MASS PHYSICS

CBSE-CUET & NEET -JEE CLASSES BY PRABHAKAR SIR

Welcome to the introduction to Class XII Mass Physics notes specifically designed for CUET (Central University entrance test) and quick revision of full syllabus of class XII physics. These notes aim to provide you with a comprehensive overview of the key concepts and topics covered in the Class XII Physics syllabus.

Class XII Physics is a crucial subject for engineering and technology aspirants, as it lays the foundation for understanding various principles and applications of physics. CUET, being a renowned exam for various Bachelor courses , expects students to have a strong grasp of the Class XII Physics syllabus.

MASS PHYSICS

CBSE-CUET & NEET-JEE CLASSES BY PRABHAKAR SIR

Physics Revision Notes CBSE/CUET

Each section of the syllabus has been condensed into concise summaries, highlighting the most crucial aspects that are likely to appear in your exams. By utilizing these notes, you will be able to revise the entire syllabus efficiently, saving time and ensuring that you focus on the most important concepts.

The revision notes cover topics such as:

Electric Charges and Fields
Electrostatic Potential and Capacitance
Current Electricity
Magnetic Effects of Current
Magnetism and Matter
Electromagnetic Induction
Alternating Currents
Electromagnetic Waves
Ray Optics and Optical Instruments
Wave Optics
Dual Nature of Radiation and Matter
Atoms
Nuclei
Semiconductor Electronic Devices
Communication Systems

These notes are designed by Mass Physics to serve as a valuable resource during your revision, providing you with a quick refresher on important concepts, key formulas, and problem-solving techniques.

I wish you the best of luck with your Class XII Physics revision and upcoming examinations. May these revision notes serve as a valuable tool to reinforce your understanding and boost your performance in both the CBSE board exams and the CUET. Happy studying!

NTA CUET : Exam Pattern

The CUET exam pattern 2023 has been released along with the syllabus by NTA. Candidates interested in taking the exam need to be familiar with the structure and format of the entrance test. This helps in understanding the question paper better and performing well in the exam.

The exam pattern of CUET 2023 comprises the nature/ type of questions, total number of questions, total marks, marking scheme, medium of instructions etc. All the important information involving the CUET exam pattern has been shared below:

Particulars

Details

Exam Name

CUET

Full Name

Common Universities Entrance Test

Medium of Instructions

Bi-lingual (English & one of the 13 languages chosen by the aspirant)

Total Questions Asked in Physics -50

Total Questions to be Attempted in Physics -40

Maxmimum Marks in Physics - 200

Question Type-MCQs

Exam Duration of Physics -45 minutes

Frequency of Exam-Once a year

Negative Marking -Applicable

Marking Scheme

Marks per correct attempt: +5

Marks per incorrect attempt: -1

Marks per unanswered & marked for review question: 0

Scheme of Examination

Subject combinations for each paper, type of questions in each paper, and mode of examination are given in the table below:

Section	Subjects/ Tests	Questions to be Attempted
Section 1A - Languages	There are **13** different languages. Any of these languages may be chosen.	40 questions to be attempted out of 50 in each language.
Section 1B - Languages	There are **20** Languages. Any of these languages may be chosen.	
Section 2 - Domain	There are **27** Domains specific subjects being offered under this section. A candidate may choose any subject as desired by the applicable University/ Universities.	**35/40** Questions to be attempted out of **45/50.**
Section 3 - General Test	For any such undergraduate programme / programmes being offered by Universities where a General Test is being used for admission.	**50 Questions to be attempted out of 60**

Note:

1. *From the above subjects / languages, the* ***candidate can choose maximum of 10 subjects from all three Sections.***
2. ***Examination will be conducted on multiple days in three shifts, depending on the number of Candidates and Subject choices.***

MASS INSTITUTE
CUSTOMIZED CLASSES FOR SCIENCE STUDENTS

Introducing Mass Institute: Your Path to Success in CUET Exam for Delhi University!
Are you aspiring to crack the CUET exam for admission to Delhi University? Look no further than Mass Institute, your trusted coaching partner for Physics, Chemistry, Mathematics, and Biology.
Why Choose Mass Institute?

Experienced Faculty: At Mass Institute, we have a team of highly experienced and qualified faculty members who specialize in their respective subjects. Our dedicated educators have a deep understanding of the CUET exam pattern and syllabus, ensuring that you receive top-notch guidance and instruction.

Comprehensive Course Coverage: Our coaching programs cover all the essential topics and concepts prescribed in the CUET syllabus. Whether it's Physics, Chemistry, Mathematics, or Biology, we leave no stone unturned in ensuring that you have a strong foundation in each subject.

Customized Study Materials: Mass Institute provides meticulously crafted study materials that are specifically designed to meet the requirements of the CUET exam. Our comprehensive notes, practice questions, and mock tests will enhance your understanding, boost your confidence, and prepare you to tackle any challenge that comes your way.

Problem-Solving Approach: We emphasize a problem-solving approach to help you develop critical thinking and analytical skills. Through regular practice sessions and problem-solving workshops, you'll become adept at tackling complex questions and optimizing your performance in the CUET exam.

Regular Assessments and Feedback: To monitor your progress, we conduct regular assessments and provide detailed feedback on your performance. This feedback helps identify your strengths and weaknesses, enabling us to tailor our coaching to meet your specific needs and maximize your potential.

Exam-focused Coaching: Mass Institute's coaching programs are designed to align with the CUET exam pattern and time constraints. We provide extensive practice with previous years' question papers and conduct mock tests to familiarize you with the exam environment, improve time management skills, and boost your confidence.

Personalized Attention: We understand that each student has unique requirements and learning styles. Our small batch sizes allow us to provide individual attention to every student, clarifying doubts, and providing personalized guidance for their academic journey.

Success Track Record: Over the years, Mass Institute has consistently produced remarkable results in the CUET exam. Our students have secured top ranks and gained admission to prestigious colleges at Delhi University, paving the way for their successful academic and professional careers.

Don't miss the opportunity to join Mass Institute, where we empower you with the knowledge, skills, and confidence to excel in the CUET exam. Enroll with us and embark on your journey towards a successful future in Delhi University!
Contact us at 9818033370 or visit our website www.massphysics.com for more information and to enroll in our coaching programs. Limited seats available, so act fast!

MASS INSTITUTE
CUSTOMIZED CLASSES FOR SCIENCE STUDENTS

राष्ट्रीय परीक्षा एजेंसी
National Testing Agency
Excellence in Assessment

ज्ञान-विज्ञान विमुक्तये
University Grants Commission

COMMON UNIVERSITY ENTRANCE TEST (UNDERGRADUATE)

PHYSICS-322

Syllabus of Class 12

PHYSICS-322

Note:

There will be one Question Paper which will have 50 questions out of which 40 questions need to be attempted.

PHYSICS

Unit I: Electrostatics

Electric charges and their conservation. Coulomb's law – force between two point charges, forces between multiple charges; superposition principle, and continuous charge distribution.

Electric field, electric field due to a point charge, electric field lines; electric dipole, electric field due to a dipole; torque on a dipole in a uniform electric field.

Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet, and uniformly charged thin spherical shell (field inside and outside).

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, the electrical potential energy of a system of two point charges, and electric dipoles in an electrostatic field.

Conductors and insulators, free charges, and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, the combination of capacitors in series and in parallel, the capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor, Van de Graaff generator.

Unit II: Current Electricity

Electric current, the flow of electric charges in a metallic conductor, drift velocity and mobility, and their relation with electric current; Ohm's law, electrical resistance, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity.

Carbon resistors, colour code for carbon resistors; series and parallel combinations of resistors; temperature dependence of resistance.

The internal resistance of a cell, potential difference, and emf of a cell, combination of cells in series and in parallel.

Kirchhoff 's laws and simple applications. Wheatstone bridge, metre bridge.

Potentiometer – principle, and applications to measure potential difference, and for comparing emf of two cells; measurement of internal resistance of a cell.

Unit III: Magnetic Effects of Current and Magnetism

Concept of the magnetic field, Oersted's experiment. Biot - Savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire, straight and toroidal solenoids. Force on a moving charge in uniform magnetic and electric fields. Cyclotron.

Force on a current-carrying conductor in a uniform magnetic field. The force between two parallel current-carrying conductors – definition of ampere. Torque experienced by a current loop in a magnetic field; moving coil galvanometer – its current sensitivity and conversion to ammeter and voltmeter.

Current loop as a magnetic dipole and its magnetic dipole moment. The magnetic dipole moment of a revolving electron. Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis. Torque on a magnetic dipole (bar magnet) in a uniform magnetic field; bar magnet as an equivalent solenoid, magnetic field lines; Earth's magnetic field and magnetic elements.

Para-, dia- and ferromagnetic substances, with examples. Electromagnets and

factors affecting their strengths. Permanent magnets.

Unit IV: Electromagnetic Induction and Alternating Currents

Electromagnetic induction; Faraday's law, induced emf and current; Lenz's Law, Eddy currents. Self and mutual inductance.

Alternating currents, peak and rms value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits, wattless current. AC generator and transformer.

Unit V: Electromagnetic Waves

Need for displacement current. Electromagnetic waves and their characteristics (qualitative ideas only). Transverse nature of electromagnetic waves.

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, x-rays, gamma rays) including elementary facts about their uses.

Unit VI: Optics

Reflection of light, spherical mirrors, mirror formula. Refraction of light, total internal reflection, and its applications, optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula. Magnification, power of a lens, combination of thin lenses in contact combination of a lens and a mirror. Refraction and dispersion of light through a prism.

Scattering of light–blue colour of the sky and reddish appearance of the sun at sunrise and sunset.

Optical instruments: Human eye, image formation, and accommodation, correction of eye defects (myopia and hypermetropia) using lenses.

Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

Wave optics: Wavefront and Huygens' principle, reflection, and refraction of plane wave at a plane surface using wavefronts.

Proof of laws of reflection and refraction using Huygens' principle.

Interference, Young's double hole experiment and expression for fringe width, coherent sources, and sustained interference of light.

Diffraction due to a single slit, width of central maximum.

Resolving the power of microscopes and astronomical telescopes. Polarisation, plane polarised light; Brewster's law, uses of plane polarised light and Polaroids.

Unit VII: Dual Nature of Matter and Radiation

Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation – particle nature of light.

Matter waves – wave nature of particles, de Broglie relation. Davisson-Germer experiment (experimental details should be omitted; only the conclusion should be explained.)

Unit VIII: Atoms and Nuclei

Alpha - particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum. Composition and size of nucleus, atomic masses, isotopes, isobars; isotones.

Radioactivity – alpha, beta, and gamma particles/rays, and their properties; radioactive decay law. Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission and fusion.

Unit IX: Electronic Devices

Energy bands in solids (qualitative ideas only), conductors, insulators, and semiconductors; semiconductor diode – *I-V* characteristics in forward and reverse bias, diode as a rectifier; *I-V* characteristics of LED, photodiode, solar cell, and Zener diode; Zener diode as a voltage regulator. Junction transistor, transistor action, characteristics of a transistor; transistor as an amplifier (common emitter configuration) and oscillator. Logic gates (OR, AND, NOT, NAND and NOR). Transistor as a switch.

Unit X: Communication Systems

Elements of a communication system (block diagram only); bandwidth of signals (speech, TV, and digital data); bandwidth of transmission medium. Propagation of electromagnetic waves in the atmosphere, sky, and space wave propagation. Need for modulation. Production and detection of an amplitude-modulated wave.

CHAPTER 1

Electric Charges and Fields

Coulomb's law, electrostatic field and electric dipole

Electric Charge

- Electrostatic charge is a fundamental property of matter due to which it produces and experiences electrical and magnetic effects.
- Properties of atoms, molecules and bulk matter are determined by electric and magnetic forces.
- It can be inferred from simple experiments based on frictional electricity that there are two type of charges in nature: negative and positive; and like charges repel and unlike charges attract.
- By convention, the charge on electron is considered as negative and the charge on proton is considered as positive and the charge present is equal. The S.I. unit of electric charge is coulomb. Its C.G.S unit is stat coulomb.
- The nature and amount of electric charge present in a charged body is detected by Gold-leaf electroscope.
- Total charge on a body is expressed as $q = \pm ne$.

Conductors and Insulators

- Objects that allow charges to flow through them are called Conductors (metals) and objects that do not allow charges to flow through are called Insulators (rubber, wood, and plastic).
- Objects that behave as an intermediate between conductors and insulators are called semi-conductors, for example- silicon.
- The process of sharing charges with the earth, when we bring a charged body in contact with the earth is called grounding or earthing.

Charging by Induction

- Charging by induction means charging without contact.
- If a plastic comb is rubbed with wool, it becomes negatively charged.

Three basic properties of electric charge

- **Quantization:** When the total charge of a body is an integral multiple of a basic quantum of charge, this is known as quantization of electric charge. i.e., $q = ne$ where
  $n = \pm 1, \pm 2, \pm 3, ...$
- **Additivity:** It means that the total charge of a system is the algebraic sum (adding taking into account negative and positive signs both) of all the charges in the system.
- **Conservation of charge:** Conservation of electric charges means that there will be no change in the total charge of the isolated system with time. There is transfer of the electric charge from one body to another, but no charge will be created or destroyed.

Coulomb's law

The force between two point charges q_1 and q_2 is directly proportional to the product of the two charges(q_1q_2) and inversely proportional to the square of the distance between them$(r^2)$and it acts along the straight line joining the two charges.

F_{21} = force on q_2 due to q_1 $= \dfrac{k\left(q_1q_2\right)}{r^2_{21}}\hat{r}_{21}$

where $k = \dfrac{1}{4\pi\varepsilon_0}$

The experimental value of the constant ε_0 is

$8.854 \times 10^{-12} C^2N^{-1}m^{-2}$

Therefore, the approximate value of k is

$9 \times 10^9 Nm^2C^{-2}$

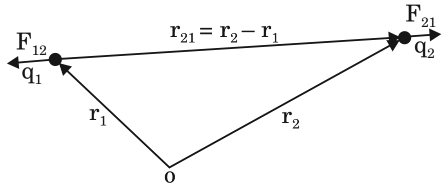


Fig. Depiction of Coulomb's law

Facts about Coulomb's law:

- Coulomb's law is not valid for charges in motion; it should only be used for point charges in vacuum at rest.
- The electrostatic force obeys Newton's third law of motion and acts along the line joining the two charges.
- Presence of other charges in the neighborhood does not affect Coulomb's force.
- The ratio of electric force and gravitational force between a proton and an electron is represented by $\frac{k e^2}{G m_e m_p} \cong 2.4 \times 10^{39}$

Superposition Principle

The presence of an (or more) additional charge does not affect the forces with which two charges attract or repel each other. Superposition principle states that the net force on any charge due to n number of charges at rest is the vector sum of all the forces on that charges, taken one at a time.

i.e. $\vec{F}_0 = \vec{F}_{01} + \vec{F}_{02} + \vec{F}_{03} + ..\vec{F}_{0n}$

- The force on a small positive test charge q placed at the point divided by the magnitude of the charge is the electric field E at a point due to charge configuration.

Electric Field

- The space around a charge up to which its force can be experienced is called electric field.
- Electric field due to a point charge q has a magnitude $E(r) = \frac{q}{4\pi\varepsilon_0 r^2}\hat{r}$
  - ➢ It is radially outwards if q is positive.
  - ➢ It is radially inwards if q is negative.
- Electric field satisfies the superposition principle.
  - ➢ The unit of electric field is N/C.
  - ➢ Electric field inside the cavity of a charged conductor is zero.

Electric Field lines

- The tangent at each point on the curve of electric field line, gives the direction of electric field at that point.
- The relative strength of electric field at different points is indicated by the relative closeness of field lines.
  - ➢ In regions of strong electric field, they crowd near each other.
  - ➢ In regions of weak electric field, they are far apart.
  - ➢ In regions of constant electric field, the field lines formed are uniformly spaced parallel straight lines.
- Field lines are continuous curves. There will be no breaks.

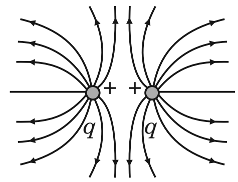


Fig. Electric field lines

- Field lines are not intersecting. They cannot cross each other.
- Electrostatic field lines begin at positive charges and terminate at negative charges.
- No closed loop can be formed by them.

Electric Dipole

- A pair of equal and opposite charges q and –q separated by small distance 2a is known as electric dipole. The magnitude of its dipole moment vector is 2qa and is in the direction of the dipole axis from –q to q.

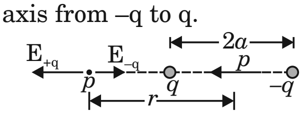


Fig. Electric dipole

- Field of an electric dipole in its equatorial plane at a distance r from the center:

$$E = \frac{-p}{4\pi\varepsilon_o}\frac{1}{\left(a^2 + r^2\right)^{3/2}}$$

$$\cong \frac{-p}{4\pi\varepsilon_o r^3} \qquad \text{for } r >> a$$

- Dipole electric field on the axis at a distance r from the center:

$$E = \frac{2pr}{4\pi\varepsilon_o\left(r^2 - a^2\right)^2}$$

$$\cong \frac{2p}{4\pi\varepsilon_o r^3} \qquad \text{for } r >> a$$

The $1/r^3$ dependence of dipole electric fields should be noted in contrast to the $1/r^2$ dependence of electric field due to a point charges.

- In a uniform electric field E, a dipole experiences a torque τ given by

$\tau = p \times E$

But no net force will be experienced by it.

Electric Flux

- Electric flux is proportional to number of lines leaving a surface, outgoing lines with positive sign, incoming lines with negative sign.

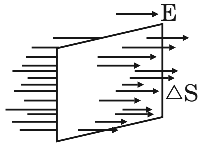


Fig. Electric flux

- Through a small area element ΔS, the flux $\Delta\phi$ of electric field E is given by

$\Delta\phi = \vec{E} . \vec{\Delta S}$

And the vector area element ΔS is

$\vec{\Delta S} = \Delta S \hat{n}$

Where ΔS is the magnitude of the area element and $\hat{n}$ is normal to the area element, which can be considered planar for the sufficiently small ΔS.

Gauss's Law and its application

- The flux of electric field through any closed surface S is $1/\varepsilon_0$ times the total charge enclosed by S.

$$\phi = E\int dA = \frac{q_{enclosed}}{\varepsilon_0}$$

- The law is mainly useful in determining electric field E, when the source distribution has simple symmetry:
  - ➢ Thin infinitely long straight wire of uniform linear charge density λ

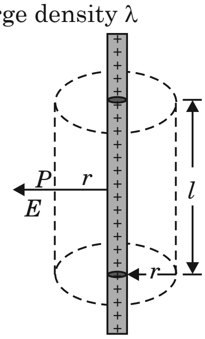


Fig. Thin infinitely long Straight wire

$$E = \frac{\lambda}{2\pi\varepsilon_o r}\hat{n}$$

Where, r is the radial (perpendicular) distance of the point from the wire and $\hat{n}$ is the radial unit vector in the plane normal to the wire passing through the point.

- Infinite plane sheet (thin) of uniform surface charge density σ

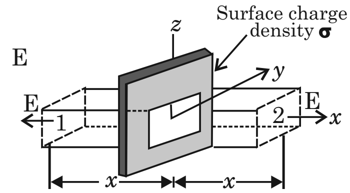


Fig. Infinite plane sheet (thin)

$$E = \frac{\sigma}{2\varepsilon_o}\hat{n}$$

Where $\hat{n}$ is a unit vector normal to the plane and going away from it.

- Thin spherical shell of uniform surface charge density σ

$$E = \frac{q}{4\pi\varepsilon_o r^2}\hat{r} \qquad (r \geq R)$$

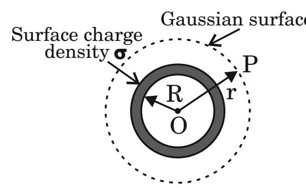


Fig.: Thin uniformly surface charged spherical shell (r > R)

(For r > R)

E = 0 (r < R)

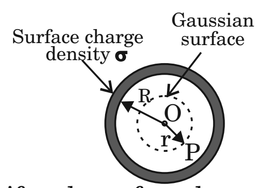


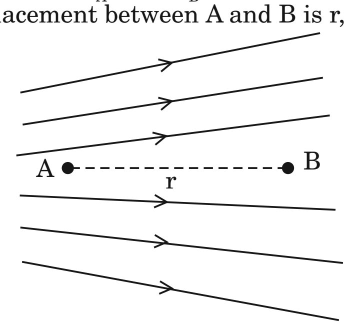
Fig.: Thin uniformly surface charged spherical shell (r < R)

(For r < R)

Where r is the distance of the point from the center of the shell whose radius is R with the total charge q. The electric field outside the shell is the same as the total charge is concentrated at the center. A solid sphere of uniform volume charge density shows the same result. Inside the shell at all the points, the field is zero.

Exercise

1. When the distance between the charged particles is halved, the force between them becomes.
   (*a*) One-fourth (*b*) Half
   (*c*) Double (*d*) Four times
2. A charge q_1 exerts some force on a second charge q_2. If third charge q_3 is brought near, the force of q_1 exerted on q_2.
   (*a*) Decreases
   (*b*) Increases
   (*c*) Remains unchanged
   (*d*) Increases if q_3 is of the same signs as q_1 and decreases if q_3 is of opposite sign
3. The minimum charge on an object is
   (*a*) 1 coulomb
   (*b*) 1 stat coulomb
   (*c*) 1.6×10^{-19} coulomb
   (*d*) 3.2×10^{-19} coulomb
4. Three charges 4q, Q and q are in a straight line in the position of 0, l/2 and l respectively. The resultant force on q will be zero, if Q =
   (*a*) –q (*b*) –2q
   (*c*) $-\frac{q}{2}$ (*d*) 4q
5. The number of electrons in 1.6 C charge will be
   (*a*) 10^{19} (*b*) 10^{20}
   (*c*) 1.1×10^{19} (*d*) 1.1×10^{2}
6. The electric charge in uniform motion produces
   (*a*) An electric field only
   (*b*) A magnetic field only
   (*c*) Both electric and magnetic field
   (*d*) Neither electric nor magnetic field
7. Figure shows the electric lines of force emerging from a charged body. If the electric field at A and B are E_A and E_B respectively and if the displacement between A and B is r, then



   (*a*) $E_A > E_B$ (*b*) $E_A < E_B$
   (*c*) $E_A = \frac{E_B}{r}$ (*d*) $E_A = \frac{E_B}{r^2}$
8. The electric field near a conducting surface having a uniform surface charge density σ is given by
   (*a*) $\frac{\sigma}{\varepsilon_0}$ and is parallel to the surface
   (*b*) $\frac{2\sigma}{\varepsilon_0}$ and is parallel to the surface
   (*c*) $\frac{\sigma}{\varepsilon_0}$ and is normal to the surface
   (*d*) $\frac{2\sigma}{\varepsilon_0}$ and is normal to the surface
9. Deutron and α-particle are put 1 Å apart in air. Magnitude of intensity of electric field due to deutron at α-particle is
   (*a*) zero (*b*) 2.88×10^{11} N/C
   (*c*) 1.44×10^{11} N/C (*d*) 5.76×10^{11} N/C
10. An electric dipole when placed in a uniform electric field E will have minimum potential energy, if the positive direction of dipole moment makes the following angle with E
    (*a*) π (*b*) $\frac{\pi}{2}$
    (*d*) zero (*d*) $\frac{3\pi}{2}$
11. The electric potential at a point on the axis of an electric dipole depends on the distance r of the point from the dipole as
    (*a*) $\propto \frac{1}{r}$ (*b*) $\propto \frac{1}{r^2}$
    (*c*) μr (*d*) $\propto \frac{1}{r^3}$
12. An electric dipole is kept in non-uniform electric field. It experiences
    (*a*) A force and a torque
    (*b*) A force but not a torque
    (*c*) A torque but not a force
    (*d*) Neither a force nor a torque
13. The distance between the two charges +q and –q of a dipole is r. On the axial line at a distance d from the centre of dipole, the intensity is proportional to
    (*a*) $\frac{q}{d^2}$ (*b*) $\frac{qr}{d^2}$
    (*c*) $\frac{q}{d^3}$ (*d*) $\frac{qr}{d^3}$

14. The electric field due to an electric dipole at a distance r from its centre in axial position is E. If the dipole is rotated through an angle of 90° about its perpendicular axis, the electric field at the same point will be

(a) E (b) $\frac{E}{4}$

(c) $\frac{E}{2}$ (d) 2E

15. An electric dipole of moment $\vec{\rho}$ placed in a uniform electric field $\vec{E}$ has minimum potential energy when the angle between $\vec{\rho}$ and $\vec{E}$ is

(a) Zero (b) $\frac{\pi}{2}$

(c) π (d) $\frac{3\pi}{2}$

16. A Cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by

(a) $2\pi R^2E$ (b) $\frac{\pi R^2}{E}$

(c) $\frac{\left(\frac{\pi R^2}{\pi R}\right)}{E}$ (d) zero

17. An electric charge q is placed at the centre of a cube of side a. The electric flux on one of its faces will be

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{q}{\varepsilon_0 a^2}$

(c) $\frac{q}{4\pi\varepsilon_0 a^2}$ (d) $\frac{q}{\varepsilon_0}$

18. Total electric flux coming out of a unit positive charge put in air is

(a) ε_o (b) ε_o^{-1}

(c) $(4\rho\varepsilon_o)^{-1}$ (d) $4\pi\varepsilon_o$

19. For a given surface the Gauss's law is stated as $\oint E \,.\, ds = 0$. From this we can conclude that

(a) E is necessarily zero on the surface

(b) E is perpendicular to the surface at every point

(c) The total flux through the surface is zero.

(d) The flux is only going out of the surface

20. A cube of side ℓ is placed in a uniform field E, where $E = E\hat{i}$. The net electric flux through the cube is

(a) zero

(b) ℓ^2E

(c) $4\ \ell^2E$

(d) $6\ \ell^2E$

21. A charge q is placed at the centre of the open end of cylindrical vessel. The flux of the electric field through the surface of the vessel is

(a) zero (b) $\frac{q}{\varepsilon_o}$

(c) $\frac{q}{2\varepsilon_o}$ (d) $\frac{2q}{\varepsilon_o}$

22. According to Gauss's Theorem, electric field of an infinitely long straight wire is proportional to

(a) r (b) $\frac{1}{r^2}$

(c) $\frac{1}{r^3}$ (d) $\frac{1}{r}$

23. The S.I. unit of electric flux is

(a) Weber (b) Newton per coulomb

(c) Volt × meter (d) Joule per coulomb

24. Gauss's law is true only if force due to a charge varies as

(a) r^{-1} (b) r^{-2}

(c) r^{-3} (d) r^{-4}

25. An electric dipole is put in north-south direction in a sphere filled with water. Which statement is correct

(a) Electric flux is coming towards sphere

(b) Electric flux is coming out of sphere

(c) Electric flux entering into sphere and leaving the sphere are same

(d) Water does not permit electric flux to enter into sphere.

Answer Keys

1. (*d*)	**2.** (*c*)	**3.** (*c*)	**4.** (*a*)	**5.** (*a*)	**6.** (*c*)	**7.** (*a*)	**8.** (*c*)	**9.** (*c*)	**10.** (*c*)
11. (*d*)	**12.** (*a*)	**13.** (*d*)	**14.** (*c*)	**15.** (*a*)	**16.** (*d*)	**17.** (*a*)	**18.** (*b*)	**19.** (*c*)	**20.** (*a*)
21. (*c*)	**22.** (*d*)	**23.** (*c*)	**24.** (*b*)	**25.** (*c*)					

Solutions

1. $\because f \propto \frac{1}{r^2}$

$\therefore$ when r is halved the force becomes four times.

2. The force will still remain unchanged.

$\therefore F = \frac{q_1 q_2}{4\pi\,\varepsilon_0 r^2}$

3. All other charges are its integral multiple.

$\therefore$ Minimum charge on an object = 1.6×10^{-19} coulomb

4. The force between 4q and q.

$F_1 = \frac{1}{4\pi\,\varepsilon_0}.\frac{4q \times q}{l^2}$

The force between Q and q

$F_2 = \frac{1}{4\pi\,\varepsilon_0}.\frac{Q \times q}{\left(\frac{l}{2}\right)^2}$

$\therefore F_1 + F_2 = 0$ or $\frac{4q^2}{l^2} = -\frac{4Qq}{l^2} \Rightarrow Q = -q$

5. $n = \frac{q}{e} = \frac{1.6}{1.6 \times 10^{-19}} = 10^{19}$

6. A movable charge produces electric field and magnetic field both.

7. In non-uniform electric field. Intensity is more, where the lines are more denser.

8. Electric field near the conductor surface is given by $\frac{\sigma}{\varepsilon_0}$ and it is perpendicular to surface.

9. Due to deutron, intensity of electric field at 1 Å distance

$E = \frac{1}{4\pi\varepsilon_0}.\frac{e}{r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19}}{10^{-20}}$

$= 1.44 \times 10^{11}$ N/C

10. Potential energy = $-pE \cos\theta$.

when $\theta = 0$,

Potential energy = $-pE$ (minimum)

11. Electric potential due to dipole in it's general position is given by $v = \frac{k.p\cos\theta}{r^2} \Rightarrow v \alpha \frac{1}{r^2}$

12. As the dipole will feel two forces which are although opposite but not equal.

$\therefore$ A net force will be there and as these forces act at different points of a body. A torque is also parent.

13. Field along the axis of the dipole

$E = \frac{1}{4\pi\varepsilon_0}.\frac{2p}{d^3} = \frac{1}{4\pi\varepsilon_0}.\frac{2(q \times r)}{d^3}$

$\therefore\ E \propto \frac{qr}{d^3}$

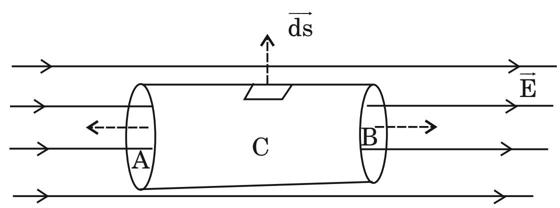
14. When the dipole is rotated through at an angle of 90° about it's perpendicular axis then given point comes out to be on equator. So field will become $\frac{E}{2}$ at the given point.

15. $U = -PE\cos\theta$.

It has minimum value when $\theta = 0°$.

i.e. $U_{min} = -PE \cos 0° = -PE$

16. Flux through surface A $\phi_A = E \times \pi R^2$ and $\phi_B = E \times \pi R^2$.



Flux through curved surface

$C = \int \vec{E}\,.\,\vec{ds} = \int E\,ds\cos 90° = 0$

$\therefore$ Total flux through cylinder = $\phi_A + \phi_B + \phi_C = 0$

17. By Gauss's theorem,

Electric flux $(\phi) = \frac{q}{6\varepsilon_o}$

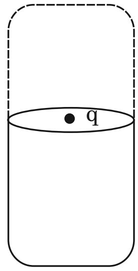
18. Total flux coming out from unit charge

$\phi = \vec{E}\,.\,\vec{ds} = \frac{1}{\varepsilon_o} \times 1 = \varepsilon_o^{-1}$

19. The total flux through the surface is zero.

20. As there is no charge residing inside the cube, hence net flux is zero.

21. To apply Gauss's theorem it is essential that charge should be placed inside a closed surface. So, imagine another similar cylindrical vessel above it as shown in figure (dotted).



$\therefore$ Required flux $\phi = \dfrac{q}{2\varepsilon_o}$

22. $E = \dfrac{\lambda}{2\pi\varepsilon_o r} \Rightarrow E \propto \dfrac{1}{r}$

23. S.I. unit of electric flux is

$$\frac{N \times m^2}{C} = \frac{J \times m}{C} = \text{volt} \times \text{metre}$$

24. Gauss's law is true only if force due to a charge varies as r^{-2}.

25. In electric dipole the flux coming out from positive charge is equal to the flux coming in at negative charge i.e. total charge on sphere = 0. From Gauss law, total flux passing through the sphere = 0.

