory-based questions.
- **Problems for Practice** *(With final answers)* in relevant chapters which covers an array of questions from simple to complex.
- **Knowledge Bank, Note,** etc. to enrich students' knowledge required to understand different concepts.
- **"Physics behind…."** is an effort to make students aware of real life engineering situations where physics plays prominent role or day-to-day experiences ruled by physics.

Three **Model Question Papers,** designed as per MSBTE Paper Pattern, are a unique tool to enable self-assessment for the students.

MSBTE Question Papers of years 2014 and 2015 are added at the end to make students familiar with the examination pattern.

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

Please write to us on : mail@targetpublications.org

A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

From,
Publisher

SYLLABUS

Applied Science : Physics

Topic and Contents	Hours	Marks
Topic 1 - Basic Electric Circuits **Specific objectives:** ➢ Calculate basic electric parameters for designing the simple electric circuits. ➢ Use basic electronic components like resistor, capacitor in electronic circuits. ➢ Use various networks such as Wheatstone's network, potentiometer ➢ Study principle and applications of condenser **1.1 Simple D.C. electric circuits: [4 Marks]** • Electric current: definition, symbol and unit, Ohm's law: statement, mathematical expression, resistivity: definition, unit, conductivity: definition, unit. **1.2 Wheatstone's network and potentiometer [6 Marks]** • Wheatstone's network, working principle, balancing condition, principle of potentiometer, potential gradient **1.3 Condensers: [6 Marks]** • Capacity of condenser-definition and its unit, definition of 1 farad capacity, principle of condenser, derivation of capacity of parallel plate condenser, statement and derivation of series and parallel combination of condensers.	12	16
Topic 2 - Semiconductor Physics **Specific objectives:** ➢ Differentiate between conductor, semiconductor, insulator ➢ Verify characteristics of P-N junction diode ➢ Study applications of P-N junction diode, photodiode. • Classification of solids on the basis of band theory: forbidden energy gap, conductor, insulator, semiconductor. • Classification of semiconductors, P-N junction diode, forward characteristics of P-N junction diode, reverse characteristics of PN junction diode, photodiode, its symbol, principle and applications.	04	10
Topic 3 - Modern Physics **Specific objectives:** ➢ State the concept of photocell ➢ State applications of X-ray ➢ State properties and applications of LASER **3.1 Photo electricity: [6 Marks]** • Photon (quantum), Plank's hypothesis, energy of photon, properties of photons. • Photo electric effect: circuit diagram, process of photoelectric emission, definitions: threshold frequency, threshold wavelength, stopping potential, characteristics of photoelectric effect • Work function, Einstein's photoelectric equation, photo resistor (LDR) - symbol, principle, applications, photoelectric cell: principle, applications.	12	18

3.2 X-rays: [6 Marks] • Origin of X-rays, production of X-rays using Coolidge's X-ray tube, minimum wavelength of X-ray, properties of X-rays, applications of X-rays: engineering, medical and scientific. **3.3 Laser: [6 Marks]** • Laser, properties of laser, spontaneous and stimulated emission, population inversion, optical pumping. • He-Ne Laser: Principle, construction and working, engineering applications of Laser		
Topic 4 - Physics of Nanoparticles **Specific objectives:** ➢ Study properties of nanoparticles. ➢ Study applications of nanotechnology. • History, nanoparticles, properties of nanoparticles, methods of synthesis of nanoparticles: physical method of synthesis of nanoparticles, engineering applications of nanotechnology.	**04**	**06**
TOTAL	**32**	**50**

Applied Science : Chemistry

Topic and Contents	Hours	Marks
Topic 1 - Metallurgy **Specific objectives:** ➢ Describe the extraction processes of copper and aluminium. ➢ State engineering applications of copper and aluminium based on their properties. **1.1 Metallurgy of copper: [4 Marks]** • Definition of metallurgy. • Extraction process: Ores of copper, extraction of copper from copper pyrites by concentration, roasting, smelting, bessemerisation, electrolytic refining. • Physical, chemical properties - action of air, water, acid, alkali, applications of copper. **1.2 Metallurgy of aluminium: [4 Marks]** • Extraction process: Ores of aluminium, extraction of aluminium from bauxite by Baeyer's process, electrolytic reduction of alumina, electrolytic refining of aluminium. • Physical, chemical properties - action of air, water, acid, alkali, applications of aluminium, anodizing of aluminium. **1.3 Solders: [4 Marks]** • Composition, properties and applications of - soft solder, Tinmann's solder, brazing alloy, rose metal, plumber's solder.	**08**	**12**
Topic 2 - Corrosion **Specific objectives:** ➢ Explain mechanism of atmospheric corrosion and immersed corrosion. ➢ Describe different methods of protection of metal from corrosion.	**10**	**14**

2.1 Corrosion: [6 Marks] • Definition of corrosion, types of corrosion. • Atmospheric corrosion: Definition, mechanism of oxidation corrosion, types of oxide films and their significance, factors affecting rate of atmospheric corrosion. • Immersed corrosion: Definition, mechanism of immersed corrosion by galvanic cell action - with evolution of hydrogen gas and absorption of oxygen gas, factors affecting immersed corrosion. **2.2 Protection of metals by: [8 Marks]** • Modification of environment, modification of properties of metal, electrochemical protection by sacrificial anodic protection and impressed current cathodic protection, use of protective coatings. • Application of metallic coatings: By galvanising, tinning, metal spraying, electroplating, metal cladding, cementation-sherardising, chromising, colourising. • Application of non-metallic coatings: paint - definition, characteristics, constituents of paint and their functions.		
Topic 3 - Cells and Batteries **Specific objectives:** ➢ Explain the concept of electrochemical cell. ➢ Describe construction and working of different types of cells. **Electrochemical cells / batteries:** • Basic concepts: Definition of electrolyte, conductivity of electrolytes, Ohm's law, specific conductance, equivalent conductance, cell, battery, electrolytic cell, electrochemical cell, charging, discharging. • Classification of electrochemical cells: Primary and secondary cells. • Primary cells: Construction, working and applications of - dry cell, Daniel cell. • Secondary cells: Construction, working and applications of - lead-acid storage cell, Ni-Cd cell. • Fuel cells: Definition, construction, working, advantages, limitations and applications of hydrogen-oxygen fuel cell.	**10**	**16**
Topic 4 - Chemistry of Electronic Materials **Specific objectives:** ➢ State role of polymers in electronic engineering. ➢ Describe applications of dielectrics and insulators in electronic devices. **4.1 Polymers: [4 Marks]** • Definitions, examples and applications of electrically conducting polymers, photoconductive polymers, electrically insulating polymers, liquid crystal polymers (LCP). **4.2 Insulators, dielectrics and adhesives: [4 Marks]** • Definitions of dielectrics and insulators, Properties of gaseous, liquid and solid insulators, their examples, properties and applications of - inert gases, silicone fluids, teflon, bakelite, ceramics and glass. • Definition, characteristics, advantages of adhesives, properties and applications of phenol formaldehyde resin, urea formaldehyde resin and epoxy resin.	**04**	**08**
TOTAL	**32**	**50**

Contents

Applied Science
Physics

UNIT I Basic Electric Circuits

Chapter - 1 Basic Electric Circuits

Chapter-1 Basic Electric Circuits

1.0 Introduction

1.1 Basic terms in electric circuits

1.2 Wheatstone's network

1.3 Potentiometer

1.4 Condensers or capacitors

1.5 Series and Parallel combination of condensers (statement and derivation)

01 Basic Electric Circuits

1.0 Introduction

i. The various types of electrical circuits are divided into a.c. circuits and d.c. circuits.

ii. *The electrical circuit in which the electric current flows throughout only in one direction are called as **d.c. circuit**.*

iii. The current obtained by connecting a source of e.m.f. like a cell or a battery in a circuit is called direct current (d.c.) and the circuit is called d.c. circuit.