CHAPTER 2

Electrostatic Potential and Capacitance

Electrostatic Potential and Electrostatic Potential Energy

Electrostatic potential:

- The amount of work done by an external force in moving a unit positive charge from one point to another in electrostatic field is called electrical potential.
- Such that $V = \frac{1}{4\pi\varepsilon}\frac{q}{r}$
- Where, q = charge causing the field, ε = permittivity, r = separation between centre of charge point.
- Electrostatic force is a conservative force.
- Work done by an external force (equal and opposite to the electrostatic force) in bringing a unit charge q from a point R to a point P is $V_P - V_R$, which is the difference in potential energy of charge q between the final and initial points.

Potential difference:

When the work is done upon a unit charge to change its potential energy then the difference between the final and the initial energy per unit charge is called electric potential difference.

Electric Potential due to a dipole:

- The electrostatic potential at a point with distance r from the dipole at a point making an angle θ with dipole moment p placed at the origin is given by $V(r) = \frac{1}{4\pi\varepsilon_o}\cdot\frac{p\cdot\hat{r}}{r^2}$.

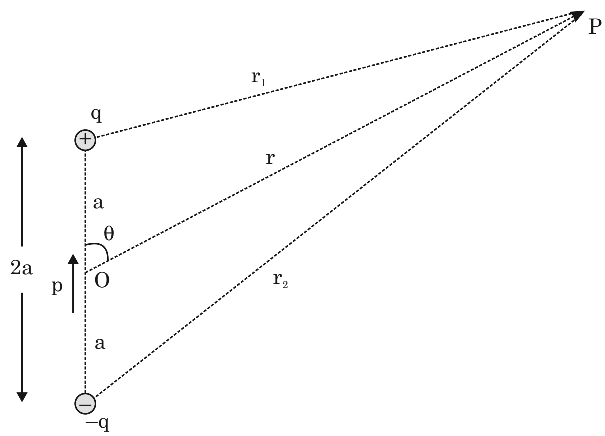


Fig. Electrical potential due to dipole

- It is a scalar quantity.

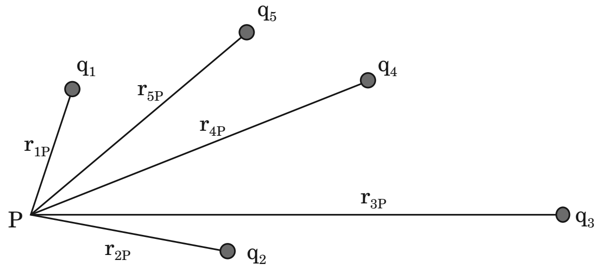
Dipole and System of charges

- For a charge configuration $q_1, q_2, \ldots\ldots, q_n$ with position vectors $r_1, r_2, r_3, \ldots\ldots, r_n$, then the potential V_1 at point P due to charge q_1 will be,

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}$$

And the sum of potentials due to individual charges is given by the superposition principle,

$$V = \frac{1}{4\pi\varepsilon_o}\left(\frac{q_1}{r_{1P}} + \frac{q_2}{r_{2P}} + \ldots. + \frac{q_n}{r_{nP}}\right)$$



- In a uniformly charged spherical shell, the electric field outside the shell with outside potential is given by,

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

Equipotential surfaces

- A surface over which potential has a constant value is known as an equipotential surface.
- The amount of work done in moving a charge over an equipotential surface is zero.
- Concentric spheres centered at a location of the charge act as equipotential surfaces for a point charge.
- The electric field E, at a point and equipotential surface are mutually perpendicular to each other through the point. The direction of the steepest decrease of potential is in E.
- Regions of strong and weak fields are located because of the spacing among equipotential surfaces.

Potential Energy of a System of Charges:

Potential energy stored in a system of charges is the work done by an external agency in assembling the charges at their locations. Total work done in assembling the charges is given by $U = \frac{1}{4\pi\varepsilon_o}\cdot\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$ where r_{12} is distance between q_1 and q_2, r_{13} is distance between q_1 & q_3 and r_{23} is distance between q_2 & relabel q_3.

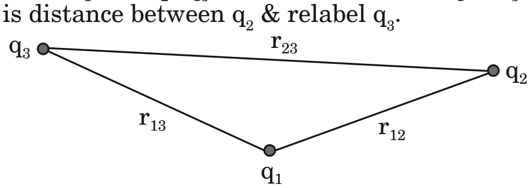


Fig. Potential energy due to System of charges

Electric potential energy of system of two point charges

- Here the work done doesn't depend on path.
- In this system the two charges q_1 and q_2 when separated by distance r, will either repel or attract each other.

Potential Energy in an External Field:

- The potential energy of a charge q in an external potential V(r) is qV(r). The potential energy of a dipole moment p in a uniform electric field E is –p.E.
- Electric dipole in an electrostatic field: Electric potential due to a dipole at a point at distance r and making an angle θ with the dipole moment p is given by

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

Electrostatics of conductors:

- Electrostatic field is zero inside a conductor.
- Electrostatic field at the surface of a charged conductor must be normal to the surface at every point.
- In the static situation, there cannot be any excess charge in the interior of a conductor.
- Throughout the volume of the conductor, the electrostatics potential is constant and has same value on its surface.
- Electrostatics field E is zero in the interior of a conductor; just outside the surface of a charged conductor, E is normal to the surface given by $E = \frac{\sigma}{\varepsilon_o}\hat{n}$ where $\hat{n}$ is the unit vector along the outward normal to the surface and σ is the surface charge density.
- **Electrostatic shielding:** A field which is inside the cavity of a conductor is always zero and it remains shielded from the electric field, which is known as electrostatic shielding.

Dielectrics and Polarization:

- **Dielectrics:** A non-conducting substance which has a negligible number of charge carriers unlike conductors is called dielectrics.
- **Electric polarization:** The difference between induced electric field and imposed electric field in dielectric due to bound and free charges is known as electric polarization. It is written as:

$$P = \frac{D - E}{4\pi}$$

Note: Polarisation can also be written as polarization (with 'z' in place of 's')

Capacitance

Capacitor and Capacitance

- **Capacitor:** The system of two conductors separated by an insulator is called capacitor.

  The device which is used to store charge is known as capacitor. The applied voltage and size of capacitor decides the amount of charge that can be stored i.e., $Q = CV$

  Two similar connecting plates are placed in capacitor in the front of each other where one plate is connected to the positive terminal and other plate is connected to the negative terminal.
- **Capacitance:** The ratio of magnitude of charge stored on the plate to potential difference between the plates is called capacitance. It is written as:

$$C = \frac{Q}{\Delta V}$$

  Size, shape, medium and other conductors in surrounding influence the capacitance of a conductor.

  Its S.I. unit is farad.

  $1F = 1CV^{-1}$ For a parallel plate capacitor (with vacuum between the plates), $C = \varepsilon_o \frac{A}{d}$ where A is the area of each plate and d in the separation between the parallel plates.

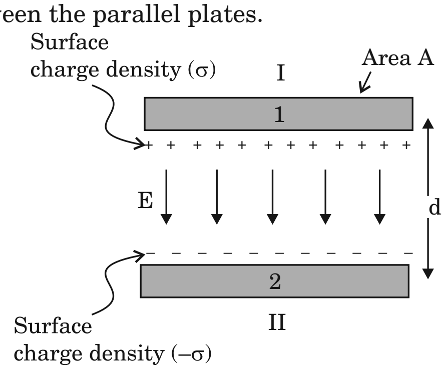


Fig. Capacitor

Effect of Dielectric on Capacitance:

- If the medium between the plates of a capacitor is filled with an insulating substance (dielectric), the electric field due to the charged plates induces a net dipole moment in the dielectric. This effect, called ***polarization***, gives rise to a field in the opposite direction.
- The dielectric is polarised by the field and also the effect is equivalent to two charged sheets with surface charge densities σ_p and $-\sigma_p$.
- The net electric field inside the dielectric and hence the potential difference between the plates is thus reduced. Consequently, the capacitance C increases from its value C_o when there is no medium (vacuum),

  $C = KC_o$ where $K = \frac{\varepsilon}{\varepsilon_0}$ is the ***dielectric constant*** of the insulating substance.

Types of capacitor:

- Parallel plate capacitor: $C = K\varepsilon_0 \frac{A}{d}$
- Cylindrical capacitor: $C = 2\pi K\varepsilon_0 \frac{1}{\ln(b/a)}$
- Spherical capacitor: $C = 4\pi K\varepsilon_0 \left(\frac{ab}{b-a}\right)$

Combination of Capacitors

- For capacitors in the series combination, the total capacitance C is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \frac{1}{C_n}$$

- In the parallel combination, the total capacitance C is $C = C_1 + C_2 + C_3 \ldots\ldots C_n$, where $C_1, C_2, C_3 \ldots\ldots$ are individual capacitances.
- Capacitors connected in series have the same charges and when connected in parallel have the same voltage.
- Potential across capacitor remains same if the battery is connected but if it is disconnected then charge remains the same which is stored in capacitor.

Electrical Energy Stored in a Capacitor:

- The energy U stored in a capacitor of capacitance C, with charge Q and voltage V is $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$.
- The electric energy density (energy per unit volume) in a region with electric field is $\frac{1}{2}\varepsilon_o E^2$.

- Electric density is alternatively known as ***electrostatic pressure***.

Van De Graaff Generator:

- A Van de Graaff generator consists of a large spherical conducting shell (a few meters in diameter).
- There are two pulleys, one at ground level and one at the center of the shell. Both of them are connected by a long and narrow endless belt of insulating material.
- The motor drives the lower pulley which keeps moving this belt continuously.
- At ground level to the top, it continuously carries the positive charge and sprayed on to it by a brush. Then the positive charge is transferred by it to another conducting brush connected to the large shell.
- After the transferring of the positive charge is done, it spreads out uniformly on the outer surface. It can build the voltage difference of as much as 6 to 8 million volts.

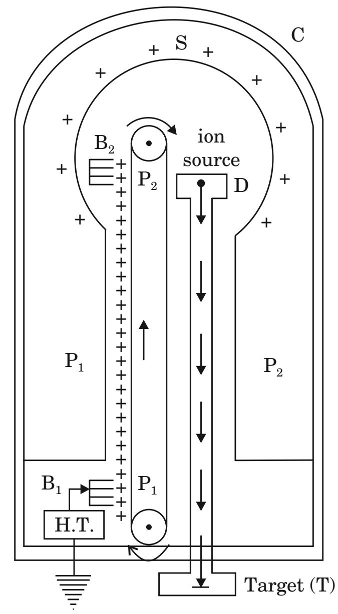


Fig. Van de Graff Generator

Exercise

1. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium, if q is equal to

(*a*) $-\dfrac{Q}{2}$

(*b*) $-\dfrac{Q}{4}$

(*c*) $+\dfrac{Q}{4}$

(d) $+\dfrac{Q}{2}$

2. Inside a hollow charged spherical conductor, the potential

(*a*) is constant

(*b*) varies directly as the distance from the centre

(*c*) varies inversely as the distance from the centre

(*d*) varies inversely as the square of the distance from the centre.

3. Two small spheres each carrying a charge q are placed r metre apart. If one of the sphere is taken around the other one in a circular path of radius r, the work done will be equal to

(*a*) Force between them × r

(*b*) Force between them × 2πr

(*c*) Force between them / 2πr

(*d*) zero.

4. Two charged spheres of radii 10 cm and 15 cm are connected by a thin wire. No charge will flow, if they have

(*a*) The same charged on each

(*b*) The same potential

(*c*) The same energy

(*d*) The same field on their surfaces

5. If a unit positive charge is taken from one point to another over an equipotential surface, then

(*a*) work is done on the charge

(*b*) work is done by the charge

(*c*) work done is constant

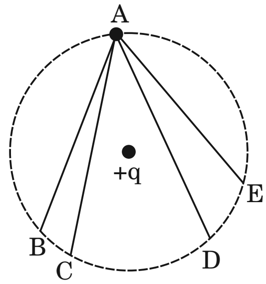
(*d*) No work is done

6. Charges of $+\frac{10}{3}\times 10^{-9}$ C are placed at each of the four corners of a square of side 8 cm. The potential at the intersection of the diagonals is

(a) $150\sqrt{2}$ volt (b) $1500\sqrt{2}$ volt

(c) $900\sqrt{2}$ volt (d) 900 volt

7. In the electric field of a point charge q, a certain charge is carried from point A to B, C, D and E. Then the work done



(a) Is least along the path AB

(b) Is least along the path AD

(c) Is zero along all the paths AB, AC, AD and AE

(d) Is least along AE

8. A conductor with a positive charge

(a) Is always at +ve potential

(b) Is always at zero potential

(c) Is always at negative potential

(d) May be at +ve, zero or-ve potential

9. If E is the electric field intensity of an electrostatic field, then the electrostatic energy density is proportional to

(a) E (b) E^2

(c) $\frac{1}{E^2}$ (d) E^3

10. Three particles, each having a charge of 10 μC are placed at the corners of an equilateral triangle of side 10 cm. The electrostatic potential energy of the system is

(Given $\frac{1}{4\pi}\varepsilon_0 = 9\times 10^9$ N-m^2/c^2)

(a) Zero (b) Infinite

(c) 27 J (d) 100 J

11. Two equal charges q are placed at a distance of 2a and a third charge –2q is placed at the midpoint. The potential energy of the system is

(a) $\frac{q^2}{8\pi\varepsilon_o a}$ (b) $\frac{6q^2}{8\pi\varepsilon_o a}$

(c) $-\frac{7q^2}{8\pi\varepsilon_o a}$ (d) $\frac{9q^2}{8\pi\varepsilon_o a}$

12. Potential at a point x-distance from the centre inside the conducting sphere of radius R and charged with charge Q is proportional to

(a) $\frac{Q}{R}$ (b) $\frac{Q}{x}$

(c) $\frac{Q}{x^2}$ (d) xQ

13. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is then slipped between the plates, which results in

(a) Reduction of charge on the plates and increase of potential difference across the plates

(b) Increase in the potential difference across the plate reduction in the stored energy, but no charge in the charge on the plates.

(c) Decrease in the potential difference across the plates, reduction in the stored energy, but no change in the charge on the plates.

(d) None of the above

14. The energy of a charged capacitor is given by the expression (q = charge on the conductor and C = its capacity)

(a) $\frac{q^2}{2C}$ (b) $\frac{q^2}{C}$

(c) 2qc (d) $\frac{q}{2C^2}$

15. The capacity of a condenser is 4×10^{-6} farad and its potential is 100 volts. The energy released on discharging it fully will be

(a) 0.02 Joule (b) 0.04 Joule

(c) 0.025 Joule (d) 0.05 Joule

16. Two conducting spheres of radii R_1 and R_2 having charges Q_1 and Q_2 respectively are connected to each other. There is

(a) No change in the energy of the system

(b) An increase in the energy of the system

(c) Always a decrease in the energy of the system

(d) A decrease in the energy of the system unless $Q_1 R_2 = Q_2 R_1$

17. If two conducting spheres are separately charged and then brought in contact

(a) The total energy of the two spheres is conserved

(b) The total charge on the two spheres is conserved

(c) Both the total energy and charge are conserved

(d) The final potential is always the mean of the original potentials of the two spheres

18. A parallel plate condenser has a capacitance 50 μF in air and 110 μF when immersed in an oil. The dielectric constant 'K' of the oil is

(*a*) 0.45 (*b*) 0.55
(*c*) 1.10 (*d*) 2.20

19. The capacity of parallel plate condenser depends on

(*a*) The type of metal used
(*b*) The thickness of plates
(*c*) The potential applied across the plates
(*d*) The separation between the plates

20. The potential to which a conductor is raised, depends on

(*a*) The amount of charge
(*b*) Geometry and size of the conductor
(*c*) Both (*a*) and (*b*)
(*d*) Only on (*a*)

21. If the dielectric constant and dielectric strength be denoted by K and x respectively, then a material suitable for use as a dielectric in a capacitor must have

(*a*) High K and high x (*b*) High K and low x
(*c*) Low K and low x (*d*) Low K and high x

22. When air is a capacitor is replaced by a medium of dielectric constant K, the capacity

(*a*) Decreases K times
(*b*) Increases K times
(*c*) Increases K^2 times
(*d*) Remains constant

23. The capacity of a parallel plate capacitor increases with the

(*a*) Decrease of its area
(*b*) Increase of its distance
(*c*) Increase of its area
(*d*) None of the above

24. A capacitor of capacity C has charge Q and stored energy is W. If the charge is increased to 2Q, the stored energy will be

(*a*) 2W (*b*) $\frac{W}{2}$
(*c*) 4W (*d*) $\frac{W}{4}$

25. The distance between the plates of a parallel plate condenser is 4 mm and potential difference is 60 volts. If the distance between the plates is increased to 12 mm, then

(*a*) The potential difference of the condenser will become 180 volts
(*b*) The P.D. will become 20 volts
(*c*) The P.D. will remain unchanged
(*d*) The charge on condenser will reduce to one third

26. The true statement is, on increasing the distance between the plates of a parallel plate condenser

(*a*) The electric intensity between the plates will decrease
(*b*) The electric intensity between the plates will increase
(*c*) The electric intensity between the plates will remain unchanged
(*d*) The P.D. between the plates will decrease

27. One plate of parallel plate capacitor is smaller than other, then charge on smaller plate will be

(*a*) Less than other
(*b*) More than other
(*c*) Equal to other
(*d*) Will depend upon the medium between them

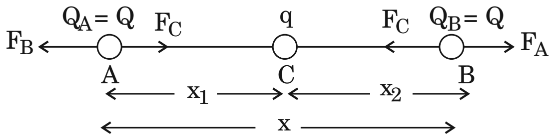
Answer Keys

1. (*b*)	**2.** (*a*)	**3.** (*d*)	**4.** (*b*)	**5.** (*d*)	**6.** (*b*)	**7.** (*c*)	**8.** (*d*)	**9.** (*b*)	**10.** (*c*)
11. (*c*)	**12.** (*a*)	**13.** (*c*)	**14.** (*a*)	**15.** (*a*)	**16.** (*d*)	**17.** (*b*)	**18.** (*d*)	**19.** (*d*)	**20.** (*c*)
21. (*a*)	**22.** (*b*)	**23.** (*c*)	**24.** (*c*)	**25.** (*a*)	**26.** (*c*)	**27.** (*c*)			

Solutions

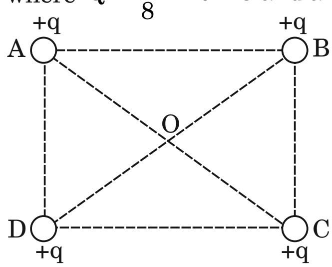
1. Suppose in the following figure, equilibrium of charge B is considered. Hence for it's equilibrium $|F_A| = |F_C|$

$$\Rightarrow \frac{1}{4\pi\varepsilon_o}\frac{Q^2}{4x^2} = \frac{1}{4\pi\varepsilon_o}\frac{qQ}{x^2} \Rightarrow q = \frac{-Q}{4}$$



2. Inside the hollow sphere, at any point the potential is constant.
3. The force is perpendicular to the displacement.
4. Because current flows from higher potential to lower potential.
5. On the equipotential surface, electric field is normal to the charged surface (where potential exists) so that no work will be done.
6. Potential at the centre O, $V = 4 \times \frac{1}{4\pi\varepsilon_o}\frac{Q}{\frac{a}{\sqrt{2}}}$

where $Q = \frac{10}{8} \times 10^{-9}$C and $a = 8\text{cm} = 8 \times 10^{-2}$m



Hence,

$$V = 4 \times 9 \times 10^9 \times \frac{\frac{10}{3} \times 10^{-9}}{\frac{8 \times 10^{-2}}{\sqrt{2}}} = 1500\sqrt{2} \text{ volt}$$

7. ABCDE is an equipotential surface, on equipotential surface no work is done in shifting a charge from one place to another.
8. May be at positive, zero or negative potential, it is according to the way one defines the zero potential.
9. Electrostatic energy density $\frac{dU}{dV} = \frac{1}{2}K\varepsilon_o E^2$

$\therefore \frac{dU}{dV} \propto E^2$

10. For pair of charge $U = \frac{1}{4\pi\varepsilon_o} \cdot \frac{q_1 q_2}{r}$

$$\therefore U_{system} = \frac{3}{4\pi\varepsilon_o}\left(\frac{10 \times 10^{-6} \times 10 \times 10^{-6}}{\frac{10}{100}}\right)$$

$$= 3 \times 9 \times 10^9 \times \frac{100 \times 10^{-12} \times 100}{10} = 27\text{J}$$

11. $$U_{system} = \frac{1}{4\pi\varepsilon_o}\frac{(q)(-2q)}{a} + \frac{1}{4\pi\varepsilon_o} \cdot \frac{(-2q)(q)}{a} + \frac{1}{4\pi\varepsilon_o}\frac{(q)(q)}{2a}$$

$$= -\frac{7q^2}{8\pi\varepsilon_o a}$$

12. Potential at any point inside the charge spherical conductor equals to the potential at the surface of the conductor i.e. Q/R
13. Battery in disconnected, so, Q will be constant as $C \propto K$. So. with introduction of dielectric slab capacitance will increase using Q = CV, V will decrease and using $U = \frac{Q^2}{2C}$, energy will decrease.
14. $q = CV$ and $U = \frac{1}{2}CV^2 = \frac{q^2}{2C}$
15. $U = \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (100)^2 = 0.02\text{J}$
16. When $\frac{Q_1}{R_1} \neq \frac{Q_2}{R_2}$; current will flow in connecting wire so that energy decrease in the form of heat through the connecting wire.
17. By law of conservation of charge, the total charge on the two spheres is conserved.
18. $C_{medium} = K\,C_{air}$

$$\Rightarrow K = \frac{C_{medium}}{C_{air}} = \frac{110}{50} = 2.20$$

19. The capacity of parallel plate condenser depends on the separation between the plates.

$\because C \propto \frac{1}{d}$

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

where Q = The amount of charge

C = Capacitance which depends on geometry and size of conductor.

21. High K means good insulating property and high x means able to withstand electric field or electric potential gradient to a higher value.

22. $C_{medium} = K \times C_{air}$

23. Capacity of parallel plate capacitor $C = \dfrac{\varepsilon_0 A}{d}$

$\therefore C \propto A$

24. $W = \dfrac{Q^2}{2C} \Rightarrow W' = 4W$

25. For capacitor $\dfrac{V_1}{V_2} = \dfrac{d_1}{d_2}$

$$\Rightarrow V_2 = \frac{V_1 \times d_2}{d_1} = \frac{60 \times 12}{4} = 180V$$

26. Electric field between the plates of a parallel plate capacitor $E = \dfrac{\sigma}{\varepsilon_o} = \dfrac{Q}{A\varepsilon_o}$

i.e. $E \propto d^\circ$

27. Because the charges are produced due to induction and moreover the net charge of the condenser should be zero.

CHAPTER 3

Current Electricity

Electricity conduction, Ohm's law and resistance

Electric Current: Net charge flowing across a given area of conductor per unit time is defined as electric current.

$I = \frac{q}{t}$, S.I. unit of current is Ampere (A).

A steady current is generated in a closed circuit where electric charge moves from higher to lower potential. ***Electromotive force*** or ***emf*** is the work done by the source in taking the charge from lower to higher potential energy.

Drift velocity: The free electrons drift with some velocity towards the positive terminal when a potential difference is applied across the ends. The average velocity with which the electrons move is termed as drift velocity.

Drift velocity, $v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$

Where e = charge on electron

E = Electric field intensity

V = Potential difference across the ends of the conductor

τ = Relaxation time

m = Mass of electron

Relation between current and drift velocity: Current is directly proportional to the drift velocity.

$I \propto v_d$

When the number of electrons are less, current is less so the drift velocity is small.

When the number of electrons are large, high current flows so the drift velocity is large.

Ohm's law: The voltage across the ends of the conductor is directly proportional to the electric current flowing through the conductor.

$V \propto I$

Or V = IR, where R is the electrical resistance of the conductor

Resistance: The property that resists the flow of current through any conductor is called the resistance of the conductor.

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

It varies directly with the length of the conductor while depends inversely on the area of cross section of the conductor.

$R = \frac{\rho l}{A}$, ρ being the resistivity of the material of the conductor.

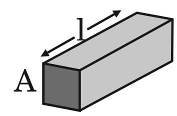


Fig.: Resistance in a conductor

Resistivity: It depends on the nature of the material and temperature. It is also termed as specific resistance.

$\rho = \frac{m}{ne^2\tau}$ gives the relation between resistivity and relaxation time.

There is an increasing order of resistivity as we go from metal to insulator.

$\rho_{metals} < \rho_{semiconductors} < \rho_{insulators}$

Conductivity and conductance: The reciprocal of resistivity is conductivity (σ).

$\sigma = \frac{1}{\rho}$ and its S.I. unit is $\Omega^{-1}m^{-1}$.

The reciprocal of resistance is the conductance of the conductor. Its S.I. unit is mho.

Current Density: The amount of charge flowing per unit area per second is called the current density.

$J = mqv_d$, where v_d is the drift velocity of the charge carriers, n is the number of charge carriers and q is the charge.

The relation between current density and conductivity is

$J = \sigma E$

Mobility: Mobility is the ratio of drift velocity to the applied electric field. Mobility is symbolized by μ.

$$\mu = \frac{v_d}{E} = \frac{q\tau}{m}$$

Its S.I. unit is $m^2s^{-1}V^{-1}$.

Resistors: The objects which resist the flow of charge are called resistors which can be of two types, i.e. wire bound resistors and carbon resistors.

Resistors can combine in two different ways; either in series or in parallel.

- Consider n number of resistors connected in series, then the combined resistance will be as follows:

  $$R_{eqv} = R_1 + R_2 + R_3 + \ldots\ldots + R_n$$

Same amount of current will flow through each resistor connected in series while the potential difference would be different for every resistor.

- Consider n number of resistors connected in parallel, then the combined resistance will be as follows:

  $$R_{eqv} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots + \frac{1}{R_n}$$

The current flowing through each resistor would be different in this case while the potential difference would be same for all the resistors.

Internal resistance: It is the resistance on the current offered by the electrolyte and the electrodes. It is symbolize by r.

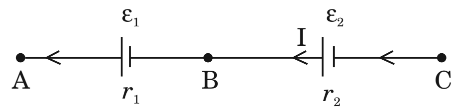
Let us assume a cell with 2 electrodes connected by an external resistance R. Then current is, $I = \frac{\varepsilon}{R + r}$

where ε = emf, r = Internal resistance

Kirchhoff's Laws, cells and their combinations

Cells in series and in parallel

- The equivalent emf of a series combination of n cells is just the sum of their individual emfs
- The equivalent internal resistance of a series combination of n cells is the sum of their internal resistances.

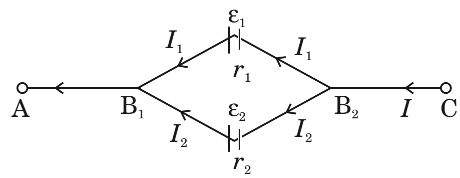


$\varepsilon = \varepsilon_1 + \varepsilon_2$

- In a parallel connection,

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \ldots\ldots + \frac{1}{r_n} \text{ and}$$

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \ldots\ldots + \frac{\varepsilon_n}{r_n}$$



Kirchhoff's law:

- **Junction Rule:** The sum of currents entering a junction would be equal to the sum of currents leaving the junction.
- **Loop Rule:** The sum of changes in potential around any loop that is closed should be zero.

  Wheatstone bridge: It is an arrangement of four resistors in a way so that a galvanometer is placed between the two opposite arms.

  There is a null-point condition in the wheat stone bridge where current is zero which can be represented as follows:

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

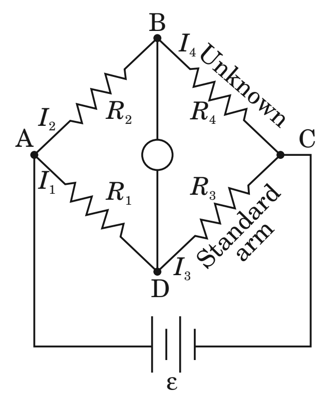


Fig.: Wheastone bridge

Electrical devices

Meter Bridge: Meter Bridge is the simplest form of the Wheatstone bridge which is used for accurate comparison of resistances.

In order to find out an unknown resistance R with the help of a standard known resistance S:

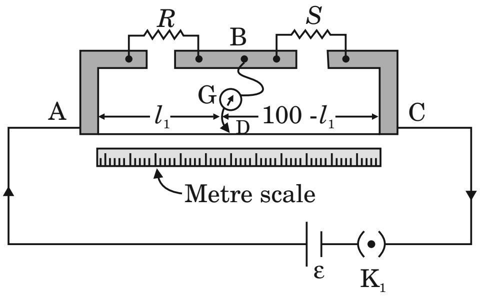


Fig.: Meter bridge

$R = S\dfrac{l_1}{100 - l_1}$, l_1 being the distance of the jockey from end A at the balance point.

Potentiometer: It is a device which is used to compare potential differences and emf"'s. It also measures the internal resistance of a cell.