1.1 Basic terms in electric circuits

1.1.(a) Electric current:

i. *The rate of flow of electric charge through any cross-section of the conducting wire in the electrical circuit is called **electric current**.* It is denoted by letter 'I'.

ii. **Formula:**

$$I = \frac{Q}{t}$$

where, Q = quantity of charge
t = time of flow of charge

iii. **Unit:** The SI unit of current is ampere.

iv. From the relation

$I = \frac{Q}{t}$,

if Q = 1 coulomb, t = 1 second, then I = 1 ampere.

v. ***One ampere** is that current which is produced in the circuit, when one coulomb of charge flows for one second through any cross-section of the conductor.*

vi. The smaller units are milliampere (mA) and microampere (μA).
1 mA = 10^{-3} A and 1μA = 10^{-6} A.

Illustrative Example:
Calculate the charge flowing through a conductor in which a current of 200 mA flows for 10 s.

Given: I = 200 m A = 200 × 10^{-3} A = 0.2 A, t = 10 s

To find: Time (t)

Formula: $I = \frac{Q}{t}$

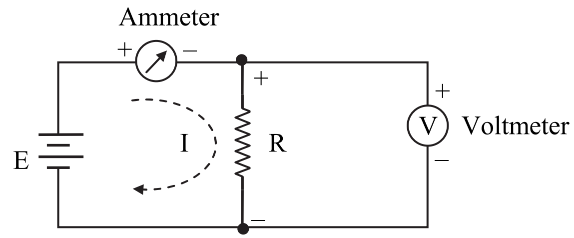
Calculation: Using formula,
Q = It = 0.2 × 10
∴ Q = **2 C**

Ans: The charge flowing through the conductor it **2 C**.

1.1.(b) Ohm's law:

As long as the physical state (material, dimensions, temperature etc.) of a conductor remains the same, the electric current flowing through a given conductor is directly proportional to the potential difference applied across it.

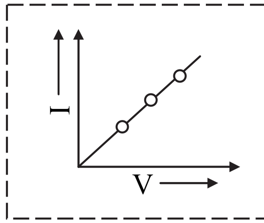
i. Mathematical expression for Ohm's law:



An electric circuit

a. As shown in figure, the voltage across resistor R is equal to V volt and the current through it is equal to I ampere.
V = potential difference
According to Ohm's law,
$I \propto V$
$\therefore \quad I = \frac{V}{R}$ where, R is a constant of proportionality called resistance of the conductor.
Hence, the **mathematical equation of Ohm's law** is,
$R = \frac{V}{I}$
Where, V = potential difference, I = electric current

b. If I versus V graph is plotted, then the slope of graph is a straight line as shown in the figure.



c. *A **linear device** is that device which exhibits a linear relation between voltage across it and the current flowing through it.* e.g. Resistor.

d. Ohm's law is not applicable to non-linear devices like diode, transistor, zener diodes etc. It is applicable only to the linear devices.

ii. Resistance of a conductor:

a. ***Resistance** of a conductor is the opposition to flow of current in the electric circuit.* It is denoted by letter 'R'.
It is numerically equal to the ratio of potential difference across the conductor to resulting current applied through it.

b. **Formula:** $R = \frac{V}{I}$

c. **Unit:** The SI unit of resistance is ohm. It is denoted by Ω.

d. In the formula,
if V = 1 volt, I = 1 ampere, then R = 1 Ω.
Thus, *the resistance of a conductor is said to be **one ohm** if a current of one ampere passes through it, when a potential difference (P.D.) of one volt is maintained between its terminals.*

iii. Conductance:

a. *The reciprocal of resistance is called* ***conductance****.* It is denoted by letter 'G'.

b. **Formula:** $G = \frac{I}{V} = \frac{1}{R}$

where, V = potential difference, I = electric current, R = resistance

c. **Unit:** SI unit is siemens (S) or mho (Ω^{-1}).

iv. Comparison between Resistance and Conductance:

	Resistance	Conductance
i.	Resistance of a material means the opposition to the flow of electric current.	Conductance is defined as the reciprocal of resistance.
ii.	Its SI unit is ohm.	Its SI unit is siemens or mho.
iii.	It is given by the formula, $R = \frac{V}{I}$	It is given by the formula, $G = \frac{1}{R} = \frac{I}{V}$

v. Resistivity or specific resistance:

a. At constant temperature, the resistance (R) of a metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A).

i.e. $R \propto \frac{l}{A} \Rightarrow R = \rho\frac{l}{A}$

where, ρ is a constant called the specific resistance or resistivity of the material of the conductor.

b. **Formula:** $\rho = \frac{RA}{l}$

c. In the formula, if $A = 1\ m^2$, $l = 1$ m and $R = 1\Omega$, then $\rho = 1\ \Omega m$.

d. ***Resistivity*** *or* ***specific resistance*** *of material is the resistance of wire of unit length and unit area of cross-section.* It is denoted by letter 'ρ'.

e. **Unit:** The S.I. unit is Ω-m or ohm-meter.

f. The specific resistance depends upon the material and temperature of the conductor. It does not depend upon its physical dimensions.

vi. Conductivity:

a. *Reciprocal of resistivity is called* ***conductivity****.* It is denoted by letter 'σ'.

b. **Formula:** $\sigma = \frac{1}{\rho}$

c. **Unit:** The S.I. unit is siemens/metre (S/m) or $(\Omega m)^{-1}$

d. Materials having large resistivity values are poor conductors or good insulators. Conversely, materials having small resistivity values are good conductors.

vii. Comparison between Resistivity and Conductivity:

	Resistivity	Conductivity
i.	Resistivity of a wire of given material is the resistance of that material having unit length and unit area of cross-section.	Conductivity of a wire of given material is the reciprocal of resistivity.
ii.	Its SI unit is ohm-metre	Its SI unit is $(\text{ohm-metre})^{-1}$.
iii.	It is given by the formula, $\rho = \frac{RA}{l}$	It is given by the formula, $\sigma = \frac{1}{\rho}$

Illustrative Examples:

Example 1

A resistance of 25 Ω carries a current of 5 A. Calculate the voltage developed across the resistor.

Given: R = 25 Ω, I = 5 A

To find: Voltage (V)

Formula: $R = \frac{V}{I}$

Calculation: Using formula,

$V = IR = 5 \times 25 = \mathbf{125\ V}$

Ans: The voltage developed across the resistor is **125 V**.