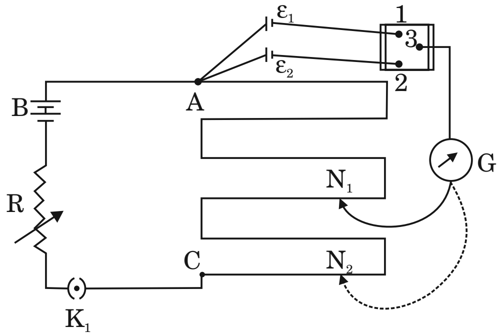


Fig.: Potentiometer

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

Potentiometer does not draw any current from the voltage source being measured. The internal resistance of a given cell can be measured by:

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

Exercise

1. Current of 4.8 ampere 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*) $\dfrac{v}{4}$ (*b*) $\dfrac{v}{2}$

(*c*) v (*d*) 4v

3. If there is 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%

4. 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

5. The resistivity of a wire

(*a*) Increase with the length of the wire

(*b*) Decrease with the area of cross section

(*c*) Decreases with the length and increases with the area of cross section of wire

(*d*) None of the above

6. 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

7. Drift velocity v_d varies with the intensity of electric field as per the relation

(a) $v_d \propto E$ (b) $v_d \propto \frac{1}{E}$

(c) v_d = constant (d) $v_d \propto E^2$

8. The specific resistance of a wire is P, its volume is $3m^3$ and its resistance is 3Ω, then its length will be

(a) $\sqrt{\frac{1}{\rho}}$ (b) $\frac{3}{\sqrt{\rho}}$

(c) $\frac{1}{\rho}\sqrt{3}$ (d) $\rho\sqrt{\frac{1}{3}}$

9. 5 ampere of current is passed through a metallic conductor. The charge flowing in one minute in coulomb will be

(a) 5 (b) 12

(c) $\frac{1}{12}$ (d) 300

10. The reciprocal of resistance is

(a) Conductance (b) Resistivity

(c) Voltage (d) None of these

11. A cell of e.m.f. 1.5 V having a finite internal resistance is connected to a load resistance of 2 Ω. For maximum power transfer the internal resistance of the cell should be

(a) 4 Ω (b) 0.5 Ω

(c) 2 Ω (d) None

12. The e.m.f. of a cell is E volt and internal resistance is r Ω. The resistance in external circuit is also r Ω. The potential difference across the cell will be

(a) $\frac{E}{2}$ (b) 2E

(c) 4E (d) $\frac{E}{4}$

13. A cell of e.m.f. E is connected with an external resistance R, then potential difference across cell is V. The internal resistance of cell will be

(a) $\frac{(E-V)R}{E}$ (b) $\frac{(E-V)R}{V}$

(c) $\frac{(V-E)R}{V}$ (d) $\frac{(V-E)R}{E}$

14. Two cells, each of e.m.f. E and internal resistance r are connected in parallel between the resistance R. The maximum energy given to the resistor will be, only when

(a) $R = \frac{r}{2}$ (b) R = r

(c) R = 2 r (d) R = 0

15. Kirchhoff's first law i.e. $\Sigma i = 0$ at a junction is based on the law of conservation of

(a) Charge (b) Energy

(c) Momentum (d) Angularmomentum

16. Kirchhoff's second law is based on the law of conservation of

(a) Charge

(b) Energy

(c) Momentum

(d) Sum of mass and energy

17. A new flashlight cell of e.m.f 1.5 volt gives a current of 15 amp, when connected directly to an ammeter of resistance 0.04 Ω. The internal resistance of cell is

(a) 0.04 Ω (b) 0.06 Ω

(c) 0.10 Ω (d) 10 Ω

18. When cells are connected in parallel, then

(a) The current decrease

(b) The current increase

(c) The e.m.f increases

(d) The e.m.f decrease

19. The internal resistance of a cell depends on

(a) The distance between the plates

(b) The area of the plates immersed

(c) The concentration of the electrolyte

(d) All the above

20. A cell of e.m.f 6 V and resistance 0.5 Ω is short circuited. The current in the cell is

(a) 3 amp (b) 12 amp

(c) 24 amp (d) 6 amp

21. Kirchhoff's I law and II law of current, prove the

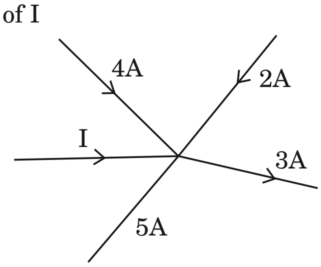
(a) Conservation of charge and energy

(b) Conservation of current and energy

(c) Conservation of mass and charge

(d) None of these

22. In the given current distribution what is the value of I



(a) 3 A (b) 8 A

(c) 2 A (d) 5 A

23. In meter bridge or wheatstone bridge for measurement of resistance, the known and the unknown resistances are interchanged. The error so removed is

(*a*) End correction
(*b*) Index error
(*c*) Due to temperature effect
(*d*) Random error

24. A galvanometer can be converted into an ammeter by connecting

(*a*) Low resistance in series
(*b*) High resistance in parallel
(*c*) Low resistance in parallel
(*d*) High resistance in series

25. By ammeter, Which of the following can be measured

(*a*) Electric potential (*b*) Potential Difference
(*c*) Current (*d*) Resistance

26. The resistance of 1 A ammeter is 0.018Ω. To convert it into 10 A ammeter, the shunt resistance required will be

(*a*) 0.18Ω (*b*) 0.0018Ω
(*c*) 0.002Ω (*d*) 0.12Ω

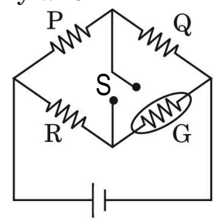
27. A galvanometer can be used as a voltmeter by connecting a

(*a*) High resistance in series
(*b*) Low resistance in series
(*c*) High resistance in parallel
(*d*) Low resistance in parallel

28. If the length of potentiometer wire is increased, then the length of the previously obtained balance point will

(*a*) Increase
(*b*) Decrease
(*c*) Remain unchanged
(*d*) Become two times

29. The figure shows a circuit diagram of a 'Wheat stone Bridge' to measure the resistance G of the galvanometer. The relation $\frac{P}{Q} = \frac{R}{G}$ will be satisfied only when



(*a*) The galvanometer shows a deflection when switch S is closed
(*b*) The galvanometer shows a deflection when switch S is open
(*c*) The galvanometer shows no change in deflection whether S is open or closed
(*d*) The galvanometer shows no deflection

30. The resistance of an ideal voltmeter is

(*a*) Zero (*b*) Very low
(*c*) Very large (*d*) Infinite

31. If an ammeter is connected in parallel to a circuit, it is likely to be damaged due to excess

(*a*) Current (*b*) Voltage
(*c*) Resistance (*d*) All the above

32. The resistance of an ideal ammeter is

(*a*) Infinite (*b*) Very high
(*c*) Small (*d*) Zero

33. The material of wire of potentiometer is

(*a*) Copper (*b*) Steel
(*c*) Manganin (*d*) Aluminium

34. To convert a galvanometer into a voltmeter, one should connect a

(*a*) High resistance in series with galvanometer
(*b*) Low resistance in series with galvanometer
(*c*) High resistance in parallel with galvanometer
(*d*) Low resistance in parallel with galvanometer

Answer Keys

1. (*a*)	**2.** (*c*)	**3.** (*a*)	**4.** (*c*)	**5.** (*d*)	**6.** (*a*)	**7.** (*a*)	**8.** (*b*)	**9.** (*d*)	**10.** (*a*)
11. (*c*)	**12.** (*a*)	**13.** (*b*)	**14.** (*a*)	**15.** (*a*)	**16.** (*b*)	**17.** (*b*)	**18.** (*b*)	**19.** (*d*)	**20.** (*b*)
21. (*a*)	**22.** (*c*)	**23.** (*a*)	**24.** (*c*)	**25.** (*c*)	**26.** (*c*)	**27.** (*a*)	**28.** (*a*)	**29.** (*c*)	**30.** (*d*)
31. (*a*)	**32.** (*d*)	**33.** (*c*)	**34.** (*a*)						

1. Number of electrons flowing per second

$\frac{n}{t} = \frac{i}{e} = \frac{4.8}{1.6 \times 10^{-19}} = 3 \times 10^{19}$

2. $v_d = \frac{J}{ne} \Rightarrow v_d \propto J$ (current density)

$J_1 = \frac{i}{A}$ and $J_2 = \frac{2i}{2A} = \frac{i}{A} = J_1$

$\therefore (v_d)_1 = (v_d)_2 = v$

3. $R \propto \ell^2 \Rightarrow \frac{\Delta R}{R} = \frac{2\Delta \ell}{\ell} \Rightarrow \frac{\Delta R}{R}\%$

$= 2 \times 0.1 = 0.2\%$

4. $R_1 \propto \frac{\ell}{A} \Rightarrow R_2 \propto \frac{2\ell}{2A} \Rightarrow R_2 \propto \frac{\ell}{A}$

$\therefore R_1 = R_2$

5. Resistivity is the property of the material. It does not depend upon size and shape.

6. Because with rise in temperature resistance of conductor increases, so graph between v and i become no linear.

7. $v_d = \frac{e}{m} \times \frac{v}{\ell}\tau$ or $v_d = \frac{e}{m}\frac{E\ell}{\ell}\tau$ (since $v = E\ell$)

$\therefore V_d \propto E$

8. Volume $= A\ell = 3$ $A = \frac{3}{\ell}$

Now $R = \rho\frac{\ell}{A} \Rightarrow 3 = \frac{\rho \times \ell}{\frac{3}{\ell}} = \frac{\rho\ell^2}{3}$

$\Rightarrow \ell^2 = \frac{9}{\rho} = \frac{3}{\sqrt{\rho}}$

9. charge = Current × Time

$= 5 \times 60 = 300$ C

10. The reciprocal of resistance is called conductance

11. For maximum power, external resistance = internal resistance. Hence, the internal resistance should be 2 Ω.

12. Since, both the resistors are same, therefore potential difference $= V + V = E \Rightarrow V = \frac{E}{2}$

13. Let the current in the circuit $= i = \frac{V}{R}$

Across the cell, $E = V + ir$

$\Rightarrow r = \frac{E-V}{i} = \frac{E-V}{\frac{V}{R}} = \left(\frac{E-V}{V}\right)R$

14. For maximum energy, we have

External resistance of the circuit

= Equivalent internal resistance of the circuit

i.e. $R = \frac{r}{2}$

15. Kirchhoff's first law is based on the law of conservation of charge.

16. Kirchhoff's second law is based on the law of conservation of energy.

17. Let the internal resistance of cell be r, then

$i = \frac{E}{R+r} \Rightarrow 15 = \frac{15}{0.04+r} \Rightarrow r = 0.06\Omega$

18. In parallel, equivalent resistance is low

$i = \frac{E}{R + \frac{r}{n}}$

19. Internal resistance ∝ distance $\propto \frac{1}{\text{Area}} \propto$ concentration

20. $i = \frac{E}{r} = \frac{6}{0.5} = 12$ amp

21. Kirchhoff's I law and II law of current, prove the conservation of charge and energy.

22. From kirchhoff's junction law

$\Rightarrow 4 + 2 + i - 5 - 3 = 0$

$\Rightarrow i = 2$ amp

23. In meter bridge experiment, it is assumed that the resistance of the L shaped plate is negligible, but actually it is not so. The error created due to this is called end error. To remove this the resistance box and the unknown resistance must be interchanged and then the mean reading must be taken.

24. To convert a galvanometer into an ammeter a low value resistance called shunt is to be connected in parallel to it.

25. Ammeter is used to measure the current through the circuit.

26. $S = \frac{i_g G}{(i - i_g)} = \frac{1 \times 0.018}{10-1} = \frac{0.018}{9} = 0.002\Omega$

27. To convert a galvanometer into a voltmeter, a high value resistance is to be connected in series with it.

28. When the length of potentiometer wire is increased, the potential gradient decrease and the length of previous balance point is increased

29. In balance condition, no-current will flow through the branch containing S. Hence, the galvanometer shows no change is deflection whether S is open or closed.

30. The resistance of an ideal voltmeter is considered as infinite.

31. When ammeter is connected in parallel to the circuit, net resistance of the circuit decreases. Hence. more current is drawn from the battery. which damages the ammeter.

32. The resistance of an ideal ammeter is zero.

33. Manganin and constantan are used for making the potentiometer wire.

34. To convert a galvanometer into a voltmeter one should connect a high resistance in series with galvanometer.

CHAPTER 4

Moving Charges and Magnetism

Magnetic Field Laws and their Applications

- The Oersted's law states that an electric current creates a magnetic field.
- The Biot Savart's law states that, the magnitude of magnetic field dB is proportional to the current I, the element length dl and inversely proportional to the square of the distance r. Its direction is perpendicular to the plane containing dl and r. Thus in vector notation, $dB \propto \frac{Idl \times r}{r^3}$, where $\frac{\mu_0}{4\pi}$ is the constant of proportionality and is equal to 10^{-7} Tm/A.

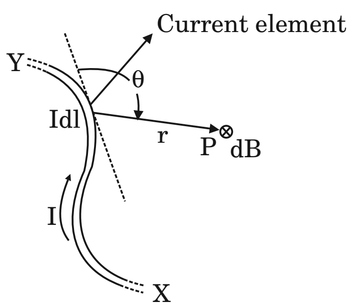


Fig.: Biot Savart's law

Applications of Biot-Savart's Law:

- Magnetic field at a point in circular loop will be

$$B = \frac{\mu_0 IR^2}{2\left(R^2 + x^2\right)^{\frac{3}{2}}}$$

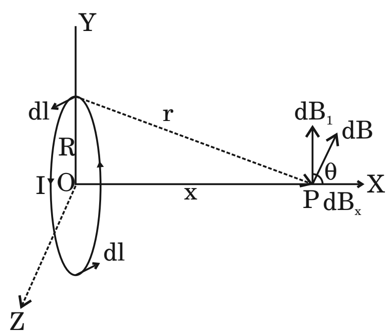


Fig.: Magnetic field at a point in circular loop

- Magnetic field at centre of the coil is $B = \frac{\mu_0 Ni}{2R}$ $(x = 0)$
- Magnetic field due to current carrying circular arc with centre O is $B = \frac{\mu_0 i}{4r}$
- If we curl the palm of our right hand around the circular wire with the fingers pointing in the direction of the current, the right hand thumb rule gives the direction of the magnetic field.
- ***Ampere's circuital law:*** The line integral of the magnetic field around some closed loop is equal to the times the algebraic sum of the currents which pass through the circular loop. For some circuital loop, C, $\oint_C B.dl = \mu_0 I$

Applications of Ampere's Law

Magnetic field due to current carrying solenoid, $B = \mu_0 nI$

At the end of a short solenoid, $B = \frac{\mu_0 nI}{2}$

- The magnetic force produced by a Solenoid as stated by Ampere's law is given as $F = \mu_0 nI$, where n is the number of turns of the wire per unit length, I is the current flowing through the wire and the direction is given using the right hand thumb rule.
- Due to a toroid a magnetic field is given as, $B = \frac{\mu_0 NI}{2\pi r}$ where 'N' is the number of turns of the toroid coil, I is the amount of current flowing and r is the radius of the toroid.
- Antiparallel currents repel and parallel currents attract.
- Magnetic moment on a rectangular current loop in a uniform magnetic field, m = NIA where m is the magnetic moment and N is the number of closely wounded turns and A is the area vector.

Lorentz Force and Cyclotron

- The electric field, E produced by the source of the field Q, is given as $E = \frac{Q\hat{r}}{(4\pi \in_0)r^2}$, where $\hat{r}$ is the unit vector and the field E is a vector field. A charge 'q' interacts with this field and experiences a force F, expressed as

$$F = qE = \frac{qQ\hat{r}}{(4\pi \in_0)r^2}$$

- In the presence of both electric field E(r) and magnetic field B(r) there is a point charge q (moving with a velocity v and located at 'r' at a given time t). The force on an electric charge 'q' due to both of them is written as

$F = q[E(r) + v \times B(r)] = F_{electric} + F_{magnetic}$. This force is called the Lorentz force.

- We can calculate the Lorentz force for a straight rod, if B is the external magnetic field by considering the straight rod as a collection of linear strips dl_j, where l is the length of the rod, j is the current density. Hence, the force can be calculated as $F = \sum_j Idl_j \times B$.

Cyclotron:

- It consists of two D's which are placed in a strong magnetic field. An oscillating electric field is applied from the oscillator which is parallel to the magnetic field.

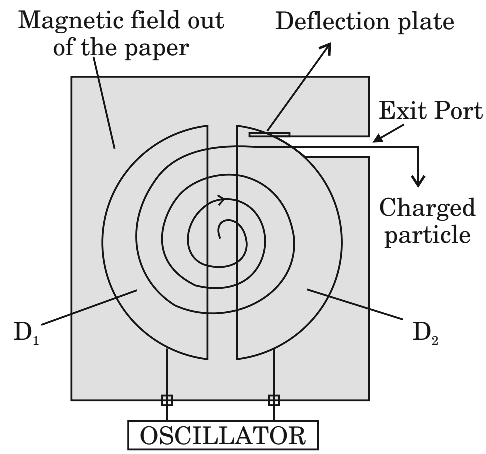


Fig.: Cyclotron

- The charged particle gets accelerated and moves in a circular path whose radius is given by $r = \frac{mv}{q_0 B}$
- The frequency of the cyclotron is given by $v = \frac{1}{T} = \frac{Bq}{2\pi m}$
- A charge of any type in uniform circular motion would have an associated magnetic moment given by $\mu_L = \frac{-e}{2m_e} l$, where l is the magnitude of angular momentum of electron.

$\frac{\mu_L}{l} = \frac{e}{2m_e} = 8.8 \times 10^{10} C / kg.$, and this ratio is called Gyro magnetic ratio.

Magnetic Force and Torque Between Two Parallel Currents

Force on a current-carrying conductor in a uniform magnetic field:

- The force on a current carrying conductor of length l in a uniform magnetic field B when θ is the angle between current and magnetic field can be calculated by $F = IB\ell \sin\theta$
- Fleming's Left-Hand Rule is used to find the direction of the magnetic force which is right angled to the plane containing conductor and magnetic field.

Force between two parallel current-carrying conductors:

Two parallel conductors carrying current experiences a force. When current flows in same direction, wire B experiences magnetic field due to wire A which is: $B_1 = \dfrac{\mu_o I I_1}{2\pi d}$

Force per unit length in the given wire is $\dfrac{F_2}{l} = \dfrac{\mu_o I_1 I_2}{2\pi d}$

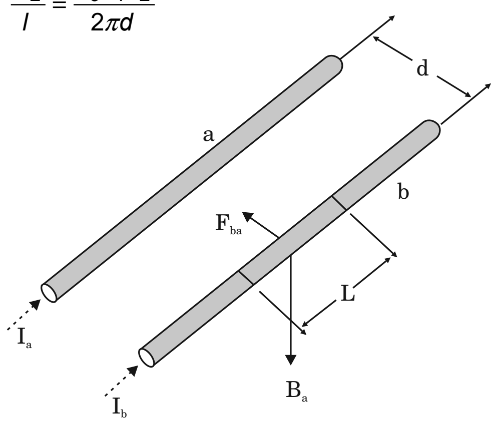


Fig.: Force between two parallel currents carrying conductores.

Torque experienced by a current loop in uniform magnetic field:

The torque experienced by a rectangular loop in uniform magnetic field B of length l, breadth b with current I lowing through it is:

$\tau = nBIA\sin\theta$

Moving coil galvanometer

- Its main use is to detect and measure small electric currents.
- The current carrying coil is suspended in a uniform magnetic field, so it produces a torque which is responsible for rotating the coil.

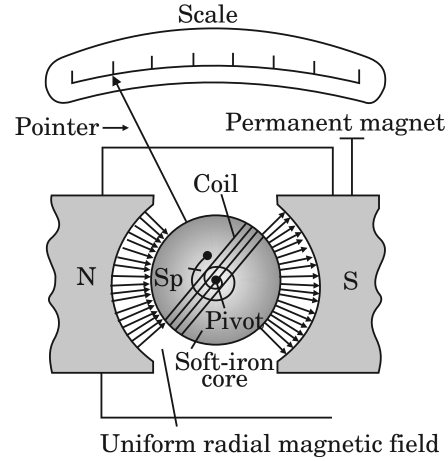


Fig.: Moving coil galvanometer

- The torque is given by $\tau = F \times b = nBIl \times b = BInA \sin\theta$

Current sensitivity of galvanometer

- When a galvanometer produces a large deflection for a small amount of current, it is said to be sensitive.
- The voltage sensitivity of galvanometer is deflection per unit voltage and is given as $\dfrac{\theta}{I} = \dfrac{nBA}{C}$

Conversion of galvanometer into ammeter

A small resistance called a Shunt resistance is attached with the galvanometer coil in parallel so that most of the current passes through the shunt resistance.

Conversion of galvanometer into voltmeter

A high resistance is connected in series with the galvanometer coil so that the galvanometer acts as a voltmeter.

Exercise

1. If a copper rod carries a direct current, the magnetic field associated with the current will be
   (*a*) Only inside the rod
   (*b*) Only outside the rod
   (*c*) Both inside and outside the rod
   (*d*) Neither inside nor outside the rod

2. If a long hollow copper pipe carries a direct current, the magnetic field associated with the current will be
   (*a*) Only inside the pipe
   (*b*) Only outside the pipe
   (*c*) Neither inside nor outside the pipe
   (*d*) Both inside and outside the pipe

3. Vector form of Biot-savart's law is
   (*a*) $d\vec{B} = \frac{\mu_o}{4\pi} i \left(\frac{d\vec{\ell} \times \vec{r}}{r} \right)$ (*b*) $d\vec{B} = \frac{\mu_o}{4\pi} i^2 \left(\frac{d\vec{\ell} \times \vec{r}}{r} \right)$
   (*c*) $d\vec{B} = \frac{\mu_o}{4\pi} i^2 \left(\frac{d\vec{\ell} \times \vec{r}}{r^2} \right)$ (*d*) $d\vec{B} = \frac{\mu_o}{4\pi} i \left(\frac{d\vec{\ell} \times \vec{r}}{r^3} \right)$

4. A charge a moves in a circle at n revolutions per second and the radius of the circle is r meter. The magnetic field at the centre of the circle is
   (*a*) $\frac{2\pi q}{nr} \times 10^{-7}$ N/A-m
   (*b*) $\frac{2\pi q}{r} \times 10^{-7}$ N/A-m
   (*c*) $\frac{2\pi nq}{r} \times 10^{-7}$ N/A-m
   (*d*) $\frac{2\pi q}{r}$ N/A-m

5. A helium nucleus makes a full rotation in a circle of radius 0.8 m in two seconds. The value of the magnetic field B at the centre of the circle will be
   (*a*) $\frac{10^{-19}}{\mu_o}$ (*b*) $10^{-19}\mu_o$
   (*c*) $2 \times 10^{-10}\mu_o$ (*d*) $\frac{2 \times 10^{-10}}{\mu_o}$

6. Field at the centre of a circular coil of radius r, through which a current I flows is
   (*a*) Directly proportional to r
   (*b*) Inversely proportional to I
   (*c*) Directly proportional to I
   (*d*) Directly Proportional to I^2

7. The magnetic field B with in the solenoid having n turns per metre length and carrying a current of i ampere is given by
   (*a*) $\frac{\mu_o ni}{e}$ (*b*) $\frac{\mu_o ni}{1}$
   (*c*) $4\pi\mu_o ni$ (*d*) ni

8. Magnetic effect of current was discovered by
   (*a*) Faraday (*b*) Oersted
   (*c*) Ampere (*d*) Bohr

9. The direction of magnetic lines of forces close to a straight conductor carrying current will be
   (*a*) Along the length of the conductor
   (*b*) Radially outward
   (*c*) Circular in a plane perpendicular to the conductor
   (*d*) Helical

10. A current carrying wire in the neighborhood produces
    (*a*) No field
    (*b*) Electric field only
    (*c*) Magnetic field only
    (*d*) Electric and magnetic fields

11. A magnetic field can be produced by
    (*a*) A moving charge
    (*b*) A charging electric field
    (*c*) None
    (*d*) Both of these

12. The magnetic moment of a current (i) carrying circular coil of radius (r) and number of turns (n) varies as
    (*a*) $\frac{1}{r^2}$ (*b*) $\frac{1}{r}$
    (*c*) r (*d*) r^2

13. The radius of curvature of the path of the charged particle in a uniform magnetic field is directly proportional to
    (*a*) The charge on the particle
    (*b*) The momentum of the particle
    (*c*) The energy of the particle
    (*d*) The intensity of the field

14. A charged particle moving in a magnetic field experiences a resultant force
    (*a*) In the direction of field
    (*b*) In the direction opposite to the field
    (*c*) In the direction perpendicular to both the field and its velocity
    (*d*) None of these

15. A proton is moving along z-axis in a magnetic field. The magnetic field is along x-axis. The proton will experience a force along

(*a*) x-axis (*b*) y-axis

(*c*) z-axis (*d*) Negative z-axis

16. A strong magnetic field is applied on a stationary electron, then

(*a*) The electron moves in the direction of the field

(*b*) The electron moves in an opposite direction

(*c*) The electron remains stationary

(*d*) The electron starts spinning

17. A charged particle is moving with velocity v is a magnetic field of induction B. The force on the particle will be maximum when

(*a*) v and B are in the same direction

(*b*) v and B are in opposite direction

(*c*) v and B are perpendicular

(*d*) v and B are at an angle of 45°

18. In a cyclotron, the angular frequency of a charged particle is independent of

(*a*) Mass (*b*) Speed

(*c*) Charge (*d*) Magnetic field

19. Maximum kinetic energy of the positive ion in the cyclotron in

(*a*) $\frac{q^2Br_o}{2m}$ (*b*) $\frac{qB^2r_o}{2m}$

(*c*) $\frac{q^2B^2r_o^2}{2m}$ (*d*) $\frac{qBr_o}{2m^2}$

20. When a charged particle enters a uniform magnetic field, its kinetic energy

(*a*) Remains constant (*b*) Increase

(*c*) Decrease (*d*) Becomes zero

21. The cyclotron frequency of an electron granting in a magnetic field of 1 T is approximately

(*a*) 28 MHz (*b*) 280 MHz

(*c*) 2.8 GHz (*d*) 28 GHz

22. An electron, moving in a uniform magnetic field of induction of intensity $\vec{B}$, has its radius directly proportional to

(*a*) Its charge (*b*) Magnetic field

(*c*) Speed (*d*) None of these

23. Two free parallel wires carrying currents in opposite direction

(*a*) Attract each other

(*b*) Repel each other

(*c*) Neither attract nor repel

(*d*) Get rotated to be perpendicular to each other

24. The radius of a circular loop is r and a current i is flowing in it. The equivalent magnetic moment will be

(*a*) ir (*b*) $2\pi ir$

(*c*) $i\pi r^2$ (*d*) $\frac{1}{r^2}$

25. A current carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon

(*a*) Shape of the loop (*b*) Area of the loop

(*c*) Value of the current (*d*) Magnetic field

26. The deflection in a moving coil galvanometer is

(*a*) Directly proportional to the torsional constant

(*b*) Directly proportional to the number of turns in the coil

(*c*) Inversely proportional to the area of the coil

(*d*) Inversely proportional to the current flowing

27. In a moving coil galvanometer, the deflection of the coil θ is related to the electrical current i by the relation

(*a*) $i \propto \tan\theta$ (*b*) $i \propto \theta$

(*c*) $i \propto \theta^2$ (*d*) $i \propto \sqrt{\theta}$

28. A moving coil galvanometer has N number of terms in a coil of effective area A, it carries a current I. The magnetic field B is radial. The torque acting on the coil is

(*a*) NA^2B^2I (*b*) $NABI^2$

(*c*) N^2ABI (*d*) NABI

29. A small coil of N turns has area A and a current I flows through it. The magnetic dipole moment of this coil will be

(*a*) $\frac{NI}{A}$ (*b*) NI^2A

(*c*) N^2AI (*d*) NIA

30. If a current is passed in a spring , it

(*a*) Gets compressed (*b*) Gets expanded

(*c*) Oscillates (*d*) Remainsunchanged

31. A circular coil of diameter 7 cm has 24 turns of wire carrying current of 0.75 A. The magnetic moment of the coil is

(*a*) 6.9×10^{-2} amp–m^2 (*b*) 2.3×10^{-2} amp– m^2

(*c*) 10^{-2} amp–m^2 (*d*) 10^{-3} amp–m^2

32. If the current is doubled, the deflection is also doubled in

(*a*) A tangent galvanometer

(*b*) A moving coil galvanometer

(*c*) Both (*a*) and (*b*)

(*d*) None

Answer Keys

1. (*c*)	**2.** (*b*)	**3.** (*d*)	**4.** (*c*)	**5.** (*b*)	**6.** (*c*)	**7.** (*b*)	**8.** (*b*)	**9.** (*c*)	**10.** (*c*)
11. (*d*)	**12.** (*d*)	**13.** (*b*)	**14.** (*c*)	**15.** (*b*)	**16.** (*c*)	**17.** (*c*)	**18.** (*b*)	**19.** (*c*)	**20.** (*a*)
21. (*d*)	**22.** (*c*)	**23.** (*b*)	**24.** (*c*)	**25.** (*a*)	**26.** (*b*)	**27.** (*b*)	**28.** (*d*)	**29.** (*d*)	**30.** (*a*)
31. (*a*)	**32.** (*b*)								

Solutions

1. The magnetic field associated with the current will be lies inside as well as outside of the rod

2. Because for inside the pipe i = 0

$$\therefore B = \frac{\mu_o i}{2\pi r} = 0$$

3. $dB = \frac{\mu_o}{4\pi} \cdot \frac{i d\ell \sin\theta}{r^2}$

$$\Rightarrow d\vec{B} = \frac{\mu_o}{4\pi} \cdot \frac{i\left(d\vec{\ell} \times \vec{r}\right)}{r^3}$$

4. The magnetic field at the centre of the circle

$$= \frac{\mu_o}{4\pi} \times \frac{2\pi i}{r} = 10^{-7} \times \frac{2\pi(nq)}{r}$$

$$= \frac{2\pi nq}{r} \times 10^{-7} N/A-m$$

5. $i = \frac{q}{T} = \frac{2 \times 1.6 \times 10^{-19}}{2} = 1.6 \times 10^{-19} A$

$$\therefore B = \frac{\mu_o i}{2r} = \frac{\mu_o \times 1.6 \times 10^{-19}}{2 \times 0.8} = \mu_o \times 10^{-19}$$

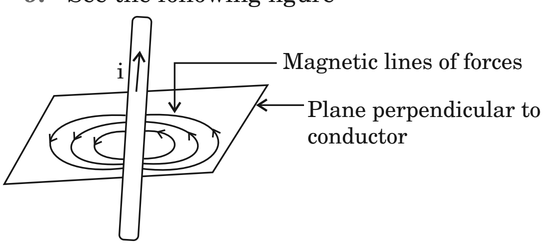
6. Field at the centre of a circular coil of radius r is $B = \frac{\mu_o I}{2r}$

$\therefore B \propto I$

7. Magnetic field inside the solenoid $B_{in} = \mu_o ni$

8. Magnetic effect of current was discovered by oersted.

9. See the following figure



10. A current carrying wire in the neighborhood produces magnetic field only.

11. A moving charge and charging electric field both produce magnetic field.

12. $M = niA = ni(\pi r^2) \Rightarrow M \propto r^2$

13. $r = \frac{p}{qB} \Rightarrow r \propto p$

14. $\vec{F} = q\vec{v} \times \vec{B}$

15. This is according to the cross product $\vec{F} = q\left(\vec{v} \times \vec{B}\right)$ otherwise can be evaluated by the left-hand rule of fleming.

16. Magnetic force acts on a moving charge.

17. Lorentz force $F = q(\nu \times B)$ or $|F| = q\,\nu\, B \sin\theta$. F will be maximum when $\theta = 90°$

18. $w = \frac{2\pi}{T} = \frac{qB}{m} \Rightarrow w \propto \nu^o \left(\because T = \frac{2\pi m}{qB}\right)$

19. $K_{max} = \frac{1}{2}m\nu^2$ and $r_o = \frac{m\nu}{qB} \Rightarrow \nu = \frac{qBr_o}{m}$

$$\Rightarrow K_{max} = \frac{1}{2}m\left(\frac{qBr_o}{m}\right)^2 = \frac{q^2B^2r_o{}^2}{2m}$$

20. Since $\vec{F}$ and $\vec{v}$ are perpendicular to each other work done by force is zero. Hence K.E. is constant

21. Cyclotron frequency

$$\nu = \frac{Bq}{2\pi m} = \frac{1 \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}}$$

$= 2.79 \times 10^{10}$ Hz

$= 27.9 \times 10^{9}$ Hz = 28 GHz

22. $r = \frac{m\nu}{qB} \Rightarrow r \propto \nu$

23. Two wires, if carry current in opposite direction, repel each other.

24. The equivalent magnetic moment $M = i\pi r^2$

25. The torque acting on it does not depend upon the shape of the loop because $\tau = NiAB \cos\theta$

26. $\theta = \dfrac{NiAB}{C} \Rightarrow \theta \propto N$ (Number of turns)

27. $i = \dfrac{C\theta}{NAB} \Rightarrow i \propto \theta$

28. $\tau = MB \sin\theta \Rightarrow \tau_{max} = NiAB$ ($\theta = 90°$)

$\therefore$ The torque acting on the coil is NABI.

29. Magnetic dipole moment of coil = NIA

30. When current is passed through a spring, it gets compressed.

31. $M = NiA = 24 \times 0.75 \times 3.14 \times (3.5 \times 10^{-2})^2$

$= 6.9 \times 10^{-2}$ A–m^2

32. In moving coil galvanometer $i \propto \theta$.

CHAPTER 5

Magnetism and Matter

Magnetic Dipole and Magnetic Field Lines

Magnetism:

- Magnetic phenomena are universal in nature. Magnetism is a physical phenomenon produced by the motion of electric charge, which results in attractive and repulsive forces between objects.
- The magnetic field of the Earth points from geographical south to the north.
- A bar magnet always points in the north-south direction when suspended freely.
- When same poles of two magnets are brought close to each other, a repulsive force is experienced. When Opposite poles of two magnets are brought close, then an attractive force is experienced.

Bar Magnet:

Iron fillings sprinkled on a glass plate kept over a short bar magnet arrange themselves in a pattern. It shows that the magnet has two poles in the same way as the positive and negative charge of an electric dipole called as the North and the South pole.

Magnetic field lines: The magnetic field lines of a bar magnet form continuous closed loops. The direction of net magnetic field at any point is determined by the tangent to the field line at that point. The magnitude of the magnetic field will be stronger for the area from which more number of field lines are passing. The magnetic field lines never intersect each other.