Example 2

An electric geyser draws a current of 4 A when connected across 220 volt supply. What current will it draw when connected across 330 volt supply?

Solution:

Given: $I_1 = 4$ A, $V_1 = 220$ V, $V_2 = 330$ V

To find: Current when heater is connected across 330 V supply (I_2)

Formula: $R = \frac{V}{I}$

Calculation: Using formula,

$$R = \frac{V_1}{I_1} = \frac{220}{4} = 55\ \Omega$$

When connected across 440 V supply, using formula,

$$I_2 = \frac{V_2}{R} = \frac{330}{55} = \mathbf{6\ A}$$

Ans: The electric heater will draw **6 A** when connected across 330 V supply.

Example 3

Calculate the resistance and conductance of a wire of 2.5 m if it operates on 230 V supply and draws a current equal to 120 mA. Also calculate its resistivity if its diameter is 2 mm.

Given: $l = 2.5$ m, V = 230 V, I = 120 mA = 120×10^{-3} A = 0.12 A,

$d = 2\ \text{mm} = 2 \times 10^{-3}\ \text{m} \Rightarrow r = \frac{2 \times 10^{-3}}{2}\ \text{m} = 1 \times 10^{-3}\ \text{m}$

To find: i. Resistance (R) ii. Conductance (G)

Formulae: i. $R = \frac{V}{I}$ ii. $G = \frac{1}{R}$

iii. $\rho = \frac{RA}{l} = \frac{R\pi r^2}{2l}$ ....∵ $A = \pi r^2$

Calculation: Using formula (i),

$$R = \frac{230}{0.12} \approx \mathbf{1916.667\ \Omega}$$

Using formula (ii),

$$G = \frac{1}{1916.67} = \mathbf{5.217 \times 10^{-4}\ \Omega^{-1}}$$

Using formula (iii),

$$\rho = \frac{1916.667 \times 3.142 \times (1 \times 10^{-3})^2}{2.5} = 2408.87 \times 10^{-6}$$

$\therefore \quad \rho = \mathbf{2.409 \times 10^{-3}\ \Omega m}$

Ans: The resistance of the filament is **1916.667 Ω**, its conductance is **$5.217 \times 10^{-4}\ \Omega^{-1}$** and it has a resistivity of **$2.409 \times 10^{-3}\ \Omega$m**.

Example 4

Calculate the resistance of 50 m length of the wire having cross-sectional area of 0.04×10^{-6} m² and having resistivity 3.2×10^{-7} Ωm.

Solution:

Given: $l = 50$ m, $A = 0.04 \times 10^{-6}$ m², $\rho = 3.2 \times 10^{-7}$ Ωm

To find: Resistance of wire (R)

Formula: $R = \rho \frac{l}{A}$

Calculation: Using formula,

$$R = \frac{3.2 \times 10^{-7} \times 50}{0.04 \times 10^{-6}} = \mathbf{400\ \Omega}$$

Ans: The resistance of the wire is **400 Ω.**

Example 5

A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6×10^{-7} m² and its resistance is measured to be 5 Ω. What is the resistivity of the material at the temperature of the experiment?

Solution:

Given: $l = 15$ m, $A = 6.0 \times 10^{-7}$ m², $R = 5\ \Omega$

To find: Resistivity (ρ)

Formula: $\rho = \frac{RA}{l}$

Calculation: Using formula,

$$\rho = \frac{5 \times 6 \times 10^{-7}}{15}$$

$\therefore \quad \rho = \mathbf{2 \times 10^{-7}\ \Omega m}$

Ans: The resistivity of the material at the temperature of the experiment is **2×10^{-7} Ωm**.

Example 6

A wire of circular cross-section and 30 ohm resistance is uniformly stretched until its new length is three times its original length. Find its resistance.

Solution:

Given: $R_1 = 30$ ohm, A_1 = original area,
l_1 = original length, l_2 = new length $\Rightarrow l_2 = 3l_1$

To find: Resistance of wire (R)

Formula: $R = \rho\dfrac{l}{A}$

Calculation: Using formula,

$$R_1 = \rho\frac{l_1}{A_1} \quad \text{....(1)}$$

$$R_2 = \rho\frac{l_2}{A_2} \quad \text{....(2)}$$

Dividing equation (1) by (2), we get,

$$\frac{R_1}{R_2} = \frac{\left(\rho\frac{l_1}{A_1}\right)}{\left(\rho\frac{l_2}{A_2}\right)}$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{l_1}{l_2}\cdot\frac{A_2}{A_1} \quad \text{....(3)}$$

The volume of wire remains the same in two cases.

∴ Original volume of wire = Volume of wire after stretching

i.e. $l_1A_1 = l_2A_2$

$$\therefore \quad \frac{A_2}{A_1} = \frac{l_1}{l_2} \quad \text{....(4)}$$

From equations (3) and (4) we get,

$$\frac{R_1}{R_2} = \frac{l_1}{l_2}\cdot\left(\frac{l_1}{l_2}\right)$$

$$\therefore \quad \frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2$$

$$\therefore \quad \frac{R_1}{R_2} = \left(\frac{l_1}{3l_1}\right)^2 \quad \text{....}(\because l_2 = 3l_1)$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{1}{9}$$

$\therefore \quad R_2 = 9R_1 = 9 \times 30 =$ **270 Ω**

Ans: The resistance of the wire is **270 Ω**.

Example 7

Calculate the resistance of 2.5 m length of the wire having 0.4 mm diameter and specific resistance 0.28×10^{-6} Ωm.

Solution:

Given: $l = 2.5$ m, d = 0.4 mm = 0.4×10^{-3} m $\Rightarrow r = \dfrac{d}{2} = \dfrac{0.4\times10^{-3}}{2} = 2 \times 10^{-4}$ m^2

$\rho = 0.28 \times 10^{-6}$ Ωm

To find: Resistance of wire (R)

Formula: $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$ ....($\because$ $A = \pi r^2$)

Calculation: Using formula,

$$R = \frac{0.28 \times 10^{-6} \times 2.5}{3.142 \times (2 \times 10^{-4})^2} = \frac{28 \times 2.5 \times 10^{-8}}{3.142 \times 4 \times 10^{-8}}$$

$$= \frac{7 \times 2.5}{3.142} = \mathbf{5.569\ \Omega}$$

Ans: The resistance of the wire is **5.569 Ω.**

Example 8

A resistance in the form of wire has length of 2.5 m and thickness 3 mm shows current of 400 mA for a potential difference of 9 volt. Calculate resistance in ohm and conductance in mho. Also calculate specific resistance of material of wire.

Solution:

Given: d = thickness = 3 mm = 1.5×10^{-3} m

$\therefore$ $r = \frac{d}{2} = \frac{3 \times 10^{-3}}{2}$ m = 1.5×10^{-3} Ωm

V = 9 V, l = 2.5 m, I = 400 mA = 400×10^{-3} A

To find: i. Resistance (R) ii. Conductance (G) iii. Specific resistance (ρ)

Formulae: i. $R = \frac{V}{I}$ ii. $G = \frac{1}{R}$

iii. $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$ ....($\because$ $A = \pi r^2$)

Calculation: Using formula (i),

$$R = \frac{9}{400 \times 10^{-3}} = \frac{90}{4} = \mathbf{22.5\ \Omega}$$

Using formula (ii),

$$G = \frac{1}{24} = \mathbf{0.0444\ mho}$$

Using formula (iii),

$$\rho = \frac{R\pi r^2}{l}$$

$$= \frac{22.5 \times 3.142 \times (1.5 \times 10^{-3})^2}{2.5}$$

$\therefore$ $\rho = \mathbf{6.4 \times 10^{-5}\ \Omega m}$

Ans: The resistance of the wire is **22.5 Ω**, its conductance is **0.0444 mho** and it has a specific resistance of **6.4 × 10^{-5} Ωm**.

Example 9

Find the resistivity and conductivity of a wire whose resistance is 0.01 Ω, length is 1.2 m and cross-sectional area is 1 mm^2.

Solution:

Given: R = 0.01 Ω, l = 1.2 m, A = 1 mm^2 = 1×10^{-6} m^2

To find: i. Resistivity (ρ) ii. Conductivity (σ)

Formulae: i. $R = \rho\frac{l}{A}$ ii. $\sigma = \frac{1}{\rho}$

Calculation: Using formula (i),

$$\rho = \frac{R \times A}{l} = \frac{0.01\times1\times10^{-6}}{1.2}$$

∴ $\rho = \mathbf{8.33 \times 10^{-9}\ \Omega\text{-m}}$

Using formula (ii),

$$\sigma = \frac{1}{\rho} = \frac{1}{8.33\times10^{-9}} = 0.12 \times 10^{9}\ (\Omega m)^{-1}$$

∴ $\sigma = \mathbf{1.2 \times 10^{8}\ (\Omega m)^{-1}}$

Ans: The resistivity of the material is **8.33×10^{-9} Ω-m** and its conductivity is **$1.2 \times 10^{8}\ (\Omega m)^{-1}$.**

1.2 Wheatstone's network

Wheatstone's network is a circuit used for accurate measurement of an unknown resistance. It was designed by British physicist Charles F. Wheatstone in 1843. Wheatstone's network is commonly referred as Wheatstone's bridge.

1.2.(a) Working principle and Balancing Condition:

i. Working principle:

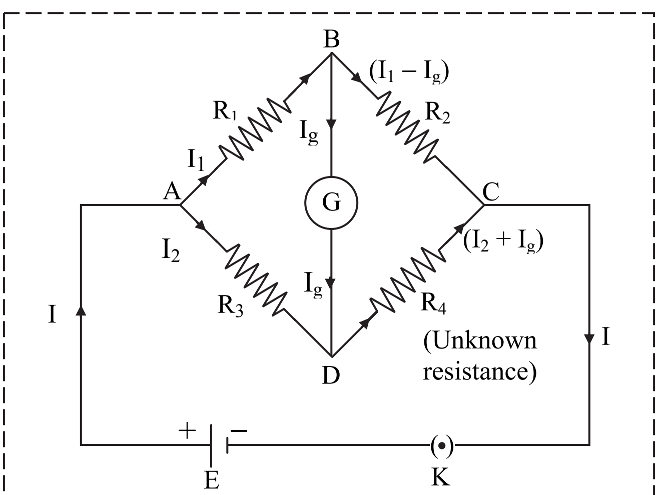
Four resistances are arranged to form a closed network. If we know the values of any three of them, then the value of the unknown resistance can be determined by using **Wheatstone's balancing condition** i.e. $\frac{R_1}{R_2} = \frac{R_3}{R_4}$.

ii. Construction of Wheatstone's bridge:

a. Wheatstone's bridge consists of four resistances R_1, R_2, R_3 and R_4 which are connected to form the four sides of quadrilateral ABCD.

b. A cell of e.m.f (E) and plug key (K) is connected in series across A and C.

c. A galvanometer (G) is connected between B and D as shown in figure.



iii. Balance condition of bridge:

a. The network is said to be balanced, if points B and D are equipotential, i.e., $V_B = V_D$. In this case, $I_g = 0$, i.e., current flowing through galvanometer must be zero.

b. Thus, in a balanced condition, even though current flows in the rest of the circuit, galvanometer will not show any deflection, i.e. it shows a null deflection.

In this position, $\frac{R_1}{R_2} = \frac{R_3}{R_4}$. This is called balancing condition of bridge.

iv. Proof for obtaining balancing condition:

a. In the network, R_1, R_2, R_3 are kept constant and R_4 is so adjusted that galvanometer shows zero deflection. The network is said to be balanced when the galvanometer shows zero deflection.

b. Balancing condition in Wheatstone's bridge can be obtained by using Ohm's law.

c. From figure, $V_B = V_D$

$\therefore$ $V_A - V_B = V_A - V_D$ ....(1) Subtracting V_A on both sides

$V_B - V_C = V_D - V_C$ ....(2) Subtracting V_C on both sides

Where, V_A, V_B, V_C and V_D are the potentials at points A, B, C and D respectively.

d. By applying Ohm's law to the resistances R_1, R_2 and R_3, R_4, we get,

$V_A - V_B = I_1R_1$, $V_B - V_C = I_1R_2$ and

$V_A - V_D = I_2R_3$, $V_D - V_C = I_2R_4$ ....($\because$ $I_g = 0$ at balancing condition)

e. Substituting these values in equation (1) and (2), we get,

$I_1R_1 = I_2R_3$ ....(3)

and $I_1R_2 = I_2R_4$ ....(4)

Dividing equation (3) by (4), we get,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

v. Calculating the unknown resistance:

a. From the balancing condition the unknown resistance R_4 can be calculated as follows:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

b. **Formula:** R_4 (unknown) $= \frac{R_3 \times R_2}{R_1}$

Note:

i. Measurement of resistance by Wheatstone's bridge method is not suitable for measuring very low and very high resistance in the circuit.

ii. By interchanging the position of galvanometer and cell, the balanced position of Wheatstone's bridge remains unchanged. Hence branches AC and BD are called conjugate arms.

iii. Accuracy of Wheatstone's bridge is maximum when each arm has equal resistance.

iv. The measurement of resistance by Wheatstone's bridge is not affected by the internal resistance of the cell.

Illustrative Examples:

Example 1

Coils of resistances 20 Ω, 30 Ω and 10 Ω are connected in the arms of PQ, QR and RS of Wheatstone's network respectively. Calculate the resistance of the coil that should be connected in arm PS of Wheatstone's network to balance the network.

Solution:

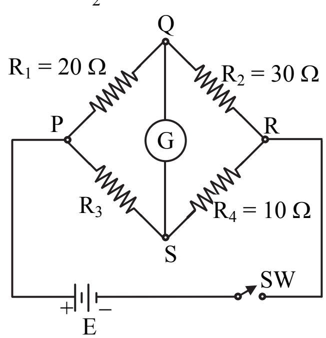
Given: $R_1 = 20\ \Omega$, $R_2 = 30\ \Omega$, $R_4 = 10\ \Omega$

To find: Unknown Resistance (R_3)

Formula: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Calculation: Using formula,

∴ $R_3 = \frac{R_1}{R_2} \times R_4 = \frac{20}{30} \times 10$



∴ $R_3 = \mathbf{6.67\ \Omega}$

Ans: The Resistance of coil that should be connected in arm AD is **6.67 Ω.**

Example 2

Resistances in Wheatstone's bridge are 30 Ω, 60 Ω, 15 Ω and a series combination of 5 Ω and X Ω. If the bridge is balanced, calculate value of X.