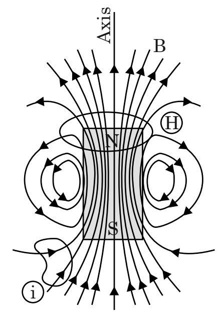


Fig: Magnetic field lines in a bar magnet

- **Bar magnet as an equivalent solenoid:** The magnetic field B due to bar magnet of size l and magnetic moment m which is at a distance r from the mid-point when r >> l, is given by

$$B = \frac{\mu_0 2m}{4\pi r^3} \qquad \text{(Along axis)}$$

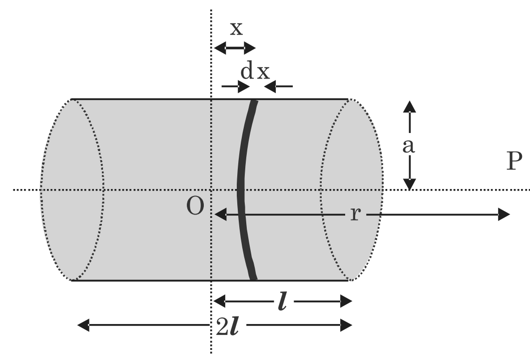


Fig: Bar magnet as an equivalent solenoid

- Dipole in a uniform magnetic field: When a bar magnet is having a dipole moment m and it is placed in uniform magnetic field B,

  The force acting on it is equal to 0.

  The torque acting on the magnet is m × B

  It has a potential energy of –m.B

Gauss's law for magnetic fields:

It states that the magnetic flux through any closed loop is equal to zero.

$$\phi_B = \sum_{all} \Delta\phi_B = \sum_{all} B.\Delta S = 0$$

Earth's Magnetism and Magnetic Properties of Material

Earth's Magnetism:

- The earth's magnetism is of the order of 10^{-5} T. Its strength is different at different place. The pole near to geographic north pole is called the north magnetic pole and the pole near to geographic south pole is called south magnetic pole. The magnetic of the field on the earth's surface is 4×10^{-5} T.
- There are three elements of the earth's magnetic field which are used to specify the magnetic field of earth's surface – the horizontal component, the magnetic declination and the magnetic dip.
- The magnetic field of a bar magnet tilted 11° from the spin axis of Earth is in the same direction as the Earth's magnetic field.

Magnetization and magnetic field:

- The magnetization M is equal to its magnetic moment per unit volume

  $$M = \frac{m_{net}}{V}$$

- The magnetic intensity H is defined as the amount of magnetic flux in a unit area perpendicular to the direction of magnetic fow.

  $$H = \frac{B_0}{\mu_0}$$

- The magnetic field B in the material is given by, $B = \mu_0(H + M)$
- The degree of magnetization of a material in response to an applied magnetic field is denoted as magnetic susceptibility. It is given by

  $$\chi = \frac{M}{H}$$

  So, $\mu = \mu_0\mu_r$

  Where $\mu_r = 1 + \chi$

Magnetic properties of materials:

Magnetic Materials are broadly classified as paramagnetic, diamagnetic and ferromagnetic materials. For paramagnetic materials χ is positive and is small, for diamagnetic materials χ is negative and lies between 0 and -1 and for ferromagnetic materials χ is positive and large.

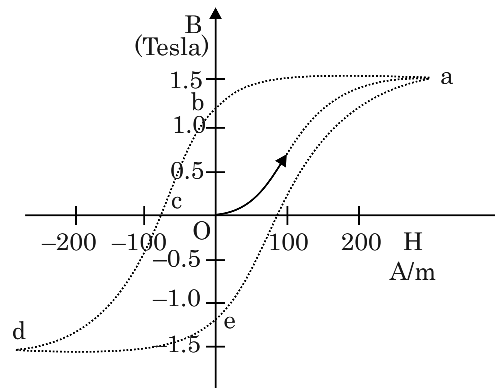


Fig: Magnetic hysteresis loop

The magnetic hysteresis loop is the B-H curve for ferromagnetic materials

Curie's law:

The intensity of magnetization I of a paramagnetic material varies directly to the strength of the external magnetic field H, called magnetizing field and is inversely proportional to absolute temperature of the material.

$\chi = \frac{C}{T}$ where C is Curie constant.

Property	*Ferromagnetic*	*Diamagnetic*	*Paramagnetic*
Effect of magnets	*They are strongly attracted by magnets.*	*They are feebly repelled by magnets.*	*They are feebly attracted by magnets.*
Susceptibility value χ_m	*Large and positive* $\chi_m > 1000$	*Small and negative*	*Small and positive*
Permeability value	$\mu >> \mu_0$	$\mu < \mu_0$	$\mu < \mu_0$
In a uniform magnetic field	*Freely suspended rod aligns itself parallel to the field.*	*Freely suspended rod aligns itself perpendicular to the field.*	*Freely suspended rod aligns itself parallel to the field.*
Relative permeability value	*It is greater than 1000.*	*Slightly less than 1.*	*Slightly greater than 1.*
Effect of temperature	*Susceptibility decreases with temperature.*	*Susceptibility is independent of temperature.*	*Susceptibility varies inversely with temperature.*
Physical state of the material	*Solids only.*	*Solid, liquid or gas.*	*Solid, liquid or gas.*
Hysteresis effect	*Shows hysteresis*	*Does not show hysteresis.*	*Does not show hysteresis.*
Removal of magnetic field	*Magnetization retain even on removal of magnetic field.*	*Magnetization is only for the time magnetic field is applied.*	*Magnetization is only for the time magnetic field is applied.*
Examples	*Fe, Ni, Gd, Co*	*Bi, Si, Cu, Pb*	*Al, Ca, Na*

Ferromagnetic materials show the property of hysteresis.

Permanent magnets:

- Permanent magnets are those substances which at room temperature retain their ferromagnetic property.
- An iron rod held in north-south direction and if it is hammered repeatedly it will become a permanent magnet.
- It can also be made by placing a ferromagnetic rod in a solenoid and passing current through it. The rod gets magnetized by the magnetic field of the solenoid.
- A material having high permeability, high coercivity, and high retentivity could be suitable for permanent magnets.

Electromagnets:

- A solenoid having a core of iron with wire wrapped around it is called an electromagnet.
- Ferromagnetic materials are used for core of electromagnets.
- Some of the applications of electromagnets are loudspeakers, electric bells, telephone diaphragms.

Exercise

1. Magnetic intensity for an axial point due to a short bar magnet of magnetic moment M is given by

   (a) $\frac{\mu_o}{4\pi} \times \frac{M}{d^3}$ (b) $\frac{\mu_o}{4\pi} \times \frac{M}{d^2}$

   (c) $\frac{\mu_o}{2\pi} \times \frac{M}{d^3}$ (d) $\frac{\mu_o}{2\pi} \times \frac{M}{d^2}$

2. A magnet is placed in iron powder and then taken out, then maximum iron powder is at
   (a) Some away from north pole
   (b) Some away from south pole
   (c) The middle of the magnet
   (d) The end of the magnet

3. The field due to a magnet at a distance R from the centre of the magnet is proportional to

   (a) R^2 (b) R^3

   (c) $\frac{1}{R^2}$ (d) $\frac{1}{R^3}$

4. Force between two unit pole strength placed at a distance of one metre is

   (a) 1 N (b) $\frac{10^{-7}}{4\pi}$N

   (c) 10^{-7} N (d) $4\pi \times 10^{-7}$ N

5. Magnetic lines of force
   (a) Always intersect
   (b) Are always closed
   (c) Tend to crowd far away from the poles of magnet
   (d) Do not pass through vacuum

6. The direction of lines of magnetic field of bar magnet is
   (a) From south pole to north pole
   (b) From north pole to south pole
   (c) Across the bar magnet
   (d) From south pole to north pole inside the magnet and from north pole to south pole outside the magnet

7. Magnetic lines of force due to a bar magnet do not intersect because
   (a) A point always has a single net magnetic field
   (b) The lines have similar charges and so repel each other
   (c) The lines always diverge from a single point
   (d) The lines need magnetic lenses to be made to intersect

8. A straight wire carrying current i is turned into a circular loop. If the magnitude of magnetic moment associated with it in M.K.S unit is M, the length of wire will be

   (a) $4\pi iM$ (b) $\sqrt{\frac{4\pi M}{i}}$

   (c) $\sqrt{\frac{4\pi i}{M}}$ (d) $\frac{M\pi}{4i}$

9. A bar magnet of magnetic moment $\vec{M}$ is placed in a magnetic field of induction $\vec{B}$. The torque exerted on it is

   (a) $\vec{M} . \vec{B}$ (b) $-\vec{M} . \vec{B}$

   (c) $\vec{M} \times \vec{B}$ (d) $\vec{B} \times \vec{M}$

10. The intensity of magnetic field is H and moment of magnet is M. The maximum potential energy is

    (a) MH (b) 2MH

    (c) 3 MH (d) 4 MH

11. Two lines of force due to a bar magnet
    (a) Intersect at the neutral point
    (b) Intersect near the poles of the magnet
    (c) Intersect on the equatorial axis of the magnet
    (d) Do not intersect at all

12. If a magnet is hanged with its magnetic axis then it stops in
    (a) Magnetic meridian
    (b) Geometric meridian
    (c) Angle of dip
    (d) None of these

13. Magnetic dipole moment is
    (a) Scalar quantity
    (b) Vector quantity
    (c) Constant quantity
    (d) None of these

14. The magnetic potential at a point on the axial line of a bar magnet of dipole moment M is V. What is the magnetic potential due to a bar magnet of dipole moment $\frac{M}{4}$ at the same point

    (a) 4 V (b) 2 V

    (c) $\frac{V}{2}$ (d) $\frac{V}{4}$

15. Earth's magnetic field always has a horizontal component except at or Horizontal component of earth's magnetic field remains zero at
(*a*) Equator
(*b*) Magnetic poles
(*c*) A latitude of 60°
(*d*) An altitude of 60°

16. At magnetic poles of earth, angle of dip is
(*a*) zero (*b*) 45°
(*c*) 90° (*d*) 180°

17. The correct relation is
(*a*) $B = \frac{B_V}{B_H}$ (*b*) $B = B_V \times B_H$
(*c*) $|B| = \sqrt{B_H^2 + B_V^2}$ (*d*) $B = B_H + B_V$

18. The north pole of the earth's magnet is near the geographical
(*a*) South (*b*) Earth
(*c*) West (*d*) North

19. At which place, earth's magnetism becomes horizontal
(*a*) Magnetic pole
(*b*) Geographical pole
(*c*) Magnetic meridian
(*d*) Magnetic equator

20. At the magnetic poles of the earth, a compass needle will be
(*a*) Vertical
(*b*) Horizontal
(*c*) Bent slightly
(*d*) Inclined at 45° to the horizontal

21. Magnets cannot be made from which of the following substances
(*a*) Iron (*b*) Nickel
(*c*) Copper (*d*) All of the above

22. The magnetic moment of atomic neon is
(*a*) zero (*b*) $\frac{\mu B}{2}$
(*c*) μ B (*d*) $\frac{3\mu B}{2}$

23. Which of the following is most suitable for the core of electromagnets
(*a*) Soft iron (*b*) Steel
(*c*) Copper-nickel alloy (*d*) Air

24. Demagnetisation of magnets can be done by
(*a*) Rough handling
(*b*) Heating
(*c*) Magnetising in the opposite direction
(*d*) All the above

25. The permanent magnet is made from which one of the following substances
(*a*) Diamagnetic
(*b*) Para magnetic
(*c*) Ferromagnetic
(*d*) Electromagnetic

26. The only property possessed by ferromagnetic substance is
(*a*) Hysteresis
(*b*) Susceptibility
(*c*) Directional property
(*d*) Attracting magnetic substances

27. Diamagnetic substances are
(*a*) Feebly attracted by magnets
(*b*) Strongly attracted by magnets
(*c*) Feebly repelled by magnets
(*d*) Strongly repelled by magnets

28. The magnetic susceptibility is
(*a*) $\chi = \frac{I}{H}$ (*b*) $\chi = \frac{B}{H}$
(*c*) $\chi = \frac{M}{V}$ (*d*) $\chi = \frac{M}{H}$

29. An example of a diamagnetic substance is
(*a*) Aluminium (*b*) Copper
(*c*) Iron (*d*) Nickel

Answer Keys

1. (*c*)	**2.** (*d*)	**3.** (*d*)	**4.** (*c*)	**5.** (*b*)	**6.** (*d*)	**7.** (*a*)	**8.** (*b*)	**9.** (*c*)	**10.** (*a*)
11. (*d*)	**12.** (*a*)	**13.** (*b*)	**14.** (*d*)	**15.** (*b*)	**16.** (*c*)	**17.** (*c*)	**18.** (*a*)	**19.** (*d*)	**20.** (*c*)
21. (*c*)	**22.** (*a*)	**23.** (*a*)	**24.** (*d*)	**25.** (*c*)	**26.** (*a*)	**27.** (*c*)	**28.** (*a*)	**29.** (*b*)	

1. Magnetic intensity $B_a = \frac{\mu_o}{4\pi}\frac{2M}{d^3} = \frac{\mu_o}{2\pi}\frac{M}{d^3}$

2. A magnet is placed in iron powder and then taken out, then maximum iron powder is at the end of the magnet.

3. Provided length of the magnet is < < the distance.

4. $F = 10^{-7} \times \frac{m^2}{r^2} = \frac{10^{-7}(1)^2}{(1)^2} = 10^{-7}N$

5. Magnetic lines of force are always closed.

6. The direction of lines of magnetic field of bar magnet is from south pole to north pole inside the magnet and from north pole to south pole outside the magnet.

7. Magnetic lines of force due to a bar magnet do not intersect because a point always has a single net magnetic field.

8. Magnetic moment of circular loop carrying current $M = IA = I(\pi R^2) = I\pi\left(\frac{L}{2\pi}\right)^2 = \frac{IL^2}{4\pi}$

$\therefore \quad L = \sqrt{\frac{4\pi M}{I}}$

9. The torque exerted = $\vec{M} \times \vec{B}$

10. Potential energy $U = -MB \cos\theta$

$\Rightarrow U_{max} = MH$ (at $\theta = 180°$)

11. Two lines of force due to a bar magnet do not intersect at all.

12. If a magnet is hanged with its magnetic axis then it stops in magnetic meridian.

13. Magnetic dipole moment is a vector quantity.

14. Magnetic potential at a distance d from the bar magnet on its axial line is given by

$$v = \frac{\mu_o}{4\pi}\cdot\frac{M}{d^2} \Rightarrow v \propto M \Rightarrow \frac{v_1}{v_2} = \frac{M_1}{M_2}$$

$$\Rightarrow \frac{v}{v_2} = \frac{M}{\frac{M}{4}} \Rightarrow v_2 = \frac{v}{4}$$

15. At magnetic poles, the angle of dip is 90°. Hence, the horizontal component $B_H = B\cos\theta = 0$

16. At magnetic poles of earth, angle of dip is 90°.

17. The correct relation is

$|B| = \sqrt{B_H^2 + B_V^2}$

18. The north pole of the earth's magnet is near the geographical south.

19. At magnetic equator, angle of dip is zero.

20. At the magnetic poles of the earth, a compass needle will be bent slightly.

21. Magnets cannot be made from copper.

22. Neon atom is diamagnetic, hence it's net magnetic moment is zero.

23. Soft iron is highly ferromagnetic.

24. Demagnetisation of magnets can be done by rough handling, Heating and magnetising in the opposite direction.

25. The permanent magnet is made from ferromagnetic

26. The only property possessed by ferromagnetic substance is hysteresis.

27. Diamagnetic substances are feebly repelled by magnets.

28. The magnetic susceptibility $\chi = \frac{I}{H}$

29. An example of a diamagnetic substance is copper.

CHAPTER 6

Electromagnetic Induction

Electromagnetic Induction Laws

- Electromagnetic Induction is the one in which by which electric current is generated with the help of a magnetic field.
- ***The Experiments of Faraday and Henry***

  The observations from the experiments of Faraday and Henry concluded that it is the relative motion between the magnet and the coil that is responsible for generation or induction of the electric current in the coil.
- ***Magnetic Flux***

  It is the amount of field lines cutting through a surface area A defined by unit area vector. The magnetic flux that passes through a plane of area A and has a uniform magnetic field B, is given by, ϕ_B = B.A = BA cosθ where θ is the angle between magnetic field B and Area A. Magnetic flux is a scalar quantity and its SI unit is weber.

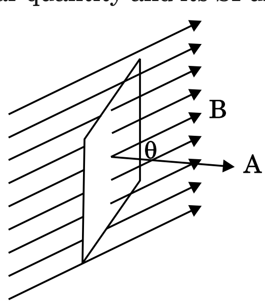


Fig. Field lines in a magnetic field

Faraday's Law of Induction

- **Faraday's First Law:** Whenever a conductor is placed in a varying magnetic field, there is an induced emf and if the conductor circuit is closed, there is an induced current.
- Faraday's Second Law: This law of electromagnetic induction states that the magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit. Mathematically, the induced emf is given by $\varepsilon = \frac{-d\,\phi_B}{dt}$, the negative sign indicates direction of the induced emf and hence the direction in a closed loop.

Lenz's law and Conservation of Energy

The Lenz's law states that the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

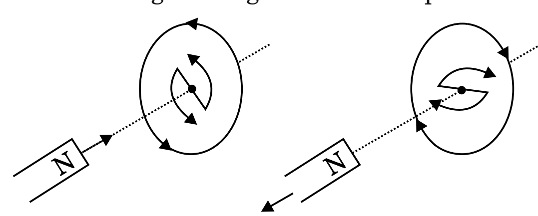


Fig. Lenz's law

Motional Electromotive Force

The relationship between induced emf and a wire moving at a constant speed v is given by ε = Blv

Energy Consideration: A Quantitative Study

- 'r' is the resistance of the movable arm PQ of the rectangular conductor. Assume that remaining arms QR, RS, SP have negligible resistance compared to r. In the presence of magnetic field there will be a force on the arm AB. This force I(l × B) is outwards directed in a direction opposite to the velocity of rod.
- Magnitude of force is $F = IlB = \frac{B^2 l^2 v}{r}$.
- Magnitude to push arm PQ $= Fv = \frac{B^2 l^2 v^2}{r}$

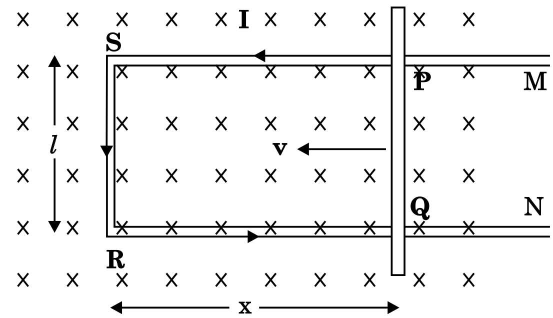


Fig. Energy Consideration in a Magnetic field

Eddy currents, self and mutual inductance

Eddy Currents

- When bulk pieces of conductors are subjected to changing magnetic flux then induced currents are produced in them which are called as eddy currents.
- Eddy currents create a significant drag known as magnetic damping.
- The applications of eddy currents are in magnetic braking in trains, electromagnetic damping, electric power meters and induction furnace.

Inductance

- Flux change produced by another coil in the close proximity of a coil or flux exchange produced by the same coil induces electric current.
- The inductance in series is given by $L_s = L_1 + L_2 + L_3 + \ldots\ldots\ldots\ldots$
- The inductance in parallel is given by $\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots\ldots\ldots\ldots$

Mutual- Inductance

- When the emf is induced into the adjacent coil situated within the same magnetic field, the emf is said to be induced magnetically or by mutual induction.
- Mutual inductance of a pair of coils, solenoids etc. depends on their relative orientation as well as their separation.

$$\varepsilon_1 = -M \frac{dI_2}{dt}$$

- Mutual Inductance of two coils is given by $M = \frac{\mu_0 \mu_r N_p N_s A_s}{l_p}$ where A_p, A_s are the cross sectional areas of primary and secondary coil in m^2, I is the coil current and N_s, N_p are the number of turns of secondary and primary coils respectively.

Self – Inductance

- The production of induced emf in a circuit when the current changes in the same circuit is called self-induction.
- The induced emf is given by $\varepsilon = -L \frac{dI}{dt}$, where is the coefficient of self-induction.
- The direction of induced emf is given by Lenz's Law.

AC Generator

- The electromagnetic induction has its applications in an AC generator, where mechanical energy is converted to electrical energy.

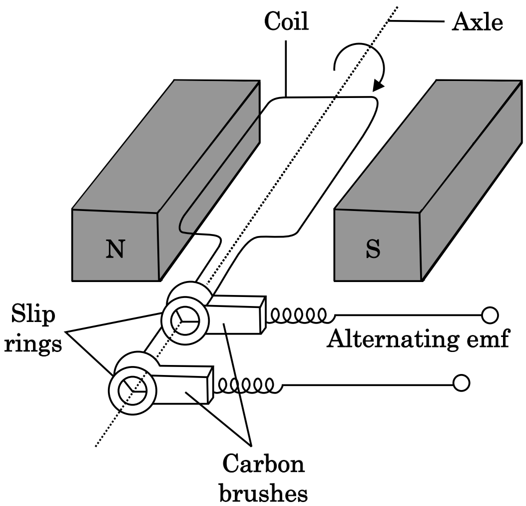


Fig. A.C. Generator

- The motional emf is of a coil with N turns and area A, rotated at v revolutions per second in a uniform magnetic field B is given as, $\varepsilon = -NBA\frac{d}{dt}(\cos \omega t)$

Exercise

1. In electromagnetic induction, the induced e.m.f. in a coil is independent of
(*a*) Change in the flux
(*b*) Time
(*c*) Resistance of the circuit
(*d*) None of these

2. Lenz's law is consequence of the law of conservation of
(*a*) Charge (*b*) Momentum
(*c*) Mass (*d*) Energy

3. In electromagnetic induction, the induced charge in a coil is
(*a*) Change in the flux
(*b*) Time
(*c*) Resistance in the circuit
(*d*) None of these

4. The magnetic flux linked with a coil is given by an equation $\phi = 8t^2 + 3t + 5$. The induced e.m.f. in the coil at the fourth second will be
(*a*) 16 units (*b*) 39 units
(*c*) 67 units (*d*) 145 units

5. The direction of induced e.m.f. during electromagnetic induction is given by.
(*a*) Faraday's law (*b*) Lenz's law
(*c*) Maxwell's law (*d*) Ampere's law

6. According to Faraday's law of electromagnetic induction
(*a*) The direction of induced current is such that it opposes the cause producing it
(*b*) The magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux.
(*c*) The direction of induced e.m.f. is such that it opposes the cause producing it
(*d*) None of these

7. Lenz's law gives
(*a*) The magnitude of the induced e.m.f.
(*b*) The direction of the induced current
(*c*) Both the magnitude and direction of the induced current
(*d*) The magnitude of the induced current

8. Faraday's laws are consequences of conservation of
(*a*) Energy
(*b*) Energy and Magnetic field
(*c*) Charge
(*d*) Magnetic field

9. Lenz's law is expressed by the following formula (here e = induced e.m.f., ϕ = magnetic flux in one turn and N = number of turns)

(*a*) $e = -\phi\frac{dN}{dt}$ (*b*) $e = -N\frac{d\phi}{dt}$

(*c*) $e = -\frac{d}{dt}\left(\frac{\phi}{N}\right)$ (*d*) $e = N\frac{d\phi}{dt}$

10. A two metre wire is morning with a velocity of 1 m/sec perpendicular to a magnetic field of 0.5 weber/m^2. The e.m.f. induced in it will be

(*a*) 0.5 volt

(*b*) 0.1 volt

(*c*) 1 volt

(*d*) 2 volt

11. A conducting wire is dropped along east-west direction, then

(*a*) No emf is induced

(*b*) No induced current flows

(*c*) Induced current flows from west to east

(*d*) Induced current flows from east to west

12. A 50 mH coil carries a current of 2 ampere. The energy stored in joules is

(*a*) 1 (*b*) 0.1

(*c*) 0.05 (*d*) 0.5

13. Average energy stored in a pure inductance L when a current i flows through it, is

(*a*) Li^2 (*b*) $2Li^2$

(*c*) $\frac{Li^2}{4}$ (*d*) $\frac{Li^2}{2}$

14. In what form is the energy stored in an inductor

(*a*) Magnetic

(*b*) Electrical

(*c*) Both magnetic and electrical

(*d*) Heat

15. When the number of turns in a coil is doubled without any change in the length of the coil, its self inductance becomes.

(*a*) Four times (*b*) Doubled

(*c*) Halved (*d*) Unchanged

16. Mutual inductance of two coils can be increased by

(*a*) Decreasing the number of turns in the coils

(*b*) Increasing the number of turns in the coils

(*c*) Winding the coils on wooden core

(*d*) None of the above

17. The current flowing in a coil of self inductance 0.4 mH is increased by 250 mA in 0.1 sec. The e.m.f, induced will be

(*a*) +1 V

(*b*) –1 V

(*c*) +1 mV

(*d*) –1 mV

18. The self inductance of a solenoid of length L, area of cross-section A and having N turns is

(*a*) $\frac{\mu_o N^2 A}{L}$ (*d*) $\frac{\mu_o NA}{L}$

(*c*) $\mu_o N^2 LA$ (*d*) $\mu_o NLA$

19. The SI unit of inductance, henery, can be written as

(*a*) weber/ampere

(*b*) Volt-second/ampere

(*c*) Joule/(ampere)^2

(*d*) All of these

20. The self inductance of a straight conductor is

(*a*) zero

(*b*) very large

(*c*) Infinity

(*d*) very small

21. The current in a coil of inductance 5H decreases at the rate of 2A/S. The induced e.m.f. is

(*a*) 2V (*b*) 5V

(*c*) 10V (*d*) –10V

22. In a choke coil, the resistance X_L and resistance R are such that

(*a*) $X_L = R$ (*b*) $X_L >> R$

(c) $X_L << R$ (d) $X_L = \infty$

23. Use of eddy currents is done in the following except

(*a*) Moving coil galvanometer

(*b*) Electric brakes

(*c*) Induction motar

(*d*) Dynamo

24. The device that does't work on the principle of mutual induction is

(*a*) Induction coil

(*b*) Motor

(*c*) Tesla coil

(*d*) Transformer

Answer Keys

1. (*c*)	**2.** (*d*)	**3.** (*b*)	**4.** (*c*)	**5.** (*b*)	**6.** (*b*)	**7.** (*b*)	**8.** (*a*)	**9.** (*b*)	**10.** (*c*)
11. (*c*)	**12.** (*b*)	**13.** (*d*)	**14.** (*a*)	**15.** (*a*)	**16.** (*b*)	**17.** (*d*)	**18.** (*a*)	**19.** (*d*)	**20.** (*a*)
21. (*c*)	**22.** (*b*)	**23.** (*d*)	**24.** (*c*)						

Solutions

1. The induced e.m.f. in a coil is independent of resistance of the circuit.

2. The energy of the field increases with the magnitude of the field. Lenz's law infers that there is an opposite field created due to increase or decrease of magnetic flux around a conductor so as to hold the law of conservation of energy.

3. We know that $|e| = \frac{d\phi}{dt}$

But $e = iR$ and $i = \frac{dq}{dt} \Rightarrow \frac{dq}{dt}R = \frac{d\phi}{dt}$

$\Rightarrow dq = \frac{d\phi}{R}$

4. $e = -\frac{d\phi}{dt} = -(16t+3) = -67$ units

5. The direction of induced e.m.f. during electro-magnetic induction is given by Lenz's law.

6. According to Faraday's law of electromagnetic induction, the magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux.

7. Lenz's law gives the direction of the induced current.

8. Faraday's laws involve conversion of mechanical energy into electrical energy. This is in accordance with the law of conservation of energy.

9. Lenz's formula. $e = -N\frac{d\phi}{dt}$

10. We know that

$e = Bvl = 0.5 \times 1 \times 2$

$= 1$ volt

11. A conducting wire is dropped along east-west direction, then induced current flows from west to east.

12. Energy stored

$$E = \frac{1}{2}Li^2 = \frac{1}{2} \times 50 \times 10^{-3} \times 4$$

$= 0.1$ Joule

13. As we know, $e = -\frac{d\phi}{dt} = -L\frac{di}{dt}$

Work done against back e.m.f. (e) in time dt and current (i) is

$$dw = -eidt = L\frac{di}{dt}idt$$

$= Lidi$

$$\Rightarrow W = L\int_0^i i\,di = \frac{1}{2}Li^2$$

14. The energy stored in an inductor is in the form of magnetic.

Energy stored $= \frac{1}{2}Li^2$, where Li is magnetic flux.

15. $\because L \propto N^2$

i.e. $\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2$

$$\Rightarrow L_2 = L_1\left(\frac{N_2}{N_1}\right)^2 = 4L_1$$

16. Mutual inductance of two coils can be increased by increasing the number of turns in the coils.

17. $e = -L\frac{di}{dt} = -0.4 \times 10^{-3} \times \frac{250 \times 10^{-3}}{0.1} = -1\text{mV}$

18. The self inductance of a solenoid $= \frac{\mu_o N^2 A}{L}$

19. All of these

20. $\because L \propto N$ (number of turns)

For straight conductor $N = 0$

Hence, $L = 0$

21. $e = -L\frac{di}{dt}$, since current decreases

so, $\frac{di}{dt}$ is negative.

Hence, $e = -5 \times (-2) = +10V$

22. A choke coil is an electrical appliance used for controlling current in an a.c. circuit. In a choke coil $R << X_L$ to avoid power dissipation.

23. Eddy current is not used in dynamo.

24. The device that does't work on the principle of mutual induction is Tesla coil.

CHAPTER 7

Alternating Current

Introduction to Alternating Current

Alternating Current

The electric main supply that varies like a sine function with time is called alternating voltage and the current drawn by it in the circuit is called Alternating current. Alternating current is the current which varies on two factors i.e. magnitude and the direction periodically and alternatively.

Mathematically alternating current can be expressed as:

$I = I_0 \sin\omega t$

Where I_0, is the peak value of alternating current.

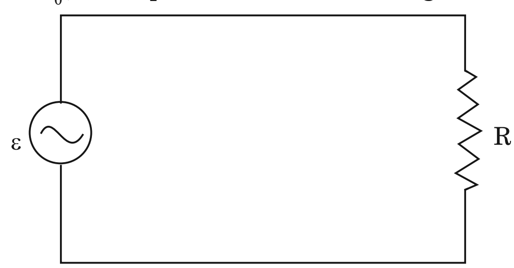


Fig.: Alternating Current in an electrical circuit.

RMS value of Alternating Current

The value of alternating current over a complete cycle which would generate same amount of heat in a given resistors that is generated by steady current in the same resistor and in the same time during a complete cycle.

$$I_{rms} = \frac{I_o}{\sqrt{2}} = 0.707 I_o$$

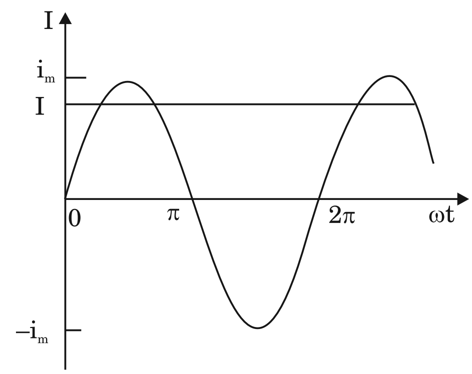


Fig.: Variation of Current with respect to wt.

Mean value of Alternating Current

The value of alternating current that would give same amount of charge in to a circuit at half cycle that is sent for steady current in the same duration.

$$I_{avg} = \frac{2I_o}{\pi} = 0.637 I_o$$

Alternating Voltage

Alternating voltage is the voltage which varies on two factors i.e. magnitude and the directions periodically and alternatively.