Solution:

Given: $R_1 = 30\ \Omega$, $R_2 = 60\ \Omega$, $R_3 = 15\ \Omega$,

$R_4 = (X + 5)\ \Omega$ ....(∵ X Ω and 5 Ω resistances are connected in series)

To find: Unknown resistance (X)

Formula: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Calculation: Using formula,

$\frac{30}{60} = \frac{15}{X+5}$

∴ $\frac{1}{2} = \frac{15}{X+5}$

∴ $X + 5 = 30$

∴ $X = \mathbf{25\ \Omega}$

Ans: The unknown resistance is **25 Ω**.

Example 3

Four resistances 4 Ω, 4 Ω, 4 Ω and 6 Ω form a Wheatstone's network. Find the resistance which when connected across the 6 Ω resistance, will balance the network.

Solution:

Given: $R_1 = R_2 = R_3 = 4\ \Omega$

To find: Resistance connected across 6 Ω resistance (X)

Formula: $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

Calculation: Let resistance connected across 6 Ω be X.

Equivalent resistance for 6 Ω and X in parallel is given by,

$$R_4 = \frac{6X}{6+X}$$

Using formula,

$$\frac{4}{4} = \frac{4}{\left(\frac{6X}{6+X}\right)}$$

$$\therefore \quad 1 = \frac{4(6+X)}{6X}$$

$$\therefore \quad 6X = 24 + 4X$$

$$\therefore \quad 2X = 24$$

$$\therefore \quad X = \mathbf{12\ \Omega}$$

Ans: The resistance connected across 6 Ω resistance to balance the network is **12 Ω**.

1.3 Potentiometer

*A **potentiometer** is an ideal instrument which is based on null deflection method to measure unknown e.m.f by comparing it with known e.m.f in the electric circuit.*

i. Principle:

The potential difference (V) between any two points of the potentiometer wire is directly proportional to the length (l) of the conducting wire between those two points.

$$V \propto l$$

OR

The fall of potential per unit length of potentiometer wire (potential gradient of wire) is constant.

OR

The potential difference between two points of conductive wire is directly proportional to the length/distance between the two points.

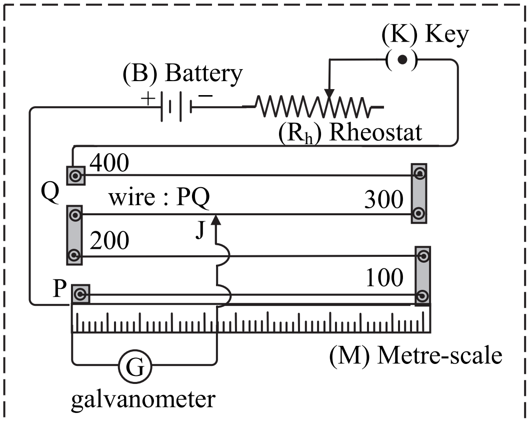
ii. Construction:

a. It consists of a number of segments of 2 m to 10 m wire PQ of uniform area of cross-section stretched over a wooden board between two thick copper strips as shown in figure.

b. Each segment of wire is 100 cm long. The wire is made of constantan or manganin.

c. A metre scale M is fixed parallel to its length. A battery B is connected across two end terminals which send current through the wire.

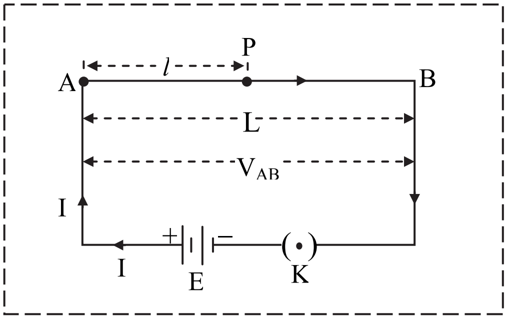
d. Current through potentiometer is kept constant by using a rheostat, R_h.



Note: The potentiometer is almost an ideal voltmeter.

iii. Working:

a. Suppose a potentiometer wire AB of length L and resistance R is stretched on the rectangular wooden board. The source of e.m.f E and negligible internal resistance is connected to the wire AB through a key K as shown in figure.



b. Resistance per unit length of wire AB is given by, $\sigma = \dfrac{R}{L}$

∴ $R = \sigma L$

c. Let V_{AB} be the P.D across the wire. There is uniform fall of potential along the wire from A to B.

d. By Ohm's law, the current I passing through the wire is given by,

$$I = \frac{V_{AB}}{R} = \frac{V_{AB}}{\sigma L}$$

e. Let P be any point on the wire, such that AP = l. The resistance of wire AP of length l is $R_{AP} = \sigma l$. So the potential difference V_{AP} between points A and P is given by,

$$V_{AP} = IR_{AP} = I\sigma l = \frac{V_{AB}}{\sigma L} \times \sigma\, l$$

$$V_{AP} = \left(\frac{V_{AB}}{L}\right).\, l$$

f. But, V_{AB} and L are constant.

∴ $V_{AP} \propto l$

Here, $\left(\dfrac{V_{AB}}{L}\right)$ is called the potential gradient (P.G.) of the wire.

g. ***Potential gradient** of a potentiometer wire is the fall or reduction of potential along the wire.*

Formula: Potential gradient = $\frac{V}{L}$ = K = constant

where, L = length of wire and V = Potential difference across wire

Note:

i. The potential gradient is given by,

$$K = \frac{V_{AP}}{l} = \frac{V_{AB}}{L} = I\sigma = \frac{IR}{L}$$

$$\therefore \quad K = \frac{I\rho L}{LA} = \frac{I\rho}{A}$$

where 'ρ' is resistivity of material of wire AB.

ii. Potential gradient of potentiometer remains unchanged by changing diameter of the wire and material of the wire and with any change effected in the secondary circuit.

iii. Value of potential gradient changes with change in primary circuit containing cell, rheostat and key. Its value is not uniform, if the cross-section of the wire is non-uniform.

iv. If 'r' is the internal resistance of source 'E' and 'R_E' is the external resistance of rheostat connected in the circuit, then the current through the circuit is given by,

$$I = \frac{E}{R + r + R_E}$$

Illustrative Examples:

Example 1

A potentiometer wire has a resistance per unit length 0.1 Ω/m. A cell of negligible internal resistance and e.m.f. 1.5 V balances against 450 cm length of the wire. Find the current through potentiometer wire.