Alternating Voltage is expressed mathematically as,

$$V = V_o \sin \omega t$$

$$V_{rms} = \frac{V_o}{\sqrt{2}} = 0.707V_o \text{ or } V_{rms} = 70.7\% \text{ of } V_o$$

$$V_{avg} = \frac{2V_o}{\pi} = 0.637V_o \text{ or } V_{avg} = 63.7\% \text{ of } V_o$$

The alternating current and alternating voltage is illustrated in the following diagram:

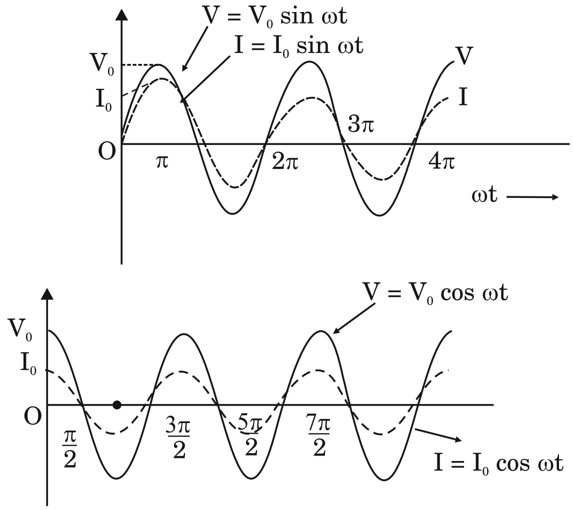


Fig.: Variation of V_0, I_0 w.r.t ωt.

AC Devices

Inductive Reactance (X_L)

When the current flows in the circuit, the inductor opposes its motion, this opposing nature of the inductor is termed as Inductive Reactance.

Mathematically it can be expressed as:

$X_L = \omega L = 2\pi fL$

Where L is self-inductance.

Instantaneous power supplied to an inductor

$$p_l = -\frac{i_m v_m}{2} \sin(2\omega t)$$

Average power supplied to an inductor over one complete cycle is zero.

In case of inductor, the current lags the voltage by $\frac{\pi}{2}$

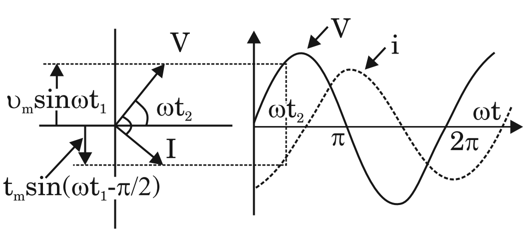


Fig.: Phasor Diagram of inductor

Inductive reactance can be graphically expressed as follows:

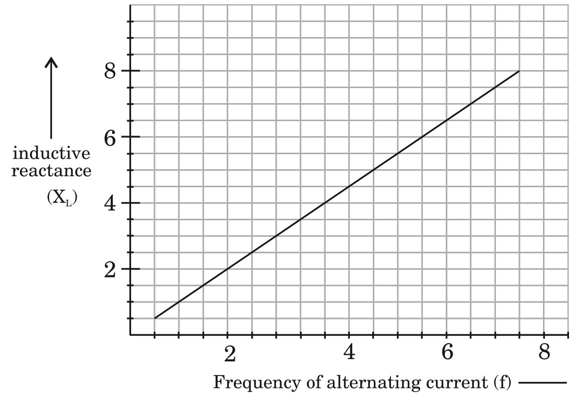


Fig.: Inductive Reactance Vs f

Capacitive Reactance (X_C)

When the current flows in the circuit, the capacitor opposes its motion, this opposing nature of the capacitor is termed as capacitive Reactance.

Mathematically it can be expressed as:

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

Where C is capacitance.

Instantaneous power supplied to the capacitor is

$$p_c = \frac{i_m v_m}{2} \sin(2\omega t)$$

In case of capacitor, the current leads the voltage by $\frac{\pi}{2}$

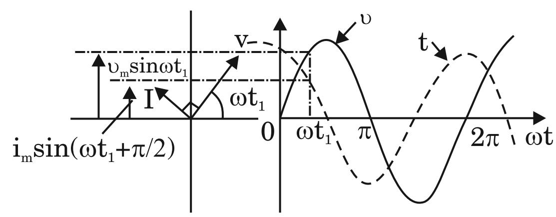


Fig.: Phasor Diagram of Capacitor

Capacitive reactance can be graphically expressed as follows:

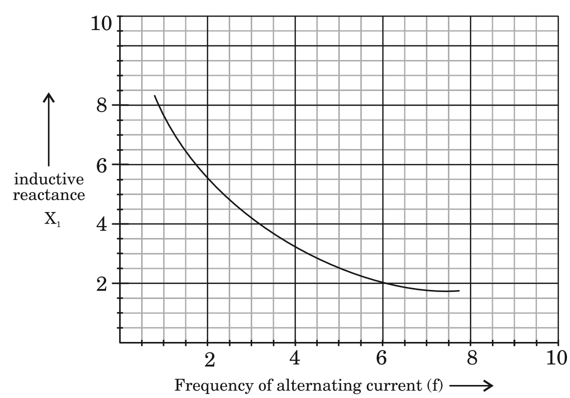


Fig.: Capacitive Reactance Vs f

- For a series LCR circuit driven by voltage $v = v_m \sin(\omega t)$, the current is given by

  $i = i_m \sin(\omega t + \phi)$.

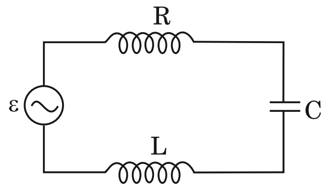


Fig.: LCR Circuit

Where $i_m = \dfrac{v_m}{\sqrt{R^2 + (X_c - X_L)^2}}$

And $\phi = tan^{-1} \dfrac{X_C - X_L}{R}$

$Z = \sqrt{R^2 + (X_C - X_L)^2}$ is called the impedance of the circuit.

Power

In an alternating circuit, the voltage and the current both keep on changing with respect to time. Hence the rate at which the electric energy is transferred in a circuit is called as it's power. The SI unit is Watt.

- **Electric Power:** The product of direct current flowing through a circuit and the voltage across the circuit.

  P = IV
- **Instantaneous Power:** The product of current and voltage as a function of time.

  $P_{inst} = E_{inst} \times I_{inst}$
- **Average Power:** Average of instantaneous power can be called as average power.

  Mathematically it is expressed as,

  $P_{avg} = V_{rms} I_{rms} \cos\Phi$

  where $\cos\Phi$ is power factor.
- **Power factor:** It is the ratio of true power to the apparent power.
- The phenomenon of ***resonance*** is an interesting characteristic of a series LCR circuit. The amplitude of the current is maximum at the resonant frequency and the circuit thus exhibits resonance, $\omega_0 = \dfrac{1}{\sqrt{LC}}$.

  The quality factor Q is defined by $Q = \dfrac{\omega_0 L}{R} = \dfrac{1}{\omega_0 CR}$

  and it tells about the sharpness of the resonance.
- ***LC Oscillations:*** When an inductor is connected to an initially charged capacitor, the charge on the capacitor and the current in the circuit exhibit the phenomenon of electrical oscillations. When the circuit has no ac source and no resistor then the charge q of the capacitor is given by $\dfrac{d^2q}{dt^2} + \dfrac{1}{LC}q = 0$

  Where $\dfrac{1}{\sqrt{LC}} = \omega_0$ is the frequency of free oscillation.

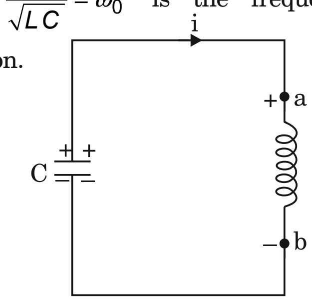


Fig.: LC Oscillalions

- ***Idle Current:*** If the average power consumed in an alternating current circuit is zero because of the current flowing through it, this current is called as Idle Current.
- Pure Inductor circuit and pure capacitor circuit are the two circuits whose average power consumed is zero as the phase difference is 90°.
- In generators and motors, the roles of input and output are reversed. In a motor, electric energy is the input and mechanical energy is the output. In a generator, mechanical energy is the input and electric energy is the output. Both devices simply transform energy from one form to another.

Transformer

- They convert an alternating voltage from one to another of greater or smaller value by using the principle of mutual induction.

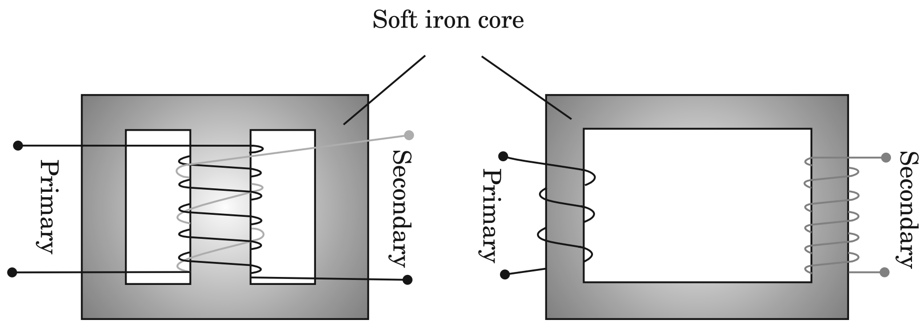


Fig.: Transformer Showing Primary & Secondary coils.

- A step-up transformer changes a low voltage in to high voltage.
- A step-down transformer changes high voltage to low voltage.
- The primary and secondary voltage and currents are given by

$$V_S = \left(\frac{N_S}{N_p}\right)V_p \quad \text{and} \quad I_s = \left(\frac{N_p}{N_s}\right)I_p$$

- Efficiency of the transformer is the ratio of the output power to the input power. It is usually   for a real one.

$$\eta = \frac{E_s I_s}{E_p I_p}$$

- ***Energy losses*** in transformers may be due to Flux leakage, resistance of windings, Eddy currents and Hysteresis.
- The choice of whether the description of an oscillatory motion is by means of sine or cosine or by their linear combinations is unimportant, since changing the zero-time position transforms one to the other.

Exercise

1. Alternating current can not be measured by dc ammeter because

(*a*) ac cannot pass through dc ammeter
(*b*) Average value of complete cycle is zero
(*c*) ac is virtual
(*d*) ac changes its direction

2. In an ac circuit, peak value of voltage is 423 vol. Its effective voltage is

(*a*) 400 volts (*b*) 323 volts
(*c*) 300 volts (*d*) 340 volts

3. In an ac circuit I = 100 sin 200 πt. The time required for the current to achieve its peak value will be

(*a*) $\frac{1}{100}$ sec (*b*) $\frac{1}{200}$ sec
(*c*) $\frac{1}{300}$ sec (*d*) $\frac{1}{400}$ sec

4. The peak value of an alternating current is 6 amp, then r.m.s value of current will be

(*a*) 3A (*b*) $3\sqrt{3}$A
(*c*) $3\sqrt{2}$A (*d*) $2\sqrt{3}$A

5. If E_o represents the peak value of the voltage in an ac circuit, the r.m.s. value of the voltage will be

(*a*) $\frac{E_o}{\pi}$ (*b*) $\frac{E_o}{2}$
(*c*) $\frac{E_o}{\sqrt{\pi}}$ (*d*) $\frac{E_o}{\sqrt{2}}$

6. The peak value of 220 volts of ac mains is

(*a*) 155.6 volts
(*b*) 220 volts
(*c*) 311 volts
(*d*) 440 volts

7. A sinusoidal ac current flows through a resistor of resistance R. If the peak current is I_p, then the power dissipated is

(*a*) $I_p^2 R \cos\theta$ (*b*) $\frac{1}{2}I_p^2R$

(*c*) $\frac{4}{\pi}I_p^2R$ (*d*) $\frac{1}{\pi}I_p^2R$

8. The frequency of ac mains in India is

(*a*) 80 Hz (*b*) 50 Hz

(*c*) 60 Hz (*d*) 120 Hz

9. The root mean square value of the alternating current is equal to

(*a*) Twice the peak value

(*b*) Half the peak value

(*c*) $\frac{1}{\sqrt{2}}$ times the peak value

(*d*) Equal to the peak value

10. The voltage domestic ac is 220 volts. What does this represent

(*a*) Mean voltage

(*b*) Peak voltage

(*c*) Root mean voltage

(*d*) Root mean square voltage

11. The process by which ac is converted into dc is known as

(*a*) Purification

(*b*) Amplification

(*c*) Rectification

(*d*) Current amplification

12. The ratio of peak value and r.m.s value of an alternating current is

(*a*) 1 (*b*) $\frac{1}{2}$

(*c*) $\sqrt{2}$ (*d*) $\frac{1}{\sqrt{2}}$

13. A transformer is based on the principle of

(*a*) Mutual Inductance (*b*) Self inductance

(*c*) Ampere's law (*d*) Lenz's law

14. Which of the following is not an application of eddy currents.

(*a*) Induction furnace

(*b*) Galvanometer damping

(*c*) Speedometer of automobiles

(*d*) x-ray crystallography

15. The core of a transformer is laminated to reduce energy losses due to

(*a*) Eddy current

(*b*) Hysteresis

(*c*) Resistance in winding

(*d*) None of these

16. Dynamo is a device for converting

(*a*) Electrical energy into mechanical energy

(*b*) Mechanical energy into electrical energy

(*c*) Chemical energy into mechanical energy

(*d*) Mechanical energy into Chemical energy

17. The working of dynamo is based on principle of

(*a*) Electromagnetic Induction

(*b*) Conversion of energy into electricity

(*c*) Magnetic effects of current

(*d*) Heating effect of current

18. Work of electric motor is

(*a*) To convert ac into dc

(*b*) To convert dc into ac

(*c*) Both (*a*) and (*b*)

(*d*) To convert ac into mechanical work

19. A transformer is employed to

(*a*) Obtain a suitable dc voltage

(*b*) convert dc into ac

(*c*) obtain a suitable ac voltage

(*d*) convert ac into dc

20. What is increased in step-down transformer

(*a*) Voltage (*b*) Current

(*c*) Power (*d*) Current density

21. The transformation ratio in the step-up transformer is

(*a*) 1

(*b*) Greater than one

(*b*) Less than one

(*d*) Depends on the other factors

22. A step up transformer has transformation ration 5 : 3. What is voltage in secondary if voltage in primary is 60V.

(*a*) 20 V (*b*) 60 V

(*c*) 100 V (*d*) 180 V

Answer Keys

1. (*b*)	**2.** (*c*)	**3.** (*d*)	**4.** (*c*)	**5.** (*d*)	**6.** (*c*)	**7.** (*b*)	**8.** (*b*)	**9.** (*c*)	**10.** (*d*)
11. (*c*)	**12.** (*c*)	**13.** (*a*)	**14.** (*d*)	**15.** (*a*)	**16.** (*b*)	**17.** (*a*)	**18.** (*d*)	**19.** (*c*)	**20.** (*b*)
21. (*b*)	**22.** (*c*)								

Solutions

1. In dc ammeter, a coil is free to rotate in the magnetic field of a fixed magnet.

If an alternating current is passed through such a coil, the torque will reverse its's direction each time the current changes direction and the average value of the torque will be zero.

2. Effective voltage

$$V_{r.m.s} = \frac{V_o}{\sqrt{2}} = \frac{423}{\sqrt{2}} = 300\text{V}$$

3. The current takes $\frac{I}{4}$sec to reach the peak value.

In the given question,

$$\frac{2\pi}{T} = 200\pi \Rightarrow T = \frac{1}{100}\text{sec}$$

$\therefore$ Time to reach the peak value $= \frac{1}{400}$sec

4. $i_{r.m.s} = \frac{6}{\sqrt{2}} = 3\sqrt{2}\text{ A}$

5. The r.m.s value of the voltage $= \frac{E_o}{\sqrt{2}}$

6. Peak value $= 220\sqrt{2} = 311\text{ V}$

7. Power $= I^2R = \left(\frac{I_P}{\sqrt{2}}\right)^2 R = \frac{{I_P}^2R}{2}$

8. The frequency of ac mains in India is 50 Hz.

9. The r.m.s value of the alternating current is equal to $\frac{1}{\sqrt{2}}$ times the peak value.

10. The voltage of domestic ac is 220 volts. It represents root mean square voltage.

11. The process by which ac is converted into dc is known as rectification.

12. The ratio of peak value and r.m.s value of an alternating current is $\sqrt{2}$.

13. A transformer is based on the principle of mutual inductance.

14. x-ray crystallography is not an application of eddy currents.

15. Circulation of eddy currents is decreased by use of laminated core.

16. Dynamo is a device for converting mechanical energy into electrical energy.

17. Rotation of magnet in the dynamo creates the variable flux which in turn produces the induced current.

18. Work of electric motor is to convert ac into mechanical work.

19. A transformer is a device used to convert alternating current at high voltage into low voltage and vice-versa.

20. We know that for step down transformer

$$V_P > V_s \text{ but } \frac{V_P}{V_S} = \frac{i_S}{i_P} \Rightarrow i_S > i_P$$

current in the secondary coil is greater than the primary.

21. Transformation ratio $k = \frac{N_S}{N_P} = \frac{V_S}{V_P}$

For step-up transformer. $N_S > N_P$, i.e. $V_S > V_P$, Hence, k> 1

22. Transformation ratio $k = \frac{V_S}{V_P}$

$$\Rightarrow \frac{5}{8} = \frac{V_S}{60}$$

$$\therefore \quad V_S = \frac{5 \times 60}{3} = 100\text{V}$$

CHAPTER 8

Electromagnetic Waves

Electromagnetic Waves, its Types & Properties

Displacement Current

- It is defined as the rate of change of electric displacement.
- It is given by $I_d = \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$ where ε_0 is the permittivity of the free space and ϕ_s is the amount of electric flux.

Properties of EM Waves

- The electric and magnetic fields E_x and B_y are always perpendicular to each other, and also to the direction z of propagation. E_x and B_y are given by:

$$E_x = E_0 \sin(kz-\omega t)$$

$$B_y = B_0 \sin(kz-\omega t)$$

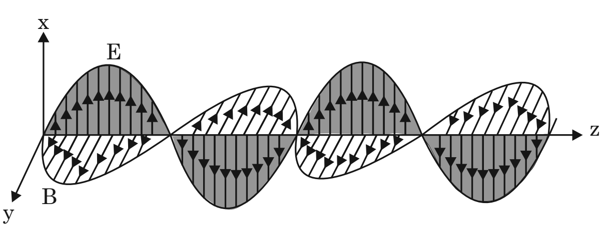


Fig. Electromagnetic Waves

Where,

"k" is the magnitude of the wave vector (or propagation vector) and can be calculated as;

$$k = \frac{2\pi}{\lambda}$$

- ω is the angular frequency,
- "k" is direction describes the direction of propagation of the wave. The speed of propagation of the wave is $\frac{\omega}{k}$.
- The frequency of EM waves can be from 0 to ∞. Ampere Circuital Law is given by: $\oint B \cdot dl = \mu_0 i(t)$

The four Maxwell's equations are given as:

- Gauss's law of electricity: $\oint E.dA = \frac{Q}{\varepsilon_0}$
- Gauss's law of magnetism: $\oint B.dA = 0$
- Faraday's law: $\oint E.dl = \frac{-d\phi_B}{dt}$
- Ampere-Maxwell law: $\oint B.dl = \mu_0 I_c + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$

An electric charge oscillating harmonically with a frequency, produces electromagnetic waves of the same frequency . The frequency of the electromagnetic wave naturally equals the frequency ofoscillation of the charge.

An electric dipole is a basic source of electromagnetic waves.

From Maxwell's equations it can be seen that the magnitude of the electric and the magnetic fields in an electromagnetic wave are related as $B_0 = \frac{E_0}{c}$

Properties of EM Waves

- Oscillations of electric and magnetic fields sustain in free space, or vacuum. So, the electromagnetic waves can travel in vacuum.

- An electromagnetic wave carries momentum and energy. Since an electromagnetic wave carries momentum, it also exerts pressure, called radiation pressure.
- Let the total energy transferred to a surface in time t is U, so the magnitude of the total momentum of an electromagnetic wave delivered to the surface (for complete absorption) is, $P = \frac{U}{c}$
- The energy of electromagnetic waves is shared equally by the electric and magnetic fields.

Types of EM Waves

- Radio waves are produced by the accelerated motion of charges in conducting wires. They are used in radio and television communication systems.The radio waves generally lie in the frequency range from 500 kHz to about 1000 MHz
- Microwaves have frequency in the range of gigahertz and are used in aircraft navigation.
- Infrared waves are also referred to as heat waves as they are produced by hot bodies and molecules.
- Visible rays can be detected by the human eye. They lie between frequency range of about 4×10^{14} Hz to about 7×10^{14} Hz or a wavelength range of about 700 –400 nm.
- Ultraviolet radiation or the UV radiation is produced by special lamps and very hot bodies.
- X-rays lie beyond the UV region and are used as a diagnostic tool in medicine and for treating various kinds of cancer.
- Gamma rays are emitted by radioactive nuclei and also are produced in nuclear reactions and are used in destroying the cancer cells.

The properties of different types of EM Waves are:

Type	*Wavelength range*	*Production*	*Detection*
Radio	*> 0.1 m*	*Rapid acceleration and decelerations of electrons in aerials*	*Receiver's aerials*
Microwave	*0.1 m to 1 mm*	*Klystron valve or magnetron valve*	*Point contact diodes*
Infra-red	*1 mm to 700 nm*	*Vibration of atoms and molecules*	*Thermopiles, Bolometer, Infrared photographic film*
Light	*700 nm to 400 nm*	*Electrons in atoms emit light when they move from one energy level to a lower energy level*	*The eye, Photocells, Photographic film*
Ultraviolet	*400 nm to 1 nm*	*Inner shell electrons in atoms moving from one energy level to a lower level*	*Photocells, Photographic film*
X-rays	*1 nm to 10^{-3} nm*	*X-ray tubes or inner shell electrons*	*Photographic film, Geiger tubes Ionisation chamber*
Gamma rays	*<10^{-3} nm*	*Radioactive decay of the nucleus*	*Photographic film, Geiger tubes Ionisation chamber*

Exercise

1. One requires 11 ev of energy to dissociate a carbon monoxide molecular into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in

(*a*) Visible region (*b*) infrared region
(*c*) ultraviolet region (*d*) microwave region

2. If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along

(*a*) $\vec{E}$ (*b*) $\vec{B}$
(*c*) $\vec{B} \times \vec{E}$ (*d*) $\vec{E} \times \vec{B}$

3. A linearly polarized electromagnetic wave given as $\vec{E} = E_o \lambda \hat{i} \cos(kz - \omega t)$ is incident normally on a perfectly reflecting infinite wall at z = a. Assuming that the material of the wall is optically inactive, the reflected wave will be given as

(a) $\vec{E}_r = E_o \hat{i} \cos(kz - \omega t)$

(b) $\vec{E}_r = E_o \hat{i} \cos(kz + \omega t)$

(c) $\vec{E}_r = -E_o \hat{i} \cos(kz + \omega t)$

(d) $\vec{E}_r = E_o \hat{i} \sin(kz - \omega t)$

4. The ratio of contributions made by the electric field and magnetic field components to the intensity of an e.m. wave is

(a) c : 1 (b) $c^2 : 1$

(c) 1 : 1 (d) $\sqrt{c} : 1$

5. Fundamental particle in an electromagnetic wave is

(a) photon (b) electron

(c) phonon (d) proton

6. x-rays of $\lambda = 1$ Å have frequency

(a) 3×10^8 Hz (b) 3×10^{18} Hz

(c) 3×10^{10} Hz (d) 3×10^{15} Hz

7. Earth's atmosphere is richest in

(a) UV-rays (b) IR-rays

(c) X-rays (d) microwaves

8. According to Maxwell's hypothesis, a changing electric field gives rise to

(a) an emf (b) electric current

(c) magnetic field (d) pressure gradient

9. The velocity of electromagnetic waves in free space is 3×10^8 m/s. The frequency of a radiowaves of wave-length 150 m is

(a) 45 MHz (b) 2 MHz

(c) 20 KHz (d) 2 KHz

10. In general, the wavelength of microwaves is

(a) more than that of radio waves

(b) less than that of UV waves

(c) more than that of IR waves

(d) less than that of IR waves

11. Electromagnetic waves are transverse in nature is evident by

(a) polarisation

(b) interference

(c) reflection

(d) diffraction

12. Infrared radiations are detected by

(a) spectrometer (b) Pyrometer

(c) Nanometer (d) Photometer

13. What is the cause of green house effect?

(a) Infrared rays (b) Ultraviolet rays

(c) X-rays (d) Radio waves

14. Which of the following radiations has the least wavelength?

(a) γ-rays (b) β-rays

(c) α-rays (d) X-rays

15. Which of the following is a natural source of γ-rays?

(a) Radio-cobalt (b) Radio-phosphorus

(c) Radon gas (d) Radio-carbon

16. An electromagnetic wave of frequency 3MHz passes from vacuum into a dielectric medium with permittivity $\epsilon_r = 4$, then

(a) The wavelength of frequency both remains unchanged

(b) The wavelength is doubled and the frequency remains unchanged

(c) The wavelength is doubled and the frequency becomes half

(d) The wavelength is halved and the frequency remains unchanged.

17. Which of the following is used to produce radio waves of constant amplitude?

(a) Oscillator (b) FET

(c) Rectifier (d) Amplifier

18. In an electromagnetic wave, the electric and magnetic fields are 100 V/m and 0.265 A/m. The maximum energy flow will be

(a) 79 W/m² (b) 13.2 W/m²

(c) 53 W/m² (d) 26.5 W/m²

19. Electromagnetic wave travel in a medium which has relative premeability 1.3 and relative permeability 2.14. The speed of e.m. wave in the medium will be

(a) 13.6×10^6 m/s (b) 1.8×10^2 m/s

(c) 36×10^8 m/s (d) 1.8×10^8 m/s

20. A small metallic ball is charged positively and negatively in a sinusoidal manner at a frequency of 10^6 cps. The maximum charge on the ball is 10^{-6} cps. What is the displacement current due to the alternating current?

(a) 6.28A (b) 3.8 A

(c) 3.75×10^{-4}A (d) 122.56A

21. The electric and magnetic fields of an electromagnetic wave are
   (*a*) in opposite phase and perpendicular to each other
   (*b*) in opposite phase and parallel to each other
   (*c*) in phase and perpendicular to each other
   (*d*) in phase and parallel to each other

22. Electromagnetic waves are produced by
   (*a*) accelerated charged particle
   (*b*) charge at rest
   (*c*) charge in uniform motion
   (*d*) none of the above

23. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagating field for an electromagnetic wave propagating in vacuum is equal to
   (*a*) the speed of light in vacuum
   (*b*) reciprocal of speed of light in vacuum
   (*c*) the ratio of magnetic permeability to the electric susceptibility of vacuum
   (*d*) unity

Answer Keys

1. (*c*)	**2.** (*d*)	**3.** (*b*)	**4.** (*c*)	**5.** (*c*)	**6.** (*b*)	**7.** (*b*)	**8.** (*c*)	**9.** (*b*)	**10.** (*c*)
11. (*a*)	**12.** (*b*)	**13.** (*a*)	**14.** (*a*)	**15.** (*c*)	**16.** (*d*)	**17.** (*a*)	**18.** (*d*)	**19.** (*d*)	**20.** (*a*)
21. (*c*)	**22.** (*a*)	**23.** (*b*)							

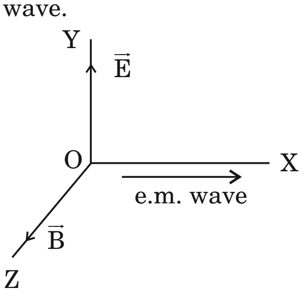
Solutions

1. As E = hν

$$\Rightarrow \nu = \frac{E}{h} = \frac{11}{4.14\times10^{-15}} = 2.7\times10^{15}\,\text{Hz}$$

$\therefore$ Frequency range of UV = 10^{14} Hz to 10^{17} Hz

2. $\vec{B} \times \vec{E} = \vec{C}$, where $\vec{C}$ is the velocity of the e.m. wave.



3. Since the wall is perfectly reflecting, amplitude (E_o) of the linearly polarised em. wave remains unchanged. Further, as the material of the wall is optically inactive there is no phase change (stokes' law). The reflected wave differs from incident wave in only one aspect i.e. it travels along-z axis. Thus

$$\vec{E} = E_o\,\hat{i}\cos(-kz - wt) = E_o\,\hat{i}\cos(kz + wt)$$

Remember that $\vec{E}$ is along x-axis (i.e., $\hat{i}$ – direction)

4. Intensity due to electric field $I_E = \frac{1}{2} c \in_o E^2$

Intensity due to magnetic field $I_B = \frac{cB^2}{2\mu_o}$

$$\therefore \frac{I_E}{I_B} = \frac{\frac{1}{2} c \in_o E^2}{\frac{cB^2}{2\mu_o}} = (\in_o \mu)\left(\frac{E}{B}\right)^2 = \frac{1}{c^2}\times c^2 = 1$$

5. Fundamental particle in an electromagnetic wave is photon.

6. $\nu = \frac{c}{\lambda} = \frac{3\times10^8}{10^{-10}} = 3\times10^{18}\,\text{Hz}$

7. Earth's atmosphere is richest in Infra-red waves.

8. According to Maxwell's hypothesis, a changing electric field gives rise to magnetic field.

9. $\nu = \frac{c}{\lambda} = \frac{3\times10^8}{150} = \frac{300\times10^6}{150} = 2\text{MHz}$

10. In general, the wavelength of microwaves is more than that of IR waves.

11. Electromagnetic waves are transverse in nature is evident by polarisation.

12. Infrared radiations are detected by pyrometer.

13. Infrared is the cause of greenhouse effect.

14. γ-rays has the least wavelength.

15. Radon gas is a natural source of γ-rays.

16. Frequency remains unchanged with change of medium

$$n = \frac{c}{v} = \frac{\frac{1}{\sqrt{\epsilon_o \mu_o}}}{\sqrt{\epsilon \mu}} = \sqrt{\epsilon_r \mu_r}$$

Since, μ_r is very close to 1, $n = \sqrt{\epsilon_r} = \sqrt{4} = 2$

Thus, $\lambda_{medium} = \frac{\lambda}{n} = \frac{\lambda}{2}$

17. Oscillator is used to produce ratio waves of constant amplitude.

18. Maximum energy flow in an electromagnetic wave,

$= E_o B_o = (100 v/m)(0.265\ A/m)$

$= 26.5\ W/m^2$

19. $n = \sqrt{\epsilon_r \mu_r} = \sqrt{2.14 \times 1.3} = 1.67$

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.67} m/s = 1.8 \times 10^8 m/s$$

20. $I_d = \frac{dq}{dt} = \frac{d}{dt}(q_o \sin \omega t) = q_o \omega \cos \omega t$

Maximum value of $I_d = q_o \omega = q_o\ (e\pi v)$

$= 10^{-6}\left(2 \times 3.14 \times 10^6\right) A = 6.28 A$

21. The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

22. Electromagnetic waves are produced by accelerated charged particle.

23. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagating in vacuum is equal to the reciprocal of speed of light in vacuum.

CHAPTER 9

Ray Optics and Optical Instruments

Reflection, refraction and dispersion of light

The speed of light in vacuum is given by c = $3 \times 10^8 ms^{-1}$, which is the highest speed that can be attained in nature.

A light wave travels along a straight line from one point to another. This path is called a ray of light, and bundle of such rays together form a beam of light.

Laws of reflection states that

- The angle of reflection (i.e., the angle between reflected ray and the normal to the reflecting surface or the mirror) equals the angle of incidence (angle between incident ray and the normal), i.e. $\angle i = \angle r$
- The incident ray, the normal to the mirror at the point of incidence and the reflected ray, they all lie in the same plane.

Snell's law for refraction is given by $\frac{\sin i}{\sin r} = n$, where the angle of incidence, angle of refraction and refractive index of the medium is given by i, r and n respectively.

The angle of incidence at which a ray travelling from a denser to rarer medium makes an angle of refraction of 90° is a ***critical angle*** and is denoted by i_c.

Cartesian sign convention:

- Positive sign is used for distances measured in the same direction as the incident light, whereas negative sign is used for those measured in the direction opposite to the direction of incident light.
- All distances are measured from the pole of the mirror or the optical centre of the lens. The heights measured upwards with respect to x-axis and normal to the principal axis of the mirror/lens is taken as positive.
- The heights measured downwards with respect to x-axis are taken as negative.