Solution:

Given: $\sigma = 0.1\ \Omega/m$, E = 1.5 V, L = 450 cm = 450×10^{-2} m = 4.5 m,
$R_E = 0$, $r = 0\ \Omega$ ....($\because$ r = 0)

To find: Current through potentiometer wire (I)

Formulae: i. $\sigma = R/L$ ii. $I = E/R$

Calculation: Using formula (i),

$R = \sigma L = 0.1 \times 4.5 = 0.45\ \Omega$

Using formula (ii),

$I = \frac{1.5}{0.45}$ = **3.33 A**

Ans: The current through the potentiometer wire is **3.33 A.**

Example 2

A potentiometer wire has a length of 2 m and resistance of 20 Ω. It is connected in series with resistance 980 Ω and a cell of e.m.f 2 V and negligible internal resistance. Calculate the potential gradient along the wire.

Solution:

Given: L = 2 m, R = 20 Ω, R_E = 980 Ω, r = 0 Ω, E = 2 V

To find: Potential gradient along wire (K)

Formulae: i. $V = IR = \dfrac{ER}{R + R_E}$ ....($\because$ r = 0)

ii. $K = \dfrac{V}{L}$

Calculation: Using formula (i),

$$V = \frac{2 \times 20}{20 + 980} = \frac{40}{1000}$$

$V = 4 \times 10^{-2}$ volt

Using formula (ii),

$$K = \frac{4 \times 10^{-2}}{2}$$

$\therefore$ $\mathbf{K = 2 \times 10^{-2}\ V/m}$

Ans: The potential gradient along the wire is $\mathbf{2 \times 10^{-2}\ V/m}$.

1.3.(a) Applications of potentiometer:

a. To measure e.m.f. of a cell
b. To compare e.m.f.'s of two given cells.
c. To determine the internal resistance of a cell.
d. To measure potential difference (P.D.) across the required component accurately.

1.3.(b) Advantages of potentiometer over voltmeter:

a. The voltmeter is used to measure terminal P.D of cell while potentiometer is used to measure small terminal P.D as well as e.m.f. of the cell.
b. The accuracy of potentiometer can be easily increased by increasing the length of wire.
c. A small P.D can be measured accurately with the help of potentiometer. The resistance of voltmeter is high but not infinity to work as an ideal voltmeter.
d. The internal resistance of a cell can be measured with the help of potentiometer.
e. Potential difference across the wire is greater than E_1 or E_2 or $E_1 + E_2$.

1.3.(c) Disadvantages of potentiometer over voltmeter:

a. Voltmeter is portable whereas potentiometer is not portable and compact.
b. Voltmeter can be used to measure very high value of terminal potential difference but potentiometer cannot be used for higher values of potential difference.
c. Voltmeter gives direct reading but potentiometer does not give direct reading.

1.3.(d) Difference between potentiometer and voltmeter:

	Potentiometer	Voltmeter
i.	Its resistance is infinite.	Its resistance is high but finite.
ii.	It does not draw any current from the source of known e.m.f.	It draws some current from the source of e.m.f.
iii.	The potential difference measured by it is equal to actual potential difference.	The potential difference measured by it is less than the actual potential difference.
iv.	It has high sensitivity.	It has low sensitivity.

v.	It measures e.m.f as well as P.D.	It measures only P.D.
vi.	It is used to measure internal resistance of a cell.	It cannot be used to measure the internal resistance of a cell.
vii.	It is more accurate.	It is less accurate.
viii.	It does not give direct reading.	It gives direct reading.
ix.	It is not portable.	It is portable.
x.	It is used to measure lower voltage values only.	It is used to measure lower as well as higher voltage values.

Note:

i. A potentiometer is said to be more sensitive, if it measures a small potential difference more accurately.

ii. Sensitivity of potentiometer can be increased by decreasing potential gradient, increasing resistance of primary circuit and increasing length of wire.

iii. If the e.m.f of driver cell of potentiometer is less than e.m.f's of other cells connected in the circuit, then the null point is obtained beyond the length of potentiometer wire.

iv. The terminal potential difference across a cell decreases as more current is drawn from the cell.

v. The internal resistance of the cell depends on the area of the plates, separation between the plates, concentration of the electrolyte and temperature.

1.4 Condensers or capacitors

i. ***Condenser** is a system consisting of two conductors having equal and opposite charges separated by an insulator or dielectric.*

ii. A condenser acts as a small reservoir of energy.

iii. A condenser does not condense energy, but it can store it.

iv. The electric field in the region between two conductors is proportional to magnitude of electric charge.

1.4.(a) Capacity of a condenser or capacitance:

i. *The ability of a condenser to store the electric charge is called **capacity of condenser** or **capacitance**.*

ii. When the charges on a conductor are increased, its potential difference also increases.
Thus, charge Q is directly proportional to the potential difference V of the conductor.
i.e. $Q \propto V \Rightarrow Q = CV$

Formula: $C = \frac{Q}{V}$

where, C = constant of proportionality called capacity of condenser

iii. Thus, ***capacity** of a condenser or capacitance is the ratio of magnitude of charge to the magnitude of potential difference across it.*

iv. **Unit:** Its SI unit is farad.

v. *The capacity or capacitance of a condenser is said to be **1 farad** if the potential difference across it rises by 1 volt, when 1C charge is given to it.*
If Q = 1 C, V = 1 volt then C = 1 F

$\therefore \quad 1\text{ F} = \frac{1\text{ C}}{1\text{ V}}$

Note:

i. Other units of capacity of condenser are microfarad (μF), nanofarad (nF), picofarad (pF).
$1\ \mu F = 10^{-6}\ F$, $1\ nF = 10^{-9}\ F$, $1\ pF = 10^{-12}\ F$

ii. The electric field in the region between two conductors is proportional to magnitude of electric charge.

Illustrative Example:

The potential difference of 40 volt is applied across a condenser of capacitance 30 μF. Calculate the charge on the plates.

Solution:

Given: $V = 40\ V$, $C = 30\ \mu F = 30 \times 10^{-6}\ F$

To find: Charge on plates (Q)

Formula: $C = \dfrac{Q}{V}$

Calculation: Using formula,

$Q = C \times V = (30 \times 10^{-6}) \times 40$

$Q = 1200 \times 10^{-6}\ C$ or $Q = \mathbf{1200\ \mu C}$ ....($\because 10^{-6}\ C = 1\ \mu C$)

Ans: The charge on the plates of the condenser is **1200 μC.**

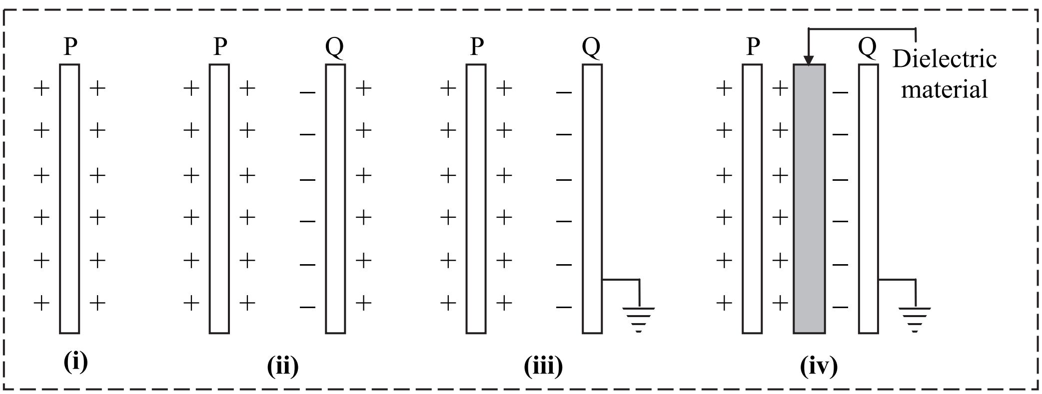
1.4.(b) Principle of Condenser:

i. A condenser consists of two closely placed conductors to increase their capacitance.

ii. Consider a metal plate P having positive charge Q on it. Let V_1 be its potential due to charge Q. (see figure i)

$\therefore$ $C_1 = \dfrac{Q}{V_1}$, where C_1 is the capacitance of a metal plate P.

iii. Now, to increase the capacitance, the potential V of the plate P must be lowered.