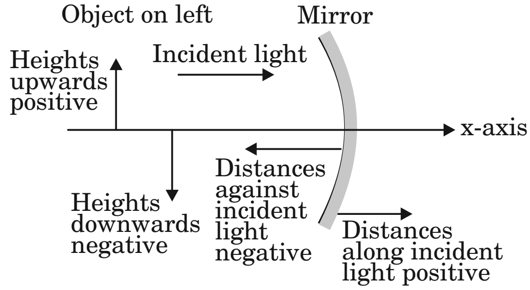


Fig.: Cartesian sign convention

If the distance of the object and the image is given by u and v, respectively and f is the focal length of the mirror. Then the ***mirror formula*** is given by,

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

Focal length f for a concave mirroris negative and is positive for a convex mirror.

The magnification produced by a mirror is given by $m=\frac{h'}{h}=-\frac{v}{u}$ where h′ is the height of the image and h is the height of the object.

Total Internal Reflection:

- When light travels from an optically denser medium to a rarer medium at the interface, it is partly reflected back into the same medium and partly refracted to the second medium. This reflection is called internal reflection when all light is reflected back, it is called total internal reflection.

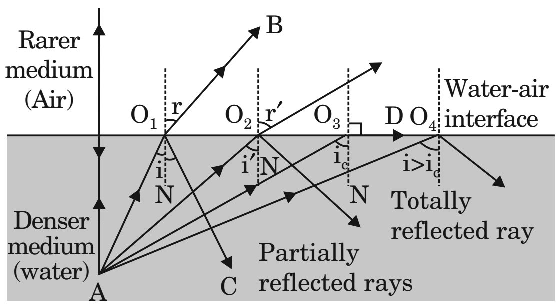


Fig.: Total Internal Reflection

- The applications of total internal reflection include mirage, diamond, prism and optical fibers.

Refraction through glass slab:

The emergent ray through a glass slab is parallel to the incident ray but it is laterally displaced.

Also, ∠Angle of incidence = ∠Angle of emergence

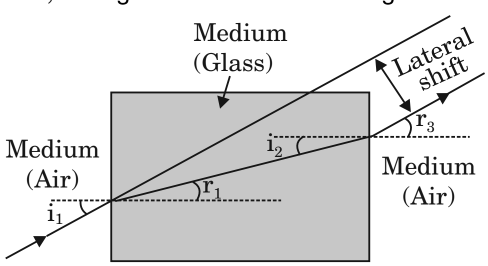


Fig.: Reflection through glass slab

Refraction at spherical surfaces

If the rays are incident from a medium of refractive index n_1 to another of refractive index n_2, then

$$\frac{n_2}{v}-\frac{n_1}{u}=\frac{n_2-n_1}{R}$$

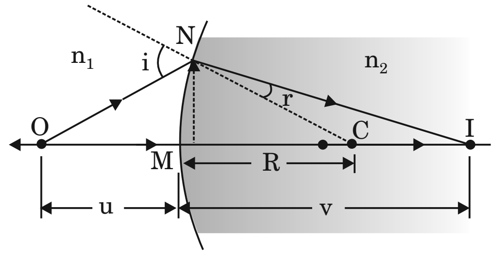


Fig.: Refraction at spherical surface

For a prism of the angle A, of refractive index n_2 placed in a medium of refractive index n_1 and D_m being the angle of minimum deviation.

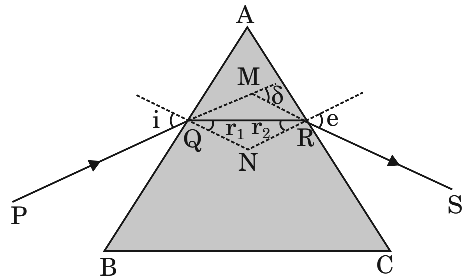


Fig.: Prism

$$n_{21}=\frac{n_2}{n_1}=\frac{sin\left[\left(A+D_m\right)/2\right]}{sin\left(A/2\right)}$$

- If the distance of the object and the image is given by u and v, respectively and f is the focal length of the lens. So, the ***lens formula*** is,

  $$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

  Focal length f is positive for a converging lens and is negative for a diverging lens.

- The magnification produced by a mirror is given by $m=\frac{h'}{h}=\frac{v}{u}$ where h′ is the height of the image and h is the height of the object.

- The ***power*** (P) of a lens is given by, $P=\frac{1}{f}$.

  Where f is the focal length of the lens and the SI unit of power is dioptre (D): 1 D = 1 m^{-1}

- The effective focal length of a combination of thin lenses of focal length f_1, f_2, f_3 ..... is given by

  $$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+\text{.........}$$

And the effective power of the same combination is given by

$P = P_1 + P_2 + P_3$ ......

Dispersion:

- Splitting of light into its constituent colors is known as ***dispersion*** of light.
- When a white light is incident on a prism, the white light is split into seven components, violet, indigo, blue, green, yellow, orange and red (given by the acronym VIBGYOR)

Some natural phenomenon due to sunlight are rainbow and scattering of light.

The Eye: It has a convex lens of focal length about 2.5 cm. This focal length can be varied somewhat by the help of ciliary muscle so that the image is always formed on the retina. This ability of the eye of adjusting the muscle to form a clear image is called ***accommodation***.

In a defective eye, if the image is focused before the retina, it is called myopia. For correction of myopia, a diverging corrective lens is needed.

In a defective eye, if the image is focused beyond the retina, it is called hypermetropia. For correction of hypermetropia, a converging corrective lens is needed.

Astigmatism: A refractive error in which the vision is blurred at all distances, is corrected by using cylindrical lenses.

Optical Instrument

Simple microscope

- A simple magnifier or microscope is a converging lens of small focal length.

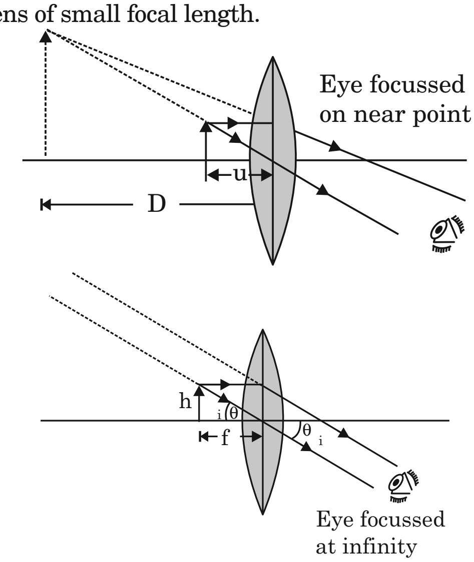


Fig.: Magnifier

- The magnifying power (m) is given by $m = 1 + \left(\frac{D}{f}\right)$,

  where D = 25 cm is the least distance of distinct vision and f is the focal length of the convex lens. If the image is at infinity, magnifying power (m) is given by, $m = \frac{D}{f}$.

- For a ***compound microscope***, the magnifying power m is given by $m = m_e \times m_0$ where, $m_e = 1 + \left(\frac{D}{f}\right)$ is the magnification due to the eyepiece and m_o is the magnification produced by the objective. Also, $m = \frac{L}{f_o} \times \frac{D}{f_e}$, where f_0 and f_e are the focal length of the objective and the eyepiece, respectively, and L is the distance between their focal points.

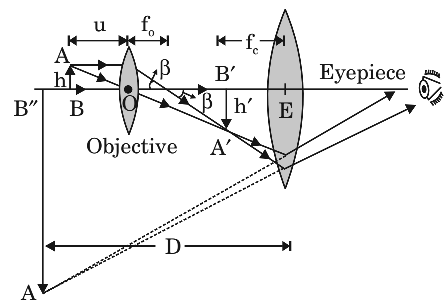


Fig.: Compound microscope

Telescope

- The telescope is used to provide angular magnification of distant objects. It also has an objective and an eyepiece
- Magnifying power (m) of a telescope is the ratio of the angle β subtended at the eye by the image to the angle α subtended at the eye by the object.

  $m = \frac{\beta}{\alpha} = \frac{f_o}{f_e}$, f_0 and f_e are the focal length of the objective and the eyepiece, respectively.

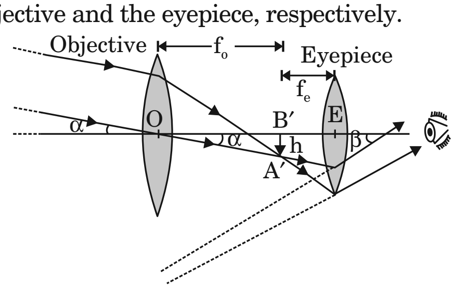


Fig.: Telescope

Exercise

1. The refractive index of a certain glass is 1.5 for light whose wavelength in vacuum is 6000Å. The wavelength of this light when it passes through glass is
   (*a*) 4000 Å (*b*) 6000 Å
   (*c*) 9000 Å (*d*) 15000 Å

2. When light travels from one medium to the other of which the refractive index is different, then which of the following will change
   (*a*) Frequency, wavelength and velocity
   (*b*) Frequency and wavelength
   (*c*) Frequency and velocity
   (*d*) Wavelength and velocity

3. When a light wave goes from air into water, the quality that remains unchanged is its
   (*a*) Speed (*b*) Amplitude
   (*c*) Frequency (*d*) Wavelength

4. If μ_o be the relative permeability and K_o the dielectric constant of a medium, its refractive index is given by
   (*a*) $\frac{1}{\sqrt{\mu_o K_o}}$ (*b*) $\frac{1}{\mu_o K_o}$
   (*c*) $\sqrt{\mu_o K_o}$ (*d*) $\mu_o K_o$

5. A cut diamond sparkles because of its
   (*a*) Hardness
   (*b*) High refractive index
   (*c*) Emission of light by the diamond
   (*d*) Absorption of light by the diamond

6. The wavelength of light in two liquids 'x' and 'y' is 3500 Å and 7000 Å, then the critical angle of x relative to y will be
   (*a*) 60° (*b*) 45°
   (*c*) 30° (*d*) 15°

7. The critical angle for diamond (refractive index = 2) is
   (*a*) About 20° (*b*) 60°
   (*c*) 45° (*d*) 30°

8. Total internal reflection is possible when light rays travel
   (*a*) Air to water
   (*b*) Air to glass
   (*c*) Glass to water
   (*d*) Water to glass

9. The critical angle for a medium is 60°. The refractive index of the medium is
   (*a*) $\frac{2}{\sqrt{3}}$ (*b*) $\frac{\sqrt{2}}{3}$
   (*c*) $\sqrt{3}$ (*d*) $\frac{\sqrt{3}}{2}$

10. A normally incident ray reflected at an angle of 90°. The value of critical angle is
   (*a*) 45° (*b*) 90°
   (*c*) 65° (*d*) 43.2°

11. A spectrum of formed by a prism of dispersive power 'ω'. If the angle of deviation is 'δ', then the angular dispersion is
   (*a*) $\frac{\omega}{\delta}$ (*b*) $\frac{\delta}{\omega}$
   (*c*) $\frac{1}{\omega\delta}$ (*d*) $\omega\delta$

12. Light from sodium lamp is passed through cold sodium vapour, the spectrum of transmitted light consist of
   (*a*) A line at 5890 Å
   (*b*) A line at 5896 Å
   (*c*) Sodium doublet lines
   (*d*) No spectral features

13. Dispersive power depends upon
   (*a*) The shape of prism
   (*b*) Material of prism
   (*c*) Angle of prism
   (*d*) Height of the prism

14. The angle of minimum deviation measured with a prism is 30° and the angle of prism is 60°. The refractive index of prism material is
   (*a*) $\sqrt{2}$ (*b*) 2
   (*c*) $\frac{3}{2}$ (*d*) $\frac{4}{3}$

15. In a compound microscope magnification will be large, if the focal length of the eye piece is
   (*a*) Large
   (*b*) Smaller
   (*c*) Equal to that of objective
   (*d*) Less than that of objective

16. The focal length of the objective lens of a compound microscope is
   (*a*) Equal to the focal length of its eye piece
   (*b*) Less than the focal length of eye piece
   (*c*) Greater than the focal length of eye piece
   (*d*) Any of the above three

17. Microscope is an optical instrument which
(*a*) Enlarges the object
(*b*) Increases the visual angle formed by the object at the eye
(*c*) Decreases the visual angle formed by the object at the eye
(*d*) Brings the object nearer

18. For which of the following colour the magnifying power of a microscope will be maximum
(*a*) White colour (*b*) Red colour
(*c*) Violet colour (*d*) Yellow colour

19. When the length of a microscope tube increases, its magnifying power.
(*a*) Decreases
(*b*) Increases
(*c*) Does not change
(*d*) May decreases on increases

20. In a compound microscope, if the objective produces an image I_o and the eye piece produces an imge I_e, then
(*a*) I_o is virtual but I_e is real
(*b*) I_o is real but I_e is virtual
(*c*) I_o and I_e are both real
(*d*) I_o and I_2 are both virtual

21. The magnifying power of a simple microscope can be increased, if we use eye-piece of
(*a*) Higher focal length (*b*) Smaller focal length
(*c*) Higher diameter (*d*) Smaller diameter

22. The maximum magnification that can be obtained with a convex lens of focal length 2.5 cm is (the least distance of distinct vision is 25 cm)
(*a*) 10 (*b*) 0.1
(*c*) 62.5 (*d*) 11

23. The magnifying power of a telescope can be increased by
(*a*) Increasing focal length of the system
(*b*) Fitting eye piece of high power
(*c*) Fitting eye piece of low power
(*d*) Increasing the distance of objects

24. An observer looks at a tree of height 15m with a telescope of magnifying power 10. To him, the tree appears
(*a*) 10 times taller (*b*) 15 times taller
(*c*) 10 times nearer (*d*) 15 times nearer

25. If the telescope is reversed, i.e., seen from the objective side
(*a*) object will appear very small
(*b*) Object will appear very large
(*c*) There will be no effect on the image formed by the telescope
(*d*) Image will be slightly greater than the earlier one

26. The aperture of a telescope is made large, because
(*a*) To increases the intensity of image
(*b*) To decrease the intensity of image
(*c*) To have greater magnification
(*d*) To have lesser resolution

27. Two convex lenses of focal lengths 0.3 m and 0.05 m are used to make a telescope. The distance kept between the two is
(*a*) 0.35 m (*b*) 0.25 m
(*c*) 0.175 m (*d*) 0.15 m

28. An astronomical telescope of ten-fold angular magnification has a length of 44 cm. The focal length of the objective is
(*a*) 4 cm (*b*) 40 cm
(*c*) 44 cm (*d*) 440 cm

Answer Keys

1. (*a*)	**2.** (*d*)	**3.** (*c*)	**4.** (*c*)	**5.** (*b*)	**6.** (*c*)	**7.** (*d*)	**8.** (*c*)	**9.** (*a*)	**10.** (*b*)
11. (*d*)	**12.** (*d*)	**13.** (*b*)	**14.** (*a*)	**15.** (*b*)	**16.** (*b*)	**17.** (*b*)	**18.** (*c*)	**19.** (*a*)	**20.** (*b*)
21. (*b*)	**22.** (*d*)	**23.** (*b*)	**24.** (*c*)	**25.** (*a*)	**26.** (*a*)	**27.** (*a*)	**28.** (*b*)		

1. $\lambda_{medium} = \frac{\lambda_{air}}{\mu} = \frac{6000}{1.5} = 4000\,\text{Å}$

2. velocity and wavelength change but frequency remains same.

3. Let ν' and λ' represent frequency and wavelength of light in medium respectively.

So, $\nu' = \frac{\nu}{\lambda'} = \frac{\frac{c}{\mu}}{\frac{\lambda}{\mu}} = \frac{c}{\lambda} = \nu$

4. $\mu = \sqrt{\frac{\mu\varepsilon}{\mu_o\varepsilon_o}} = \sqrt{\mu_r K}$

5. Due to high refractive index its critical angle is very small so that most of the light incident on the diamond is total internally reflected repeatedly and diamond sparkles.

6. The critical angle c is given by

$\sin C = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{3500}{7000} = \frac{1}{2} \Rightarrow C = 30°$

7. $\mu = \frac{1}{\sin c} \Rightarrow c = \sin^{-1}\left(\frac{1}{2}\right) = 30°$

8. Total internal reflection occurs when light ray travels from denser medium to rarer medium.

9. $\mu = \frac{1}{\sin c} = \frac{1}{\sin 60°} = \frac{2}{\sqrt{3}}$

10. Critical angle c is equal to incident angle if ray reflected normally. $\therefore$ c = 90°.

11. We know that $\frac{\delta_v - \delta_r}{\delta_{mean}} = \omega$

$\Rightarrow$ Angular dispersion $= \delta_v - \delta_r = \theta = \omega\delta_{mean}$.

12. According to Kirchhoff's law, a substance in unexcited state will absorb these wavelength which it emits in de-excitation.

13. Dispersive power (ω) depends only on nature of material.

14. $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 45°}{\sin 80°} = \sqrt{2}$

15. For a compound microscope $m \propto \frac{1}{f_o f_e}$

16. For a compound microscope $f_{objective} < f_{eye\ piece}$.

17. In microscope final image formed is enlarged which in turn increases the visual angle.

18. Magnifying power of a microscope $m \propto \frac{1}{f}$

Since $f_{violet} < f_{red}$;

$\therefore m_{violet} > m_{red}$

19. For a microscope $|m| = \frac{v_o}{u_o} \times \frac{D}{\mu_e}$ and $L = v_o + u_e$

For a given microscope, with increase in L, u_e will increase and hence magnifying power (m) will decrease.

20. In compound microscope objective forms real image while eye piece forms virtual image.

21. $m = 1 + \frac{D}{f}$

Smaller the focal length, higher the magnifying power.

22. $m_{max} = 1 + \frac{D}{f} = 1 + \frac{25}{2.5} = 11$

23. Magnifying power of telescope is $\frac{f_o}{f_e}$, so as $\frac{1}{f_e}$ increases, magnifying power increases.

24. Telescope is used to see the distant objects. More magnifying power means more nearer image.

25. Because magnification in this case becomes reciprocal of initial magnification.

26. For greater aperture of lens, light passing through lens is more and so intensity of image increases.

27. If final image is formed at infinity, then the distance between the two lenses of telescope is equal to length of tube = $f_o + f_e$ = 0.3 + 0.05 = 0.35 m

28. $L = f_o + f_e = 44$ and $|m| = \frac{f_o}{f_e} = 10$

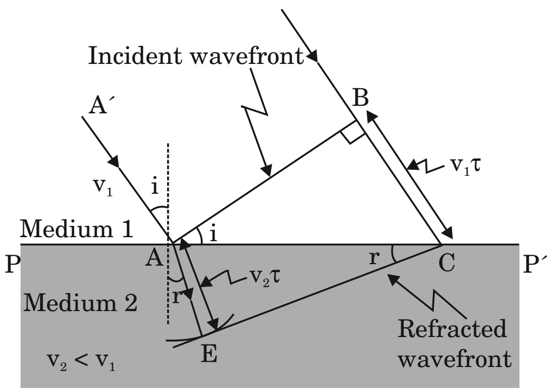
This gives f_o = 40 cm.

CHAPTER 10

Wave Optics

Huygens Principle

- The effects which depend on wave nature of light are included under wave optics. Interference and diffraction of light shows that light behaves as wave and not as a stream of particles.
- ***Huygens principle:*** It states that each point of the wavefront is the source of a secondary disturbance. Also, the wavelets emanating from these points spread out in all directions with the speed of the wave which are referred to as secondary wavelets and if we draw a common tangent to all these spheres, a new position of the wavefront is obtained at a later time.
- When a wave gets refracted into a denser medium the wavelength and the speed of propagation decrease but the frequency remains the same.



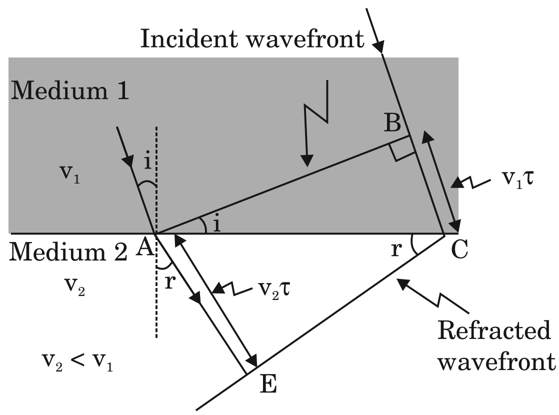


Fig.: Huygen's Principle

$n_1 \sin i = n_2 \sin r$ is the ***Snell's law*** of refraction.

- Doppler Effect is defined as the change in wavelength or frequency of a wave in relation to observer who is moving relative to the wave source. The Doppler shift is expressed as:

$$\frac{\Delta\nu}{\nu} = -\frac{\upsilon_{radial}}{c}$$

Interference of Light

- ***Superposition principle*** states that at a particular point in the medium, the resultant displacement produced by a number of waves is the vector sum of the displacements produced by each of the waves.

- The resultant displacement at a point from two coherent sources will be equal to the sum of the individual displacement at that point.

  $y = 2a \cos \omega t$

  Resultant intensity is four times the intensity produced by each source.

  $I = 4I_0$ and $I_0 \propto a^2$
- ***Constructive interference:*** It is observed in cases when two coherent sources are vibrating in phase having path difference for a point P as

  $S_1P - S_2P = n\lambda$ (n = 0, 1, 2, ...) and resultant intensity is $4I_0$
- ***Destructive interference:*** It is observed in cases when two coherent sources are vibrating in phase having path difference for a point P as

  $S_1P - S_2P = \left(n + \frac{1}{2}\right)\lambda$ $(n = 0, 1, 2, ...)$ and resultant intensity is zero.
- ***Young's double slit*** of length d gives equally spaced fringes which are at angular separation $\frac{\lambda}{d}$. The midway-point of the slits, the central bright fringe and the source, all lie in a straight line. But this fringe gets destroyed by an extended source, if the angle subtended is more than $\frac{\lambda}{d}$ at the slits.

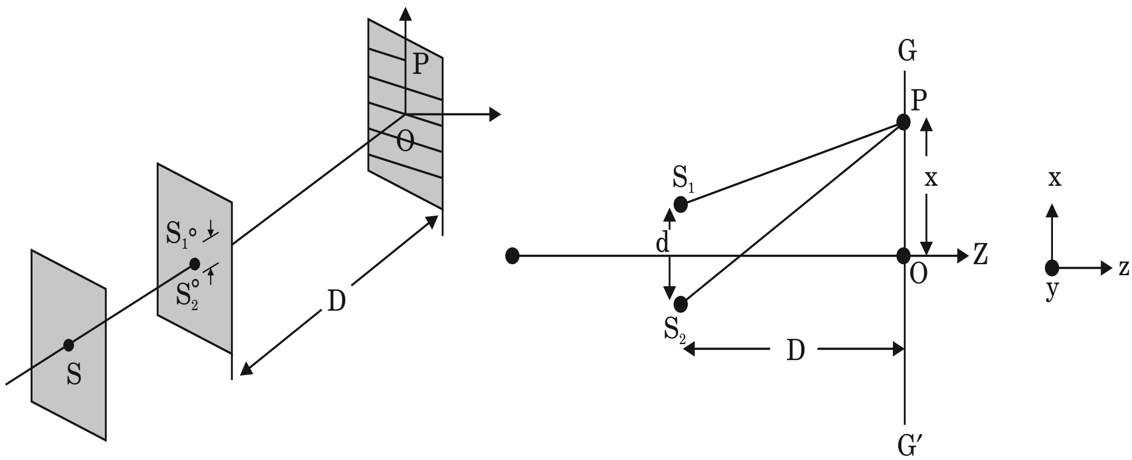


Fig.: Young's Double Slit Experiment

- Path difference, $y = \frac{n\lambda D}{d}$
- **Fringe width:** Distance between two consecutive bright and dark fringes represented by $\frac{\lambda D}{d}$

Diffraction and Polarisation of Light

- ***Diffraction:*** Bending of light around corners of an obstacle into the region where shadow of obstacle is expected.

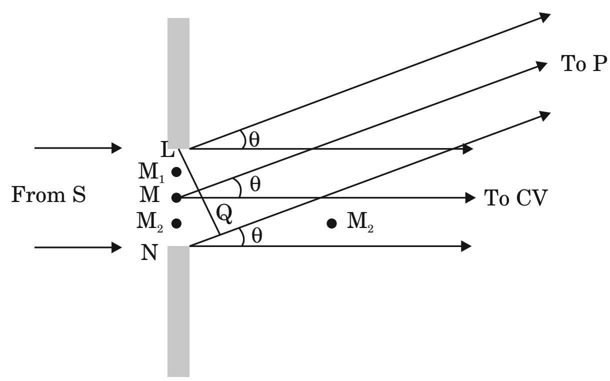


Fig.: Diffraction Phenomenon

- Light energy is redistributed in interference and diffraction. When it reduces in one region, emitting a dark fringe, it increases in another region, emitting a bright fringe. In this process the energy remains constant i.e. neither energy is gained nor lost, with the principle of conservation of light.
- The ***resolving power of the microscope*** is given by the reciprocal of the minimum separation of two points seen as distant. The resolving power can be increased by choosing a medium of higher refractive index.

$$d_{min} = \frac{1.22\lambda}{2\sin\beta}$$

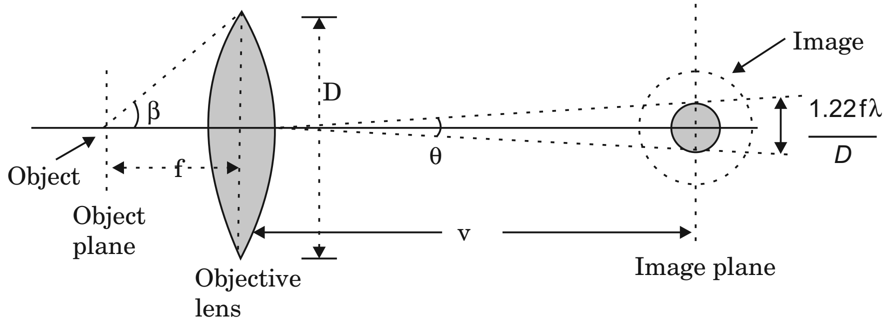


Fig.: Resolving power of the microscope

- ***Resolving power of telescope:*** For two stars to be just resolved,

  $$f\,\Delta\theta \approx \frac{0.61\lambda f}{a}$$

  So, $\Delta\theta \approx \frac{0.61\lambda}{a}$

  Telescope will have better resolving power if a is large.
- A diffraction pattern with a central maximum is given by a single slit of width a. At angles of $\pm\frac{\lambda}{a}, \pm\frac{2\lambda}{a}$, etc., along with successively weaker secondary maxima in between, the intensity reduces to zero. The angular resolution of a telescope is limited to $\frac{\lambda}{D}$, due to diffraction where D is the diameter. Strongly overlapping images are formed when two stars are closer than this angle. Similarly, in a medium of refractive index n, a microscope objective subtending angle 2β at the focus, will just separate two objects spaced at a distance $\frac{\lambda}{(2n\ \sin\beta)}$, which is the resolution limit of a microscope.
- The ***Fresnel distance*** is given by the formula $Z_P = \frac{a^2}{\lambda}$, where a is the size of the aperture and λ is the wavelength.
- ***Polarized wave:*** A long string is held horizontally, the other end of which is assumed to be fixed. If the end of the string is moved up and down in a periodic manner, a wave propagating in the +x direction will be generated. Each point on the string moves on a straight line, the wave is also referred to as linearly polarised wave. The linearly polarized waves are transverse waves; i.e., the displacement of each point of the string is always at right angles to the direction of propagation of the wave.
- ***Unpolarized wave:*** When the plane of vibration of the string is changed randomly in very short intervals of time, then we have what is known as an unpolarised wave. Thus, for an unpolarised wave the displacement will be randomly changing with time though it will always be perpendicular to the direction of propagation.
- A ***Polaroid*** consists of long chain molecules aligned in a particular direction. The electric vectors along the direction of the aligned molecules get absorbed. Thus if an unpolarised light wave is incident on such a Polaroid then the light wave will get linearly polarized with the electric vector oscillating along a direction perpendicular to the aligned molecules; this direction is known as the pass-axis of the Polaroid.
- If I is the intensity of polarized light after passing through the first polariser P_1 then the intensity of the light after passing through the second polarizer P_2 will be I = Icosθ. This is called ***Malus' Law***.

- Natural light from the sun is unpolarised which means that the electric vector takes all possible random directions in the transverse plane. A polaroid transmits only one component of these vectors, which is parallel to a special axis. Therefore the light wave is called plane polarised. When this kind of light is viewed through another polaroid which is rotated through an angle 2π, we can see two maxima and minima of same intensity.
- Plane polarised light can also be produced by reflection at a special angle known as the Brewster angle and by scattering through $\frac{\pi}{2}$ in the earth's atmosphere.

Exercise

1. By corpuscular theory of light, the phenomenon which can be explained is
(*a*) Refraction (*b*) Interference
(*c*) Diffraction (*d*) Polarisation

2. According to corpuscular theory of light, the different colours of light are due to
(*a*) Different electromagnetic waves
(*b*) Different force of attraction among the corpuscles
(*c*) Different size of the corpuscles
(*d*) None

3. The idea of the quantum nature of light has emerged in an attempt to explain
(*a*) Interference
(*b*) Diffraction
(*c*) Radiation spectrum of a black body
(*d*) Polarisation

4. By Huygen's wave theory of light, we cannot explain the phenomenon of
(*a*) Interference
(*c*) Diffraction
(*c*) Photoelectric effect
(*d*) Polarisation

5. The idea of secondary wavelets for the propagation of a wave was first given by
(*a*) Newton
(*b*) Huygen
(*c*) Maxwell
(*d*) Fresnel

6. Which one of the following phenomenon is not explained by Huygen's construction of wavefront
(*a*) Refraction (*b*) Reflection
(*c*) Diffraction (*d*) Origin of spectra

7. Two coherent sources of light can be obtained by
(*a*) Two different lamps
(*b*) Two different lamps but of the same power
(*c*) Two different lamps of same power and having the same colour
(*d*) None of these

8. The phenomenon of interference is shown by
(*a*) Longitudinal mechanical waves only
(*b*) Transverse mechanical waves only
(*c*) Electromagnetic waves only
(*d*) All the above

9. Soap bubble appears coloured due to the phenomenon of
(*a*) Interference (*b*) Diffraction
(*c*) Dispersion (*d*) Reflection

10. Wave nature of light is verified by
(*a*) Interference
(*b*) Photoelectric effect
(*c*) Reflection
(*d*) Refraction

11. The frequency of light ray having the wavelength of 3800Å is
(*a*) 9×10^{13} cycles/s (*b*) 10^{15} cycles/s
(*c*) 90 cycles/s (*d*) 3000 cycles/s

12. A slit of width a is illuminated by white light. For red light (λ = 6500 Å), the first minima is obtained at $\theta = 30°$, then the value of a will be
(*a*) 3250 Å (*b*) 6.5×10^{-4} mm
(*c*) 1.24 microns (*d*) 2.6×10^{-4} cm

13. The light of wavelength 6328 Å is incident on a slit of width 0.2 mm perpendicularly, the angular width of central maxima will be
(*a*) 0.36° (*b*) 0.18°
(*c*) 0.72° (*d*) 0.09°

14. The penetration of light into the region of geometrical shadow is called
(*a*) Polarisation
(*b*) Interference
(*c*) Diffraction
(*d*) Refraction

15. A diffraction is obtained by using a beam of red light. What will happen if the red light is replaced by blue light.
(*a*) Bands will become narrower and crowd full together
(*b*) Bands will become broader and further apart
(*c*) No change will take place
(*d*) Bands disappear

16. Through which character we can distinguish the light waves from sound waves
(*a*) Interference
(*b*) Refraction
(*c*) Polarisation
(*d*) Reflection

17. The angle of polarisation for any medium is 60°, what will be critical angle for this
(*a*) $\sin^{-1}\sqrt{3}$ (*b*) $\tan^{-1}\sqrt{3}$
(*c*) $\cos^{-1}\sqrt{3}$ (*d*) $\sin^{-1}\frac{1}{\sqrt{3}}$

18. The angle of incidence at which reflected light is totally polarized for reflection from air to glass is
(*a*) $\sin^{-1}(n)$ (*b*) $\sin^{-1}\left(\frac{1}{n}\right)$
(*c*) $\tan^{-1}\left(\frac{1}{n}\right)$ (*d*) $\tan^{-1}(n)$

19. Which of following cannot be polarised
(*a*) Radio waves
(*b*) Ultraviolet rays
(*c*) Infrared rays
(*d*) Ultrasonic waves

20. In the propagation of electromagnetic waves the angle between the direction of propagation and plane of polarisation is
(*a*) 0°
(*b*) 45°
(*c*) 90°
(*d*) 180°

21. When an unpolarized light of intensity I_o is incident on a polarizing sheet, the intensity of the light which does not get transmitted is
(*a*) zero (*b*) I_o
(*c*) $\frac{1}{2}I_o$ (*d*) $\frac{1}{4}I_o$

Answer Keys

1. (*a*)	2. (*c*)	3. (*c*)	4. (*c*)	5. (*b*)	6. (*d*)	7. (*d*)	8. (*d*)	9. (*a*)	10. (*a*)
11. (*b*)	12. (*c*)	13. (*a*)	14. (*c*)	15. (*a*)	16. (*c*)	17. (*d*)	18. (*d*)	19. (*d*)	20. (*a*)
21. (*c*)									

Solutions

1. Corpuscular theory explains refraction of light.
2. According to corpuscular theory different colours of lights are due to different sizes of corpuscules.
3. According t Planks hypothesis, black bodies emit radiations in the form of photons.
4. Huygen's wave theory fails to explains the particles nature of light (i.e., photoelectric effect).
5. The idea of secondary wavelets is given by Huygen.
6. Origin of spectra is not explained by Huygen's theory.
7. The coherent source cannot be obtained from two different light sources.
8. Interference is shown by electromagnetic as well as mechanical waves.
9. Phenomenon of interference of light takes place.
10. Interference of light verifies the wave nature of light.
11. $V = \frac{c}{\lambda} = \frac{3 \times 10^8}{3000 \times 10^{-10}} = 10^{15}$ cycles/sec

12. For first minima $\theta = \frac{\lambda}{a}$ or $a = \frac{\lambda}{\theta}$

$\therefore \quad a = \frac{6500 \times 10^{-8} \times 6}{\pi} \left(\text{As } 30° = \frac{\pi}{6} \text{red} \right)$

$= 1.24 \times 10^{-4}$ cm = 1.24 microns

13. The angular half width of the central maxima is given by $\sin\theta = \frac{\lambda}{a} \Rightarrow \theta = \frac{6328 \times 10^{-10}}{0.2 \times 10^{-3}}$ rad

$= \frac{6328 \times 10^{-10} \times 180}{0.2 \times 10^{-3} \times \pi}$ degree $= 0.18°$

$\therefore$ Total width of central maxima = $2\theta = 0.36°$.