In order to achieve this, another metal plate Q is brought near P (see figure ii). The positive charge on P induces a negative charge on inner side of Q and positive charge on outer side. The positive charges on P hold the negative charges on Q. Hence, potential of P decreases to V_2 and its capacitance increases to C_2.

$\therefore$ $C_2 = \dfrac{Q}{V_2}$

iv. Now, plate Q is earthed (Earth is supposed to be at zero potential). Free positive charges on outer side of Q move to earth but negative charges on Q are held by positive charges on P and remain on the metal plate. (see figure iii)
Due to absence of positive charges on plate 'Q', effective potential of plate P further reduces to V_3 thus increasing the capacitance to C_3.

$\therefore \quad C_3 = \dfrac{Q}{V_3}$

v. Now, if a slab or sheet of a dielectric material like mica is introduced between P and Q, capacitance of P increases to C_4. (see figure iv) It is observed that at every stage, capacitance of plate P increases to C_4 for the arrangement shown in figure (d). Such an arrangement is called condenser.

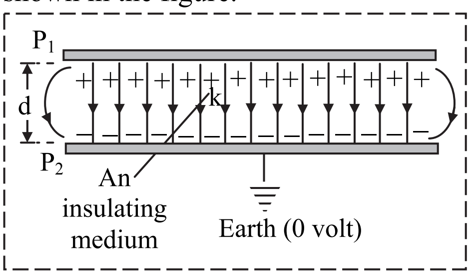
Note: ***Dielectric*** *is a non-conducting substance which when subjected to an external electric field sets up an opposing electric field within it.* This field reduces the electric field within the dielectric.
e.g., Mica, ceramics, glass, mineral oil etc.

1.4.(c) Capacity of a Parallel plate condenser:

i. Expression for capacity of a parallel plate condenser:

a. A parallel plate capacitor consists of two parallel metal plates P_1 and P_2 separated by a small distance 'd'. (see figure).

b. The space between the plates is filled with a medium of dielectric constant k as shown in the figure.



c. Plate P_1 is given a charge +Q while plate P_2 is earthed.

d. Positive charge +Q which is given to plate P_1 induces a negative charge –Q on the inner surface of plate P_2. Positive charge on the outer side of plate P_2 will get earthed because of production of electrostatic repulsive force between two positive charges.

e. As distance 'd' between the two plates is very small as compared to the linear dimensions of the plates, the electric field is produced in the dielectric medium. This field is directed from P_1 to P_2.

f. Magnitude of the electric intensity at a point in the dielectric medium is given by,

$$E = \frac{\sigma}{k\varepsilon_0} \qquad \text{....(1)}$$

where, σ is the magnitude of the surface charge density on either plate.

But, $\sigma = \dfrac{Q}{A}$

$$\therefore \quad E = \frac{Q}{k\varepsilon_0 A} \qquad \text{....(2)}$$

Formulae: i. $C_S = \frac{C_1 C_2}{C_1 + C_2}$

ii. $C_S = \frac{Q}{V}$

Calculation: Using formula (i),

$$C_S = \frac{C_1 C_2}{C_1 + C_2} = \frac{0.5 \times 1.5}{0.5 + 1.5}$$

$= \mathbf{0.375\ \mu F}$

Using formula (ii),

$Q = C_S \times V$

$= 0.375 \times 10^{-6} \times 12$

$= 4.5 \times 10^{-6}$ C

$= \mathbf{4.5\ \mu C}$

Ans: i. The resultant capacitance is **0.375 μF.**

ii. The charge on each condenser is **4.5 μC.**

---

21. Three condensers of capacitance 6 μF, 12 μF and 16 μF are connected in series. A potential difference of 220 volt is applied to the combination. How much charge will be drawn across the capacitors? [S-15] [4 M]

Solution:

Given: $C_1 = 6\ \mu F = 6 \times 10^{-6}$ F,

$C_2 = 12\ \mu F = 12 \times 10^{-6}$ F,

$C_3 = 16\ \mu F = 16 \times 10^{-6}$ F,

V = 220 volt

To find: Charge drawn (Q)

Formulae: i. $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

ii. $C = \frac{Q}{V}$

Calculation: Using formula (i),

$$\frac{1}{C_S} = \frac{1}{6} + \frac{1}{12} + \frac{1}{16}$$

$$= \frac{8+4+3}{48}$$

$$\therefore \quad \frac{1}{C_S} = \frac{15}{48}$$

$$\therefore \quad C_S = \frac{48}{15} = 3.2\ \mu F$$

Using formula (ii),

$Q = C_S V$

$= 3.2 \times 10^{-6} \times 220$

$= 704 \times 10^{-6}$ C

$\therefore$ Q = **704 μC**

Ans: The charge drawn across the capacitor will be **704 μC**.

---

22. Two condensers of capacitances of 15 μF and 10 μF are connected in parallel and connected to a battery of 12 V. Find the resultant capacitance and charge on each condenser. [S-07, 12] [4 M]

Solution:

Given: $C_1 = 15\ \mu F = 15 \times 10^{-6}$ F,

$C_1 = 10\ \mu F = 10 \times 10^{-6}$ F,

V = 12 V

To find: i. Resultant capacitance (Rp)

ii. Charge on each condenser (Q_1, Q_2)

Formulae: i. $C_P = C_1 + C_2$

ii. $C_P = \frac{Q}{V}$

Calculation: Using formula (i),

$C_P = C_1 + C_2 = 15\ \mu F + 10\ \mu F$

$= \mathbf{25\ \mu F}$

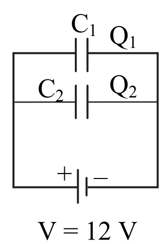
In parallel connection, the voltage across each capacitor is same.