14. It is caused due to turning of light around corners.

15. Band width $\alpha\ \lambda$,

$\because \lambda_{blue} < \lambda_{red}$, hence for blue light the diffraction bands becomes narrower and crowded together.

16. Polarisation is not shown by sound waves.

17. By using $\mu = \tan\theta_p \Rightarrow \mu = \tan 60° = \sqrt{3}$

also $c = \sin^{-1}\left(\frac{1}{\mu}\right) \Rightarrow c = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

18. $\mu n = \tan\theta_p \Rightarrow \theta_p = \tan^{-1}(n)$

19. Ultrasonic waves are longitudinal waves.

20. A plane, which contains $\vec{E}$ and the propagation direction is called the plane of polarization.

21. If an unpolarised light is converted into plane polarised light by passing through a polaroid, it's intensity becomes half.

CHAPTER 11

Dual Nature of Radiation and Matter

Photoelectric Effect

- ***Work Function:*** The minimum energy which is necessary for an electron to get away from the surface of metal is called the work function of the metal which is denoted by ϕ_0. The unit for measuring work function is electron volt (eV). This minimum energy can be provided by thermionic emission, field emission or photo-electric emission.

  Thermionic emission: When a metal is heated, thermal energy is imparted to free the electrons from the surface of the metal.

  Field emission: Electrons can be pulled out of metal by applying a very strong electric field (of the order of 108 Vm^{-1}) to it, as in a tesla coil.

  Photo-electric emission: Electrons are emitted when a light of suitable frequency hits a metal surface. This can be seen in a photodiode.
- 1eV is the energy attained by an electron when it has been accelerated by a potential difference of 1, so that 1eV = 1.602×10^{-19}J.
- ***Photoelectric Effect:*** When metals are irradiated by light of suitable frequency, electrons start emitting from the metal surface. This phenomenon is known as photoelectric effect.

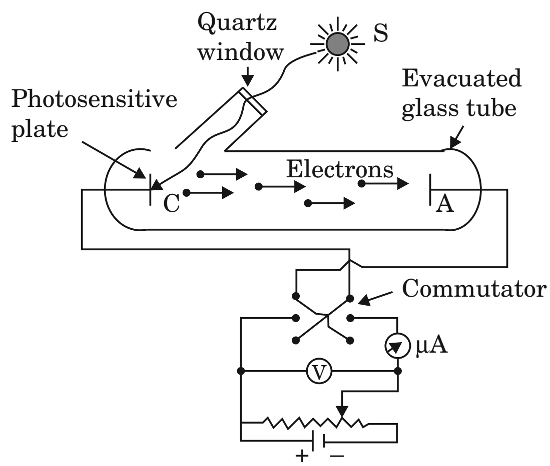


Fig.: Depiction of Photoelectric effect

- Some metals are sensible to ultraviolet light and some to visible light also. Photocurrent depends upon the intensity of light, frequency of incident light, potential difference between both the plates and the material of the plate.
- ***Stopping Potential:*** Stopping potential or cut-off potential is the minimum retarding (negative) potential for which the photoelectric current stops at a particular frequency of incident light. It is denoted by V_0.

- ***Saturation Current:*** At a certain potential difference, the photoelectric current stops increasing further. This maximum value of photocurrent is known as the saturation current.
- ***Maximum Kinetic Energy:*** The maximum kinetic energy of the photoelectric electrons is denoted by K_{max} and it depends directly on the frequency of the incident light. It is independent of the intensity of the light.

  The maximum kinetic energy $K_{max} = eV_0$
- ***Threshold Frequency:*** The minimum cut-off frequency which is required for the emission of electrons is called the threshold frequency which is denoted by ν_0. No emission is possible for the frequency lower than the cut-off frequency.
- In the photoelectric effect, the light energy is converted into the electrical energy. The photoelectric emission is a quick process having very less time lag.
- ***Effect of intensity of light on photocurrent:*** Number of photoelectrons emitted per second varies directly with the intensity of incident radiation.
- ***Effect of potential on photoelectric current:*** The stopping potential is independent of its intensity for a given frequency of the incident radiation.
- ***Effect of frequency of incident radiation on stopping potential:***

  The stopping potential V_0 varies linearly with the frequency of incident radiation for a given photosensitive material.

  There exists a certain minimum cut-off frequency ν_0 for which the stopping potential is zero.
- ***Einstein's Photoelectric Equation:*** Einstein proposed that light is comprised of small discrete energy packets known as photons or quanta and energy carried by each photon is hv, where v is the frequency of light and Planck's constant. The momentum carried by each photon is $\frac{h}{\lambda}$. In photoelectric effect, emission is possible because of the absorption of a photon by an electron. The maximum kinetic energy of the emitted electron is:

  $K_{max} = h\nu - \phi_0$, where ϕ_0 is the work function.

  $= h(\nu - \nu_0)$

  The photoelectric emission is possible only when $h\nu > \phi_0$ as K_{max} must be non-negative.

  $\Rightarrow \nu > \nu_0$ where $\nu_0 = \frac{\phi_0}{h}$
- From the photoelectric equation,

  $eV_0 = h\nu - \phi_0$, for $\nu \geq \nu_0$ (as $K_{max} = eV_0$)

  or $V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi_0}{e}$

  According to this result, the graph of V_0 versus ν is a straight line having the slope equal to $\left(\frac{h}{e}\right)$.

Matter Wave

Dual Nature of matter

- ***Particle Nature of matter:***

  Radiation behaves as if it is made up of particles in interaction of radiation with matter, called photons.

  Each photon has energy E = hv and momentum $p = \frac{h\upsilon}{c}$, and speed c that is the speed of light.
- ***Wave Nature of Matter:***

  De Broglie proposed that the moving particles are associated with the waves. If a particle is having a momentum p, then the associated wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$, where ν is the speed of the moving particle and its mass. The wavelength λ is known as the ***de Broglie wavelength*** and the above relation as the ***de Broglie relation***.

  The wavelength of an electron accelerated with the potential V is:

  $$\lambda = \frac{1.227}{\sqrt{V}} nm$$
- ***Heisenberg's uncertainty principle:*** This principle states that, "it is not possible to measure both the position and momentum of an electron at the same time exactly. There is always some uncertainty in the position and in momentum.

  $\Delta x \, \Delta p \approx \hbar$, where $\hbar = \frac{h}{2\pi}$
- The wave nature of electron was verified and confirmed by the electron diffraction experiments performed by Davisson and Germer, and G.P. Thomson. Many other experiments later also confirmed the wave nature of electron.

Exercise

1. The momentum of a photon is 3.3×10^{-29} Kg–m/s. Its frequency will be
   (*a*) 3×10^3 Hz (*b*) 6×10^3 Hz
   (*c*) 7.5×10^{12} Hz (*d*) 1.5×10^{13} Hz
2. The momentum of a photon is 2×10^{-16} gm–cm/sec. Its energy is
   (*a*) 0.61×10^{-26} erg (*b*) 2.0×10^{-26} erg
   (*c*) 6×10^{-6} erg (*d*) 6×10^{-8} erg
3. The momentum of the photon of wavelength 5000 Å will be
   (a) 1.3×10^{-27} Kg-m/s (*b*) 1.3×10^{-28} Kg-m/s
   (*c*) 4×10^{29} Kg-m/s (*d*) 4×10^{-18} Kg-m/s
4. The momentum of a photon of energy hν will be
   (*a*) hν (*b*) hν/c
   (*c*) hνc (*d*) h/ν
5. A photon in motion has a mass
   (*a*) c/hν (*b*) h/ν
   (*c*) hν (*d*) hν/c^2
6. The energy of a photon is E = hν and the momentum of photon $p = \frac{h}{\lambda}$, then the velocity of photon will be
   (*a*) $\frac{E}{P}$ (*b*) EP
   (*c*) $\left(\frac{E}{P}\right)^2$ (*d*) 3×10^8 m/s
7. An important spectral emission line has a wavelength of 21 cm. The corresponding photon energy is
   (*a*) 5.9×10^{-4} eV (*b*) 5.9×10^{-6} eV
   (*c*) 5.9×10^{-8} eV (*d*) 11.8×10^{-6} eV
8. The energy of a photon of light of wavelength 450 nm is
   (*a*) 4.4×10^{-19} J (*b*) 2.5×10^{-19} J
   (*c*) 1.25×10^{-17} J (*d*) 2.5×10^{-17} J
9. If a photon has velocity c and frequency ν, then which of following represents its wavelength?
   (*a*) $\frac{hc}{E}$ (*b*) $\frac{h\nu}{c}$
   (*c*) $\frac{h\nu}{c^2}$ (*d*) hν
10. Einstein's photoelectric equation states that EK = hν– ϕ. In this equation E_K refers to
    (*a*) Kinetic energy of all the emitted electrons
    (*b*) Mean kinetic energy of the emitted electrons
    (*c*) Maximum kinetic energy of the emitted electrons
    (*d*) Minimum kinetic energy of the emitted electrons
11. As the intensity of incident light increases
    (*a*) Photoelectric current increases
    (*b*) Photoelectric current decreases
    (*c*) Kinetic energy of emitted photoelectrons increases
    (*d*) Kinetic energy of emitted photoelectrons decreases
12. The photoelectric effect can be understand on the basis of
    (*a*) The principle of superposition
    (*b*) The electromagnetic theory of light
    (*c*) The special theory of relativity
    (*d*) Line spectrum of the atom
13. The minimum wavelength of photon is 5000 Å, its energy will be
    (*a*) 2.5 eV (*b*) 50V
    (*c*) 5.48 eV (*d*) 7.48 eV
14. In photoelectric effect, the electrons are rejected from metals if the incident light has certain minimum
    (*a*) Wavelength (*b*) Frequency
    (*c*) Amplitude (*d*) Angle of incidence
15. The idea of matter waves was given by
    (*a*) Davisson and Germer
    (*b*) de-Broglie
    (*c*) Einstein
    (*d*) Planck
16. Wave is associated with matter
    (*a*) When it is stationary
    (*b*) When it is in motion with the velocity of light only
    (*c*) When it is in motion with any velocity
    (*d*) None of these

17. The de-Broglie wavelength associated with the particle of mass m moving with velocity v is

(*a*) h/mv (*b*) mv/h

(*c*) mh/v (*d*) m/hv

18. A photon, an electron and a uranium nucleus all have the same wavelength. The one with the most energy

(*a*) is the photon

(*b*) is the electron

(*c*) is the uranium nucleus

(*d*) Depends upon the wavelength and properties of the particle.

19. A particle which has zero rest mass and non-zero energy and momentum, must travel with a speed

(*a*) Equal to c, the speed of light in vacuum

(*b*) Greater than c

(*c*) Less than c

(*d*) Tending to infinity

20. If the de-Broglie wavelengths for a proton and an α-particle are equal, then the ratio of their velocities will be

(*a*) 4 : 1 (*b*) 2 : 1

(*c*) 1 : 2 (*d*) 1 : 4

21. The de-Broglie wavelength λ associated with an electron having kinetic energy E is given by the expression

(*a*) $\frac{h}{\sqrt{2mE}}$ (*b*) $\frac{2h}{mE}$

(*c*) 2mhE (*d*) $\frac{2\sqrt{2mE}}{h}$

22. What will be the of de-Broglie wavelengths of proton and α-particle of same energy

(*a*) 2 : 1 (*b*) 1 : 2

(*c*) 4 : 1 (*d*) 1 : 4

23. If particles are moving with the same velocity, then maximum de-Broglie wavelength will be for

(*a*) Neutron

(*b*) Proton

(c) β-particle

(d) α-particle

24. The de-Broglie wavelength proportional to

(*a*) $\lambda \propto \frac{1}{v}$ (*b*) $\lambda \propto \frac{1}{m}$

(c) $\lambda \propto \frac{1}{p}$ (d) $\lambda \propto p$

25. Particle nature and wave nature of electromagnetic waves and electrons can be shown by

(*a*) Electron has small, deflected by the metal sheet

(*b*) x-ray is diffracted, reflected by thick metal sheet

(*c*) Light is refracted and defracted

(*d*) Photoelectricity and electron microscopy

26. The speed of an electron having a wavelength of 10^{-10} m is

(*a*) 7.25×10^6 m/s (*b*) 6.26×10^6 m/s

(*c*) 5.25×10^6 m/s (*d*) 4.24×10^6 m/s

27. The de-Broglie wavelength associated with a hydrogen molecule moving with a thermal velocity of 3 km/s will be

(*a*) 1 Å (*b*) 0.66 Å

(*c*) 6.6 Å (*d*) 66 Å

28. The energy that should be added to an electron to reduce its de-Broglie wavelength from one nm to 0.5 nm is

(*a*) Four times the initial energy

(*b*) Equal to the initial energy

(*c*) Twice the initial energy

(d) Thrice the initial energy

Answer Keys

1. (*d*)	**2.** (*c*)	**3.** (*a*)	**4.** (*b*)	**5.** (*d*)	**6.** (*a*)	**7.** (*b*)	**8.** (*a*)	**9.** (*a*)	**10.** (*c*)
11. (*a*)	**12.** (*d*)	**13.** (*a*)	**14.** (*b*)	**15.** (*b*)	**16.** (*c*)	**17.** (*a*)	**18.** (*a*)	**19.** (*a*)	**20.** (*a*)
21. (*a*)	**22.** (*a*)	**23.** (*c*)	**24.** (*c*)	**25.** (*d*)	**26.** (*a*)	**27.** (*b*)	**28.** (*d*)		

Solutions

1. $p = \frac{hv}{c}$

$\Rightarrow v = \frac{pc}{h} = \frac{3.3\times10^{-29}\times3\times10^{8}}{6.6\times10^{-34}}$

$= 1.5\times10^{13}$ Hz

2. $p = \frac{E}{c}$

$\Rightarrow E = p \times c = 2 \times 10–16 \times (3 \times 10^{10})$

$= 6 \times 10^{-6}$ erg.

3. $p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{(5000\times10^{-10})} = 1.3\times10^{-27}$ Kg-m/s

4. $p = \frac{E}{c} = \frac{hv}{c}$

5. $E = h\nu = mc^2$.

$\therefore \quad m = \frac{hv}{c^2}$

6. Momentum of photon $c = \frac{E}{p}$

$\Rightarrow$ velocity of photon $c = \frac{E}{p}$

7. $E = \frac{hc}{\lambda} = \frac{3\times10^{8}\times6.62\times10^{-34}}{0.21\times1.6\times10^{-19}} = 5.9\times10^{-6}$ eV

8. $E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^{8}}{450\times10^{-9}} = 4.4\times10^{-19}$ J

9. $E = \frac{hc}{\lambda} = \lambda = \frac{hc}{E}$

10. According to Einstein's photoelectric equation, E_K refers to maximum kinetic energy of the emitted electrons.

11. Intensity increases means more photons of same energy will emit more electrons of same energy, hence, only photoelectric current increases.

12. Photoelectric effect can be explained on the basis of spectrum of an atom.

13. $E = \frac{12375}{\lambda} = \frac{12375}{5000} = 2.47\text{eV} \approx 2.5\text{eV}$

14. In photoelectric effect for a given photosensitive material, there exists a certain minimum cut-off frequency, called the threshold frequency, below which no emission of photoelectrons takes place no matter how intense the light is.

15. The idea of matter waves was gives by de-Broglie.

16. According to de-Broglie hypothesis, wave is associated with matter when it is in motion with any velocity.

17. $\lambda = \frac{h}{P} = \frac{h}{mv}$

18. $\lambda = \frac{h}{P} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

$\therefore \; E = \frac{h^2}{2m\lambda^2}$

λ is same for all, so $E \propto \frac{1}{m}$.

Hence, energy will be maximum for particle with lesser mass.

19. Particle is photon and it travels with the velocity equal to light in vacuum.

20. $\lambda = \frac{h}{m_1v_1} = \frac{h}{m_2v_2}$

$\therefore \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{4}{1}$

21. $\frac{1}{2}mv^2 = E \Rightarrow mv = \sqrt{2mE}$

$\therefore \; \lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

22. $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$

$\Rightarrow \frac{\lambda_P}{\lambda_\alpha} = \sqrt{\frac{m\alpha}{m_p}} = \frac{2}{1}$

23. $\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{m}$

$\therefore$ The mass of β-particle is more than all given Hence, maximum de-Broglie wavelength will be for β-particle.

24. $\lambda = \frac{h}{P} \Rightarrow \lambda \propto \frac{1}{m}$

25. In photoelectric effect particle nature of electron is shown. While in electron microscope, beam of electron is considered as electron wave.

26. By using $\lambda_{electron} = \frac{h}{m_e v} \Rightarrow v = \frac{h}{m_e \lambda_e}$

$$= \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{-10}} = 7.25 \times 10^6 \, m/s$$

27. $\lambda = \frac{h}{mv_{rms}}$:

$$\Rightarrow \lambda = \frac{6.6 \times 10^{-34}}{2 \times 1.67 \times 10^{-27} \times 3 \times 10^3} = 0.66 \mathring{A}$$

28. $\lambda = \frac{h}{\sqrt{2mE}}; \frac{\lambda'}{\lambda} = \sqrt{\frac{E}{E'}} \Rightarrow \frac{E}{E'} = \left(\frac{0.5}{1}\right)^2$

$$\therefore \; E' = \frac{E}{0.25} = 4E$$

The energy that should be added to decrease wavelength = $E' - E = 3E$

CHAPTER 12

Atoms

Rutherford's Atomic Model, Bohr's Model & Energy Level Diagram

Introduction

- Atoms in simple terms are defined as the smallest unit of matter.
- Atoms are electrically neutral because they contain same number of electrons and protons.

Plum-Pudding Model

- In 1898, J. J. Thomson proposed the first model of atom.
- He stated, there is a uniform distribution of the positive charge of the atom throughout the volume of the atom and like seeds in a watermelon, the negatively charged electrons are embedded in it. This model was picturesquely called plum pudding model of the atom.

Alpha-Particle Scattering

- Rutherford used a "Gold foil experiment"
- Rutherford only identified one of type of radiation given off by radioactive elements like polonium, uranium and named them as alpha particles.
- The alpha particles are fast moving and positively charged Helium nuclei with two protons and two neutrons.

Rutherford observed the deflection of alpha particles after passing through metal sheet and proposed his atomic model

- After passing through the metal sheet, the alpha particles strike on fluorescent screen which was coated with zinc sulphide and produced a visible flash of light
- He concluded that an atom consists of a minute positively charged body at its center called as nucleus. The nucleus, though small, contains all the protons and neutrons.

Alpha-Particle Trajectory

- The trajectory traced by an α particle depends on the impact parameter, b of collision.
- The particle near to the nucleus suffers large scattering.
- Only a small fraction of the number of incident particles rebound back indicating that the number of α-particles undergoing head on collision is small.

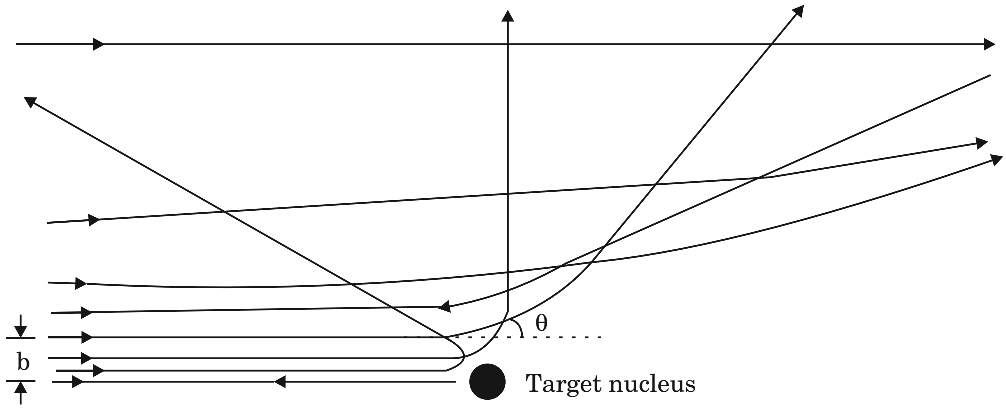


Fig.: Alpha-Particle Trajectory

Rutherford's nuclear model of Atom

- According to Rutherford's model, the entire positive charge and most of the mass of the atom is concentrated in a small volume called the nucleus with electrons revolving around the nucleus just as planets revolve around the sun.
- Rutherford scattering is a powerful way to determine an upper limit to the size of the nucleus.
- **Drawbacks of Rutherford's model:** There were two major drawbacks in Rutherford nuclear model in explaining the structure of atom:

  It cannot explain the characteristic line spectra of atoms of different elements.

  It contradicts the stability of matter because it speculates that atoms are unstable because the accelerated electrons revolving around the nucleus must spiral into the nucleus.

Electron Orbits

- The electrostatic force of attraction, F_e between the revolving electrons and the nucleus provides the requisite centripetal force (F_c) to keep them in their orbits. Hence, for a dynamically states orbit in a hydrogen atom $F_e = F_c$
- The total energy of the electron is negative. It is given by $E = -\dfrac{e^2}{8\pi\varepsilon_0 r}$.

Atomic Spectra

- Each element has a characteristic spectrum of radiation, which it emits.
- Study of emission line spectra of a material can therefore serve as a type of "fingerprint" for identification of the gas.
- The atomic hydrogen emits a line spectrum consisting of various series as:

  Lyman series: $v = Rc\left(\dfrac{1}{1^2} - \dfrac{1}{n^2}\right): n = 2, 3, 4, \ldots$

  Balmer series: $v = Rc\left(\dfrac{1}{2^2} - \dfrac{1}{n^2}\right): n = 3, 4, 5, \ldots$

  Paschen series: $v = Rc\left(\dfrac{1}{3^2} - \dfrac{1}{n^2}\right): n = 4, 5, 6, \ldots$

  Brackett series: $v = Rc\left(\dfrac{1}{4^2} - \dfrac{1}{n^2}\right): n = 5, 6, 7, \ldots$

  Pfund series: $v = Rc\left(\dfrac{1}{5^2} - \dfrac{1}{n^2}\right): n = 6, 7, 8, \ldots$

Bohr Model of the Hydrogen Atom

Bohr combined classical and early quantum concepts, explained the spectrum of hydrogen atom based on quantum ideas and gave his theory in the form of three postulates. These are:

- Bohr's first postulate was that an electron in an atom could revolve in certain stable orbits without the emission of radiant energy, contrary to the predictions of electromagnetic theory. According to this postulate, each atom has certain definite stable states in which it can exist, and each possible state has definite total energy. These are called the stationary states of the atom.
- Bohr's second postulate defines these stable orbits. This postulate states that the electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $h/2\pi$ where h is the Planck's constant ($= 6.6 \times 10^{-34}$ Js). Thus the angular momentum (L) of the orbiting electron is quantised. That is $L = nh/2\pi$.

- Bohr's third postulate incorporated into atomic theory the early quantum concepts that had been developed by Planck and Einstein. It states that an electron might make a transition from one of its specified non-radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states. The frequency of the emitted photon is then given by

  $h\nu = E_i - E_f$, where E_i and E_f are the energies of the initial and final states and $E_i > E_f$.
- Bohr radius is represented by the symbol a_0, is given by $a_0 = \dfrac{h^2\varepsilon_0}{\pi m e^2}$.
- The total energy of the electron in the stationary states of the hydrogen atom is given by

  $$E_n = -\frac{13.6}{n^2} eV$$

De Broglie's Explanation of Bohr's Second Postulate of Quantisation

- De Broglie hypothesis provided an explanation for Bohr's second postulate for the quantisation of angular momentum of the orbiting electron. The quantised electron orbits and energy states are due to the wave nature of the electron and only resonant standing waves can persist.
- De Broglie's hypothesis is that electrons have a wavelength $\lambda = \dfrac{h}{mv}$.

Limitations of Bohr's model: Bohr's model however has many limitations.

- It is applicable only to hydrogenic (single electron) atoms.
- It cannot be extended to even two electron atoms such as helium.
- While the Bohr's model correctly predicts the frequencies of the light emitted by hydrogenic atoms, the model is unable to explain the relative intensities of the frequencies in the spectrum.

Exercise

1. If in nature there may not be an element for which the principal quantum number n > 4, then the total possible number of elements will be

(*a*) 60 (*b*) 32
(*c*) 4 (*d*) 64

2. In the Bohr's hydrogen atom model, the radius of the stationary orbit is directly proportional to (n = principal quantum number)

(*a*) n^{-1} (*b*) n
(*c*) n^{-2} (*d*) n^2

3. In the following atoms and molecules for the transaction from n = 2 to n = 1, the spectral line of minimum wavelength will be produced by

(*a*) Hydrogen atom (*b*) Deuterium atom
(*c*) Uni-ionized helium (*d*) di-ionized lithium

4. The Lyman series of hydrogen spectrum lies in the region

(*a*) Infrared (*b*) Visible
(*c*) Ultraviolet (*d*) Of X-rays

5. The size of an atom is of the order of

(*a*) 10^{-8} m (*b*) 10^{-10} m
(*c*) 10^{-12} m (*d*) 10^{-14} m

6. Which one of the series of hydrogen spectrum is in the visible region

(*a*) Lyman series (*b*) Balmer series
(*c*) Paschen series (*d*) Bracket series

7. The energy required to remove an electron in a hydrogen atom from n = 10 state is

(*a*) 13.6 eV (*b*) 1.36 eV
(*c*) 0.136 eV (*d*) 0.0136 eV

8. The kinetic energy of the electron in an orbit of radius r in hydrogen atom is (e = electronic charge)

(*a*) $\dfrac{e^2}{r^2}$ (*b*) $\dfrac{e^2}{2r}$
(*c*) $\dfrac{e^2}{r}$ (*d*) $\dfrac{e^2}{2r^2}$

9. The ratio of the energies of the hydrogen atom in its first to second excited state is

(*a*) $\frac{1}{4}$ (*b*) $\frac{4}{9}$

(*c*) $\frac{9}{4}$ (*d*) 4

10. According to Bohr's theory the radius of electron in an orbit described by principal quantum number n and atomic number Z is proportional to

(*a*) Z^2n^2 (*b*) $\frac{Z^2}{n^2}$

(*c*) $\frac{Z^2}{n}$ (*d*) $\frac{n^2}{Z}$

11. The radius of electrons second stationary orbit in Bohr's atom is R. The radius of the third orbit will be

(*a*) 3R (*b*) 2.25 R

(*c*) 9R (*d*) $\frac{R}{3}$

12. In any Bohr orbit of the hydrogen atom, the ratio of kinetic energy to potential energy of the electron is

(*a*) ½ (*b*) 2

(*c*) –½ (*d*) –2

13. The spectral series of the hydrogen spectrum that lies in the ultraviolet region is the

(*a*) Balmer series (*b*) Pfund series

(*c*) Paschen series (*d*) Lyman series

14. In Bohr model of the hydrogen atom, the lowest orbit corresponds to

(*a*) Infinite energy

(*b*) The maximum energy

(*c*) The minimum energy

(*d*) Zero energy

15. If an electron jumps from 1st orbital to 3rd orbital then it will

(*a*) Absorb energy (*d*) Release energy

(*c*) No gain of energy (*d*) None of these

16. To explain his theory, Bohr used

(*a*) Conservation of linear momentum

(*b*) Conservation of angular momentum

(*c*) Conservation of quantum frequency

(*d*) Conservation of energy

17. Number of spectral lines in hydrogen atom is

(*a*) 3 (*b*) 6

(*c*) 15 (*d*) Infinite

18. Minimum excitation potential of Bohr's first orbit in hydrogen aotm is

(*a*) 13.6 V (*b*) 3.4 V

(*c*) 10.2 V (*d*) 3.6 V

19. According to the Rutherford's atomic model, the electrons inside the atom are

(*a*) Stationary (*b*) Not stationary

(*c*) Centralized (*d*) None of these

20. According to classical theory, the circular path of an electron in Rutherford atom is

(*a*) Spiral (*b*) Circular

(*c*) Parabolic (*d*) Straight line

21. Rutherford's α-particle experiment showed that the atoms have

(*a*) Proton (*b*) Nucleus

(*c*) Neutron (*d*) Electrons

22. In hydrogen atom, when electron jumps from second to first orbit, then energy emitted is

(*a*) –13.6 eV (*b*) –27.2 eV

(*c*) –6.8 eV (*d*) None of these

23. For ionising an excited hydrogen atom, the energy required (in eV) will be

(*a*) A little less than 13.6

(*b*) 13.6

(*c*) More than 13.6

(*d*) 3.4 or less

24. The kinetic energy of electron in the first Bohr orbit of the hydrogen atom is

(*a*) –6.5 eV (*b*) –27.2 eV

(*c*) 13.6 eV (*d*) –13.6 eV

Answer Keys

1. (*a*)	**2.** (*d*)	**3.** (*d*)	**4.** (*c*)	**5.** (*b*)	**6.** (*b*)	**7.** (*c*)	**8.** (*b*)	**9.** (*c*)	**10.** (*d*)
11. (*b*)	**12.** (*c*)	**13.** (*d*)	**14.** (*c*)	**15.** (*a*)	**16.** (*b*)	**17.** (*d*)	**18.** (*c*)	**19.** (*b*)	**20.** (*a*)
21. (*b*)	**22.** (*d*)	**23.** (*d*)	**24.** (*c*)						

Solutions

1. For n = 1, maximum number of states = $2n^2 = 2$ and for n = 2, 3, 4, maximum number of states would be 8, 18, 32 respectively. Hence, number of possible elements
= 2 + 8 + 18 + 32 = 60

2. Bohr radius
$$r = \frac{\varepsilon_0 n^2 h^2}{\pi Z m e^2}$$
$\therefore r \propto n^2$

3. $$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$
For di-ionised lithium the value of Z is maximum.