Using formula (ii),

$V_1 = V_2 = 12$ V

Q = CV

$\therefore$ $Q_1 = C_1 V$ and $Q_2 = C_2 V$



$\therefore$ $Q_1 = 15 \times 10^{-6} \times 12$
$= 180 \times 10^{-6}$C or **180 μC**
$Q_2 = 10 \times 10^{-6} \times 12$
$= 120 \times 10^{-6}$C or **120 μC**

Ans: i. The resultant capacitance is **25 μF**.
ii. The charges on condensers are **180 μC** and **120 μC.**

---

23. Show that the total equivalent capacity of parallel combination of two identical condensers is four times their equivalent capacity of series combination. [W-12] [4 M]

Solution:

Let capacities of two condensers be C_1 and C_2

$\therefore$ $C_1 = C_2 = C$ μF

For condensers in parallel combination,
The equivalent capacitance,

$C_P = C_1 + C_2 = C + C = 2C$ μF ....(i)

For condensers in series combination,
The equivalent capacitance,

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{C} + \frac{1}{C}$$

$$\therefore \quad \frac{1}{C_S} = \frac{2}{C}$$

$$\therefore \quad C_S = \frac{C}{2} \qquad ....(ii)$$

From equations (i) and (ii),

$C_P = 4 \times C_S$

$\therefore$ Total equivalent capacity of parallel combination of two identical condensers is four times their equivalent capacity of series combination.

---

24. Two condensers have an equivalent capacity of 12 μF when connected in parallel and 2.25 μF when connected in series. Calculate their individual capacitances. [S-08, 11] [4 M]

Solution:

Given: $C_P = 12$ μF,
$C_S = 2.25$ μF

To find: Individual capacitances (C_1, C_2)

Formula: $C_S = \dfrac{C_1 C_2}{C_1 + C_2}$

Calculation:

Using formula,

$C_P = C_1 + C_2 = 12$ μF ....(1)

For the series combination,

$$C_S = \frac{C_1 C_2}{C_1 + C_2} = 2.25 \text{ μF} \qquad ....(2)$$

Substitute Equation (1) in (2)

$$C_S = \frac{C_1 C_2}{12 \text{ μF}} = 2.25 \text{ μF}$$

$\therefore$ $C_1 C_2 = 2.25 \times 10^{-6} \times 12 \times 10^{-6}$

$\therefore$ $C_1 C_2 = 27 \times 10^{-12}$ ....(3)

But $C_1 + C_2 = 12 \times 10^{-6}$

$\therefore$ $C_1 = (12 \times 10^{-6} - C_2)$

Substitute this into Equation (3) to get,

$(12 \times 10^{-6} - C_2) C_2 = 27 \times 10^{-12}$

Solving we get,

$C_2 = 9 \times 10^{-6}$ F or $\mathbf{3 \times 10^{-6}}$ **F**

and $C_1 = 3 \times 10^{-6}$ F or $\mathbf{9 \times 10^{-6}}$ **F**

Ans: The individual capacitance are **3 μF** and **9 μF.**

Additional Theory Questions

1. Distinguish between resistance and conductance.

Ans: *Refer 1.1.(b):(iv)*

2. Distinguish between resistivity and conductivity.

Ans: *Refer 1.1.(b):(vii)*

3. Distinguish between series combination of condensers and parallel combination of condensers.

Ans: *Refer 1.5.(c)*

4. State the applications of condensers.

Ans: *Refer 1.4.(g)*

5. Distinguish between voltmeter and potentiometer.

Ans: *Refer 1.3.(d)*

Problems for Practice

1. A 2 m long copper wire has diameter 0.45 mm. If its resistance is 0.2 Ω, calculate its resistivity and conductivity.

2. Calculate the resistance of a wire of 4 m length and cross-sectional area of 0.05×10^{-6} m^2 and having resistivity 2.5×10^{-7} Ωm.

3. A current of 1.2 A flows through a resistance of 50 Ω. Calculate voltage across it.

4. An electric heater draws a current of 2 A when connected across 220 V supply. What current will it draw when connected across 110 V supply?

5. Four resistances in the Wheatstone's network are 4 Ω, 12 Ω, X Ω, and 6 Ω respectively in the cyclic order. Calculate the value of R_3 to get null deflection in the galvanometer (to balance the network).

6. Coils of resistances 10 Ω, 30 Ω and 24 Ω are connected in the arms PQ, QR and RS of Wheatstone's network respectively. Calculate the resistance of the coil that should be connected in arm PS of Wheatstone's network to balance the network.

7. A battery of e.m.f. 9 V is connected across a potentiometer wire of 6 m, length. Calculate the potential gradient (P.G.) along the wire (neglect internal resistance of cell).

8. A potential gradient along a potentiometer wire is 0.04 V/cm. Calculate P.D. across a potentiometer wire of length 8 m.

9. A charge of 3 μC raises the potential of a capacitor by 30 V. Calculate its capacitance.

10. Calculate the potential difference across a capacitor of capacitance 200 μF, having its charge 500 μC on its plates.

11. A current of 120 mA flows through a conductor for 15 second. Calculate the charge flowing through it.

12. A wire of circular cross-section and 20 ohm resistance is uniformly stretched until its new length is two times its original length. Find its resistance.

13. An electric iron draws a current of 2.5 A when connected across 220 volt supply. What current will it draw when connected across 440 volt supply?

14. Calculate the resistance of 40 m length of the wire having cross-sectional area of 0.04×10^{-6} m^2 and having resistivity 2.8×10^{-7} Ωm.

15. Calculate the resistance of 2.5 m length of wire having diameter 0.4 mm and specific resistance 0.28×10^{-6} Ωm.

16. Coils of resistances 60 Ω, 80 Ω and 20 Ω are connected in the arms of AB, BC and CD of Wheatstone's network respectively. Calculate the resistance of the coil that should be connected in arm AD of Wheatstone's network to balance the network.

17. Obtain the relation between the equivalent capacities of two identical condensers connected in series and in parallel.

18. Area of parallel plate condenser is 2×10^{-4} and distance between the two plates is 4 mm. The dielectric constant is 4. Calculate the capacitance of the condenser.

19. Two condensers have an equivalent capacity of 25 μF when connected in parallel and 6 μF when connected in series. Calculate their individual capacitances.

20. Four capacitors are of the same capacity. If three of them are connected in parallel and the remaining one is connected in series with this combination, the resultant capacity is 3.75 μF. Find the capacity of each capacitor.

21. Two condensers of capacitances of 42 μF and 84 μF are connected in parallel and connected to a battery of 15 V. Find the resultant capacitance and charge on each condenser.

22. A resistance in the form of wire has length of 5 m and thickness 1.5 mm shows current of 600 mA for a potential difference of 10 volt. Calculate resistance in ohm and conductance in mho. Also calculate specific resistance of material of wire.

23. Calculate the resistance of 2.8 m length of wire having diameter 0.4 mm and specific resistance 0.42×10^{-6} Ωm.

Answers to Practice Problems

1. 1.6×10^{-8} Ωm, 6.3×10^{7} s/m
2. 20 Ω
3. 60V
4. 1 A
5. 18 Ω
6. 8 Ω
7. 0.015 V/cm
8. 32 V
9. 0.1 μF
10. 2.5 V
11. 1.8 C
12. 80 Ω
13. 5A
14. 280 Ω
15. 5.569 Ω
16. 15 Ω
17. $C_p = 4 \times C_S$
18. 1.78 n F
19. 15 μF and 12 μF
20. 5 μF
21. 126 μF, 630 μC, 1260 μC
22. 16.67 Ω, 0.0599 mho, 6.292 Ωm
23. 9.36 Ω