4. Lyman series lies in the UV region.

5. The size of the atom is of the order of 1 Å = 10^{-10} m

6. Balmer series lies in the visible region.

7. Energy required
$$= \frac{13.6}{n^2} = \frac{13.6}{10^2} = 0.136\text{eV}$$

8. Potential energy of electron in n^{th} orbit of radius r in H-atom
$$U = -\frac{e^2}{r}(\text{in CGS})$$
$$\because \text{ K.E.} = \frac{1}{2}|\text{P.E.}| \Rightarrow K = \frac{e^2}{2r}$$

9. First excited state i.e., second orbit (n = 2)
Second excited state i.e., third orbit (n = 3)
$$\because \text{ E.} = -\frac{13.6}{n^2} \Rightarrow \frac{E_2}{E_3} = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$$

10. $$r = \frac{\varepsilon_0 n^2 h^2}{\pi Z m e^2}$$
$$\therefore r \propto \frac{n^2}{Z}$$

11. $$r \propto n^2 \Rightarrow \frac{r_{(n=2)}}{r_{(n=3)}} = \frac{4}{9}$$
$$\therefore r_{(n=3)} = \frac{9}{4}R = 2.25R$$

12. $$\text{K.E} = \frac{kZe^2}{2r} \text{ and P.E.} = -\frac{kZe^2}{r}$$
$$\therefore \frac{\text{K.E}}{\text{P.E.}} = -\frac{1}{2}$$

13. Lyman series lies in the UV region.

14. In hydrogen atom, the lowest orbit (n = 1) correspond to minimum energy (–13.6 eV).

15. When an electron jumps from the orbit of lower energy (n = 1) to the orbit of higher energy (n = 3), energy is absorbed.

16. Bohr postulated that the angular momentum of the electron is conserved.

17. Infinitely large transitions are possible (in principle) for the hydrogen atom.

18. $$\text{Excitation potential} = \frac{\text{Excitation energy}}{e}$$
Minimum excitation energy corresponds to excitation from n = 1 to n = 2
∴ Minimum excitation energy in hydrogen atom
= –3.4 – (–13.6) = + 10.2eV
Hence, minimum excitation potential = 10.2 V

19. According to the Rutherford's atomic model, the electron, inside the atoms are not stationary.

20. According to classical theory, the circular path of an electron in Rutherford atom is spiral.

21. Rutherford's α-particle experiment showed that the atoms have nucleus.

22. $$E_{n_1 \to n_2} = -13.6\left[\frac{1}{{n_2}^2} - \frac{1}{{n_1}^2}\right]; n_1 = 2 \text{ \& } n_2 = 1$$
$$\Rightarrow E_{II} \to E_I = -13.6 \times \frac{3}{4} = -10.2\text{eV}$$

23. Energy required ionising an excited hydrogen atom = ionisation energy –excitation energy (in first excited state)
= 13.6 – 10.2 = 3.4 eV

24. K.E. = –(Total energy)
= – (–13.6 eV) = + 13.6 eV

CHAPTER 13

Nuclei

Radioactivity and Decay Law

- **Nucleus:** Nucleus can be defined as the central part of an atom, made up of neutrons, protons, and other elementary particles. The nucleus has protons and neutrons inside it. They are called nucleons.
- **Mass Number:** The total number of protons and neutrons present inside the nucleus of an atom of an element is referred to as mass number (A) of the element.
- **Atomic Number:** The number of protons present in the nucleus of an atom of an element is known as atomic number (Z) of the element.
- **Nuclear Size:** The radius of the nucleus $R \propto A^{\frac{1}{3}}$
- $R = R_o A^{\frac{1}{3}}$ where $R_0 = 1.2 \times 10^{-15}$ m is an empirical constant.
- **Nuclear Density:** Nuclear density is independent of mass number and is therefore same for all nuclei.

  $$\rho = \frac{Mass\ of\ nucleus}{volume\ of\ nucleus}$$

  $\rho = \dfrac{3m}{4\pi R_0^3}$ where is the average mass of a nucleon.
- **Atomic Mass Unit:** Abbreviated as amu and is defined as one-twelfth of the mass of a carbon nucleus. It is also denoted by u.

  Therefore,

  $$1\ amu = \frac{1.992678 \times 10^{-26}}{12}\ kg$$

  $= 1.6 \times 10^{-27}$ kg = 931 MeV
- **Isomers:** The atoms that have the same mass number, atomic number but different radioactive properties are known isomers.
- **Isotones:** Atoms of elements that have different mass numbers, atomic numbers but same number of neutrons are known as isotones. e.g., $_1H^3$, $_2H^4$ and $_6C^{14}$, $_8O^{16}$ are isotones.
- **Isobars:** The atoms of an element having different atomic numbers but same mass numbers are known as isobars. e.g., $_1H^3$, $_2H^3$ and $_{10}Na^{22}$, $_{10}Ne^{22}$ are isobars.
- **Isotopes:** Atoms of an element that have different mass numbers but same atomic number are known as isotopes. e.g., $_1H^1$, $_1H^2$, $_1H^3$ is an example of isotopes.
- **Nuclear Force:** Nuclear force can be referred to as the force that acts inside the nucleus or between nucleons. These forces are neither electrostatic nor gravitational in nature. They have a very short range and are independent of any charge. They are a hundred times that of electrostatic force and 10^{38} times that of gravitational force.
- **Radioactivity:** Radioactivity refers to the breakdown of heavy elements into comparably lighter elements by the emission of radiations. This phenomenon was discovered by Henry Becquerel in 1896.
- **Packing Fraction (P):**

  $$P = \frac{(Exact\ nuclear\ mass) - (Mass\ number)}{Mass\ number}$$

  $$= \frac{(A - M)}{M}$$

For greater stability of the nucleus, the value of packing friction should be larger.

- ***Radioactive Decay law***

The Radioactive law states that the rate of disintegration of radioactive atoms at any instance is directly proportional to the number of radioactive atoms present in the given sample at that instant.

Rate of disintegration $\left(-\frac{dN}{dt}\right) \propto N$

$-\frac{dN}{dt} = \lambda N$, where λ is the decay constant.

The number of undecayed atoms present in the sample at any instance $N = N_0 e^{-\lambda t}$ where, N_0 is number of atoms at time t = 0 and N is number of atoms at time t.

- **Activity of a radioactive element**

The activity of a radioactive element is equal to its rate of disintegration.

Activity $R = \left(-\frac{dN}{dt}\right)$

Activity of the sample after time t, $R = R_0 e^{-\lambda t}$

Its SI unit is Becquerel (Bq). Curie and Rutherford are its other units.

1 Curie = 3.7×10^{10} decay/s and 1 rutherford = 10^6 decay/s

- **Half-life of a radioactive element**

Half-life (T) of a radioactive element is the time taken for the radioactivity of an isotope to fall to half its original value. The relation between disintegration constant and half-life is given by

$$T = \frac{\log_e 2}{\lambda} = \frac{0.6931}{\lambda}$$

- **Average Life or Mean Life (τ)**

Average life or mean life (τ) of a radioactive element can be defined as the ratio of total life time of all the atoms and total number of atoms present, initially in the sample.

Relation between half-life and average life $\tau = 1.44T$

Relation between average life and decay constant $\tau = \frac{1}{\lambda}$

- **Alpha decay:** In alpha decay, a nucleus gets transformed into a different nucleus and an α particle is emitted. The general form can be expressed as:

  ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ and the Q value:

  $Q = (m_X - m_Y - m_{He})c^2$

- **Beta decay:** When a nucleus undoes beta decay, it emits an electron or a positron. When an electron is emitted, it is said to be beta minus decay while in beta plus decay, a positron is emitted.
- **Gamma decay:** In gamma decay, the photons are emitted from the nuclei having MeV energy and thus the gamma rays are emitted. This is called as gamma decay.

Mass Defect and Binding Energy

- **Mass Defect***:* Mass defect can be mentioned as the difference between the sum of masses of all nucleons (M) and the mass of the nucleus (m).

  Mass Defect (Δm) = M – m

  = $[Zm_p + (A - z)m_n - m_n]$

- **Nuclear Binding Energy***:* Nuclear binding energy can be referred to as the minimum energy that is required to separate the nucleons up to an infinite distance from the nucleus.

Nuclear binding energy per nucleon = Nuclear binding energy / Total number of nucleons Binding energy, E_b = $[Zm_p + (A - Z)m_n - m_n]c^2$

- **Nuclear Fission**

The process of the splitting a heavy nucleus into two or more lighter nuclei is known as nuclear fission.

When a slow moving neutron strikes with a uranium nucleus $\left({}_{92}U^{235}\right)$, it splits into ${}_{56}Ba^{141}$ and ${}_{36}Kr^{92}$ along with three neutrons and a lot of energy.

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} \rightarrow 3\,{}_{0}n^{1} + energy$$

- **Nuclear Chain Reaction**

Nuclear chain reactions are defined as a chain of nuclear fission reactions (splitting of atomic nuclei), and each one of them is initiated by a neutron produced in the previous fission reaction. Nuclear chain reactions are of two types:

➢ Controlled chain reaction

➢ Uncontrolled chain reaction

- **Nuclear Reactor**

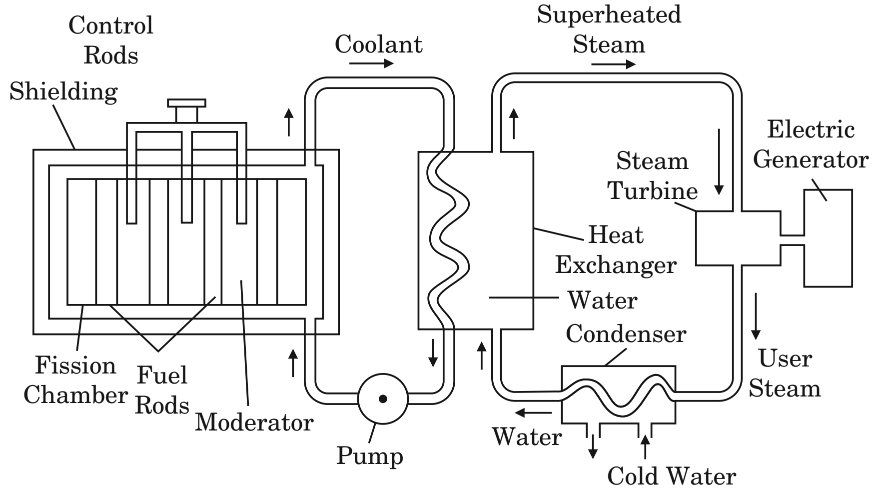


Fig.: Setup of a Nuclear Reactor

The vital parts of a nuclear reactor are the following:

- Fuel: Fissionable materials like ${}_{92}U^{235}$, ${}_{92}U^{238}$, ${}_{94}U^{239}$ are used as fuel.
- Moderator: Graphite, heavy water and beryllium oxide are used to slower down fast moving neutrons.
- Coolant: Liquid oxygen, cold water, etc. are used to remove heat generated in the fission process.
- Control rods: Cadmium or boron rods are considered as good absorber of neutrons and are therefore used to control the fission reaction.

- **Nuclear Fusion:** The process of combining two light nuclei in order to form a single large nucleus is called nuclear fusion. A large amount of energy is released in this process. The example of nuclear fusion is:

${}_1^1H + {}_1^1H \rightarrow {}_1^2H + e^+ + v + 0.42$ MeV, where a deuteron and a positron are formed by the combination of two protons and 0.42 MeV energy is released.

The source of energy of sun and all the stars is a nuclear fusion reaction in which hydrogen nuclei combine to form helium nuclei.

$$4\,{}_1^1H + 2e^- \rightarrow {}_2^4He + 2v + 6\gamma + 26.7 \text{ MeV}$$

- **Advantages of Nuclear fusion:**
  - Nuclear fusion does not cause any waste as the only by product is helium.
  - Nuclear fusion is very simple to control as there is no change of chain reaction.
  - There is unlimited supply of fuel for nuclear fusion.

Exercise

1. Radioactive substances do not emit

(*a*) Electron (*b*) Helium nucleus

(*c*) Positron (*d*) Proton

2. In a radioactive substances of t = 0, the number of atoms is 8×10^4. Its half life period is 3 years. The number of atoms 1×10^4 will remain after interval

(a) 9 years (b) 8 years

(*c*) 6 years (*d*) 24 years

3. The half life period of radium is 1600 years. The fraction of a sample of radium that would remain after 6400 years is

(*a*) $\frac{1}{4}$ (*b*) $\frac{1}{2}$

(*c*) $\frac{1}{8}$ (*d*) $\frac{1}{16}$

4. Some radioactive nucleus may emit

(*a*) Only one α, β or γ at a time

(*b*) All the three α, β and γ one after another

(*c*) All the three α, β and γ simultaneously

(*d*) Only α and β simultaneously

5. Which can pass through 20 cm thickness of the steel
   (*a*) α-particles (*b*) β-particles
   (*c*) γ-rays (*d*) ultraviolet rays
6. The half-life period of radium is 1600 years. Its average life time will be
   (*a*) 3200 years (*b*) 4800 years
   (*c*) 2319 years (*d*) 4217 years
7. What percentage of original radioactive atoms is left after five half lives
   (*a*) 0.3% (*b*) 1%
   (*c*) 31% (*d*) 3.125%
8. Beta rays emitted by a radioactive material are
   (*a*) Electromagnetic radiation
   (*b*) The electrons orbiting around the nucleus
   (*c*) Charged particles emitted by nucleus
   (*d*) Neutral particles
9. In the given reaction
   $${}_{2}X^{A} \rightarrow {}_{2+10}Y^{A} \rightarrow {}_{Z-1}X^{A-4} \rightarrow {}_{Z-1}X^{A-4}$$
   radioactive radiations are emitted in the sequence.
   (a) α, β, γ (b) β, α, γ
   (c) γ, α, β (d) β, γ, α
10. Half life of Bi^{210} is 5 days. If we start with 50,000 atoms of this isotope, the number of atoms left over after 10 days is
   (*a*) 5,000 (*b*) 25,000
   (*c*) 12,500 (*d*) 20,000
11. Half life of radioactive element depends upon
   (*a*) Amount of element present
   (*b*) Temperature
   (*c*) Pressure
   (*d*) Nature of element
12. The decay constant of radium is 4.28×10^{-4} per year. Its half life will be
   (*a*) 2000 years (*b*) 1240 years
   (*c*) 63 years (*d*) 1620 years
13. Which of the following is not a mode of radioactive decay.
   (*a*) Positron emission (*b*) Electron capture
   (*c*) Fusion (*d*) Alpha decay
14. Half life of a radioactive substance is T. The time taken for all the nuclei to disintegrate will be
   (*a*) 2T (*b*) T^2
   (*c*) 4T (*d*) Uncertain
15. Decay constant of radium is λ. By a suitable process its compound radium bromide is obtained. The decay constant of radium bromide will be
   (*a*) λ (*b*) More than λ
   (*c*) Less than λ (*d*) Zero
16. Which of the following particles are constituents of the nucleus
   (*a*) Protons and electrons
   (*b*) Protons and neutrons
   (*c*) Neutrons and electrons
   (*d*) Neutrons and positrons
17. The particles which can be added to the nucleus of an atom without changing its chemical properties are called
   (*a*) Electrons (*b*) Protons
   (*c*) Neutrons (*d*) None of these
18. The neutron was discovered by
   (*a*) Marie Curie
   (*b*) Pierre Curie
   (*c*) James Chadwick
   (*d*) Rutherford
19. The mass number of a nucleus is
   (*a*) Always less than its atomic number
   (*b*) Always more than its atomic number
   (*c*) Always equal to its atomic number
   (*d*) Sometimes more than and sometimes equal to its atomic number
20. The energy equivalent of 1 kilogram of matter is about
   (*a*) 10^{-15} J (*c*) 1 J
   (*c*) 10^{-12} J (*d*) 10^{17} J
21. Nuclear binding energy is equivalent to
   (*a*) Mass of proton
   (*b*) Mass of neutron
   (*c*) Mass of nucleus
   (*d*) Mass defect of nucleus
22. If the binding energy of the deuterium is 2.23 MeV. The mass defect given in a.m.u. is
   (*a*) –0.0024 (*b*) –0.0012
   (*c*) 0.0012 (*d*) 0.0024
23. Which of the following has the mass closest in value to that of the positron
   (*a*) Proton (*b*) Electron
   (*c*) Photon (*d*) Neutron

24. The mass defect for the nucleus of helium is 0.0303 a.m.u. What is the binding energy per nucleon for helium in MeV

(*a*) 28 (*b*) 7
(*c*) 4 (*d*) 1

25. The average binding energy per nucleon in the nucleus of an atom is approximately

(*a*) 8 eV (*b*) 8 KeV
(*c*) 8 MeV (*d*) 8J

26. Binding energy of a nucleus is

(*a*) Energy given to its nucleus during its formation
(*b*) Total mass of nucleus converted to energy units
(*c*) Loss of energy from the nucleus during its formation
(*d*) Total K.E. and P.E. of the nucleons in the nucleus

27. Equivalent energy of mass equals to 1 amu is

(*a*) 931 KeV (*b*) 931 eV
(*c*) 931 MeV (*d*) 9.31 MeV

28. The mass number of a nucleus is equal to the number of

(*a*) Electrons it contains
(*b*) Protons it contains
(*c*) Neutron it contains
(*d*) Nucleons it contains

29. The mass of a neutron is the same as that of

(*a*) A proton (*b*) A meson
(*c*) An epsilon (*d*) An electron

30. The mass defect per nucleon is called

(*a*) Binding energy (*b*) Packing fraction
(*c*) Ionisation energy (*d*) Excitation energy

31. The binding energy per nucleon is maximum in the case of

(*a*) ${}_{4}^{2}He$ (*b*) ${}_{26}^{56}Fe$
(c) ${}_{56}^{141}Ba$ (d) ${}_{92}^{235}U$

Answer Keys

1. (*d*)	2. (*a*)	3. (*d*)	4. (*a*)	5. (*c*)	6. (*c*)	7. (*d*)	8. (*c*)	9. (*b*)	10. (*c*)
11. (*d*)	12. (*d*)	13. (*c*)	14. (*d*)	15. (*a*)	16. (*b*)	17. (*c*)	18. (*c*)	19. (*d*)	20. (*d*)
21. (*d*)	22. (*d*)	23. (*b*)	24. (*b*)	25. (*c*)	26. (*c*)	27. (*c*)	28. (*d*)	29. (*a*)	30. (*b*)
31. (*b*)									

Solutions

1. Radioactive substances do not emit protons.

2. By formula $N = N_o\left(\frac{1}{2}\right)^{\frac{t}{T}}$

$$\Rightarrow 10^4 = 8\times10^4\left(\frac{1}{2}\right)^{\frac{t}{3}}$$

$$\Rightarrow \left(\frac{1}{8}\right) = \left(\frac{1}{2}\right)^{\frac{t}{3}} \Rightarrow \left(\frac{1}{2}\right)^{3} = \left(\frac{1}{2}\right)^{\frac{t}{3}}$$

$$\Rightarrow 3 = \frac{t}{3} \quad \therefore\ t = 9 \text{ years}$$

3. Fraction $= \frac{N}{N_o} = \left(\frac{1}{2}\right)^{\frac{6400}{1600}} = \left(\frac{1}{2}\right)^{4} = \frac{1}{16}$

4. No radioactive substance emits both α and β particles simultaneously. Some substances emit α-particle and some other emits β-particles. γ-rays are emitted along with both α and β-particles.

5. γ-rays are highly penetrating.

6. Average live

$$\frac{1}{\lambda} = \frac{1600}{0.693} = 2308 \approx 2319 \text{ years}$$

7. Fraction of atoms remains after five half lives

$$\frac{N}{N_o} = \left(\frac{1}{2}\right)^{\frac{t}{T}} = \left(\frac{1}{2}\right)^{\frac{5T}{T}} = \left(\frac{1}{2}\right)^{5} = \frac{1}{32}$$

$\Rightarrow$ Percentage atom remains

$$\frac{1}{32}\times 100 = 3.125\%$$

8. β-rays emitted from nucleus and they carry negative charge.

9. $${}_{z}X^{A} \xrightarrow{{}_{-1}\beta^{0}} {}_{z+1}Y^{A} \xrightarrow{{}_{2}He^{4}(\alpha)} {}_{z-1}K^{A-4} \xrightarrow{{}_{0}\gamma^{0}} {}_{z-1}K^{A-4}$$

10. $N_t = N_o\left(\frac{1}{2}\right)^{\frac{t}{T}} = 50000\left(\frac{1}{2}\right)^{\frac{10}{5}} = 12500$

11. Half life of a substance doesn't depends upon amount, temperature and pressure. It depends upon the nature of the substance.

12. $T = \frac{0.6931 \times 1}{\lambda} = \frac{0.6931}{4.28 \times 10^{-4}} = 1620$ years

13. In fusion two lighter nuclei combine, it is not the radioactive decay.

14. Uncertain, because it is infinite. No radioactive element can be disintegrated fully.

15. Decay constant remains unchanged in a chemical reaction.

16. Protons and neutrons are constituents of the nucleus.

17. Neutrons are neutral particles.

18. James Chadwick discovered the neutron.

19. In hydrogen, atomic number and mass number are equal.

20. $E = mc^2 = 1 \times (3 \times 10^8)^2$
$= 9 \times 10^{16} \approx 10^{17}$ J

21. Binding energy = Δm amu = $\Delta m \times 931$ MeV

22. Mass defect $\Delta m = \frac{2.23}{931} = 0.0024$ amu

23. Positron is the antiparticle of electron.

24. $\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{0.0303 \times 931}{4} \approx 7$

25. The average binding energy per nucleon in the nucleus of an atom is approximately 8 MeV.

26. Energy released while forming a nucleus is known as binding energy.

27. Equivalent energy to 1 amu = 931 MeV

28. The mass number of a nucleus is equal to the number of nucleons it contains.

29. Mass of neutron = Mass of Proton

30. The mass defect per nucleon is called packing fraction.

31. Binding energy per nucleon increases with atomic number and is maximum for iron. After that it decreases.

CHAPTER 14

Semiconductor Electronics

Semiconductor, diode and its applications

- The materials which are present in solid state and their conductivity lies between insulator and conductor are called as semiconductors. Semiconductors are either pure substance like silicon, germanium or they can also be formed by addition of impurities which form a compound like gallium arsenide, cadmium selenide, etc.
- Semiconductors have resistivity in the range of metals and insulators. Insulators have resistivity in the range of $10^{11} - 10^{19}$ Ωm and metals have resistivity in the range of 10^{-2} to 10^{-8} Ωm while semiconductors have resistivity in the range of $10^{-5} - 10^{6}$ Ωm
- Semiconductors can be elemental (without doping) as well as compound (by doping).
- ***Intrinsic semiconductors:*** These are pure semiconductors where the conductivity is due to electrons moving from valence band to conduction band. Their conductivity is called intrinsic conductivity. In intrinsic conductors, $n_e = n_h$
- ***Extrinsic semiconductors:*** When Impurity is added to pure semiconductor to increase its conductivity, is called as extrinsic semiconductor.

  It can be divided into two types, i.e. p-type semiconductors and n-type semiconductors.

  In p-type semiconductors, number of holes are greater than number of electrons.

  $n_h >> n_e$

  In n-type semiconductors, number of electrons are greater than number of holes.

  $n_e >> n_h$

  Trivalent atoms (B, Al, etc.) called acceptor atoms are used for doping p-type semiconductors while pentavalent atoms (As, Sb, etc.) called donor atoms are used for doping n-type semiconductors.
- ***Energy bands:*** Valence electrons of an atom are shared by different number of atoms in the crystal which causes splitting of energy levels. These energy levels are called energy bands. The energy band which contains valence electrons is called as valence band. It always has some electrons and can never be empty.

➢ The energy band which contains conduction electrons is called as conduction band. It can be empty or have some electrons which take part in flow of current.

➢ The band which lies between conduction band and valence band is called as forbidden band. The minimum amount of energy required to transfer electrons from valence band to conduction band is called as band gap.

➢ Metals do not have any band gap and $E_g \approx 0$ while band gap in insulators is greater than 3 eV and the band gap for semiconductors lies between 0.2 eV and 3 eV.

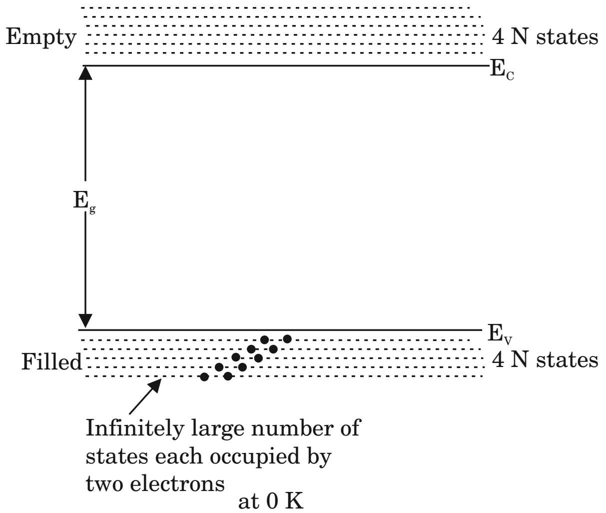


Fig.: The energy band positions in a semiconductor at 0 K. The upper band is conduction band and the lower band is called valence bond.

- ***p-n junction:*** p-type semiconductor when brought in contact with n-type semiconductor forms a p-n junction.

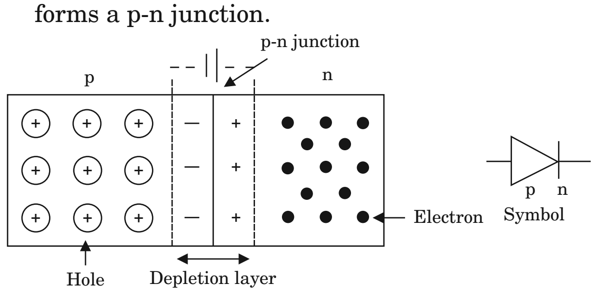


Fig.: p–n junction depicting Depletion layer

When there are no charge carriers, a region is created at the p-n junction called as depletion layer.

➢ **Forward Biasing:** When the p-side is connected to the positive terminal and n-side is connected to the negative terminal of a battery, it is called forward biasing. Majority charge carriers cause forward current flow in this biasing and the width of the depletion layer decreases.

➢ **Reverse Biasing:** When the n-side is connected to the positive terminal and p-side is connected to the negative terminal of the battery then it is called reverse biasing. Minority charge carriers cause reverse current flow in this biasing and width of the depletion layer increases.

- ***Junction diode as rectifier:*** By applying alternating voltage across a diode the current flows in only that part if the diode is forward biased and by using this property diode could be used to design a circuit which can be used as a rectifier.

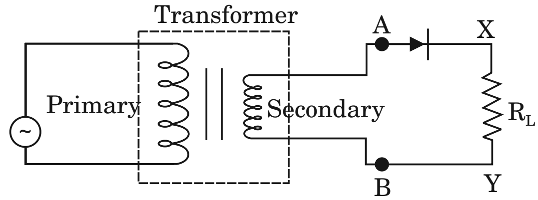


Fig.: Half-wave rectifier circuit using diode

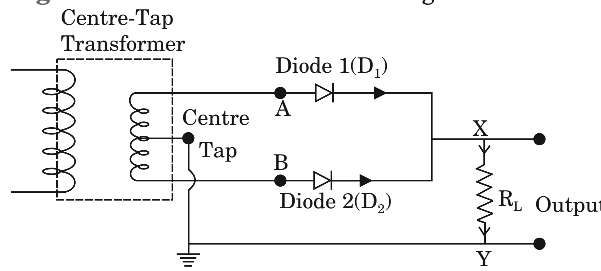


Fig.: Full-wave rectifier circuit using diode

- ***Diodes:*** Ac voltage can be restricted to one direction using diodes. Some examples of p-n junction diodes are zener diode, light-emitting diode, photo-diode, etc.

➢ In ***zener diodes***, when it is reversed biased the current increases after a certain voltage and the voltage is called breakdown voltage. This property of zener diodes is used in regulating voltage.

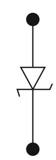


Fig.: Zener diode

➢ In ***photodiodes***, photons are excited which result in change of reverse saturation current to measure light intensity.

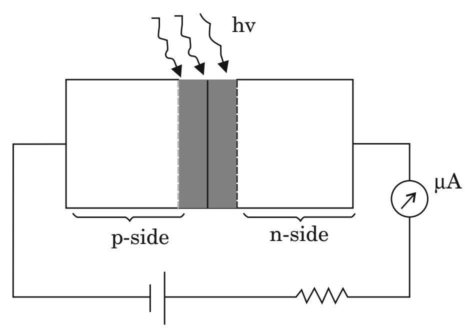


Fig.: An illuminated photodiode

➢ In ***light emitting diodes,*** electrons are excited by a biasd voltage resulting in generation of light.

➢ In ***solar cells,*** emf is generated when solar radiation falls on the p-n junction. It works on the principle of photovoltaic effect.

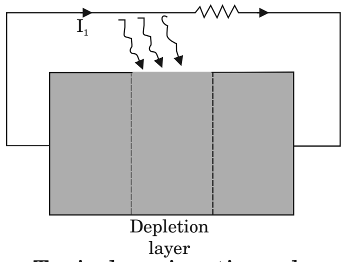
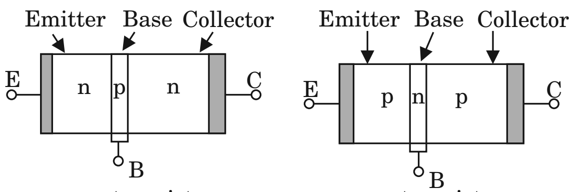


Fig.: Typical p-n junction solar cell

Transistors, its application and logic gates

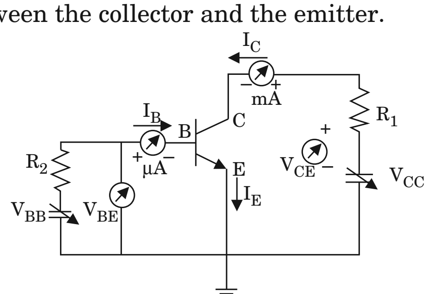
- A thin layer of one type of semiconductor is added between two thick layers of other semiconductor of same type and this forms a transistor.

  It can be done in two ways, i.e. adding a p-type semiconductor between two n-type semiconductors forming n-p-n transistor or by adding an n-type semiconductor between two p-type semiconductors forming p-n-p transistor.



n-p-n transistor   p-n-p transistor

- Any transistor has 3 parts: Base (central block), Emitter and Collector (two electrodes). Therefore the three parts of the transistor can be connected in three ways: Common Emitter (CE), Common Collector (CC) and Common Base (CB).
- For fixed I_B, the plot between I_C gives output characteristics and for fixed V_{CE}, the plot between I_B and V_{BE} gives input characteristics.
- ***Common emitter transistor:*** The input is between the base and the emitter and output is between the collector and the emitter.



n-p-n transistor in CE configuration

- ***Input resistance*** is the ratio of change in base emitter voltage to the resulting change in base current at constant collector emitter voltage and is given by

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

- Output resistance is the ratio of change in collector emitter voltage to the change in collector current at a constant base current and is given by

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

- ***Current gain:*** There are two low current gains defined as follows:
- ***Common base current amplification factor (α) :*** Ratio of the small change in collector current to the small change in emitter current at constant collector-base voltage.

$$\alpha = \left[\frac{\delta I_C}{\delta I_E}\right]_{V_{CB} = \text{constant}}$$

- ***Common emitter current amplification factor (β)***: Ratio of the small change in collector current to the small change in base current at constant collector-emitter voltage.

$$\beta = \left[\frac{\delta I_C}{\delta I_B}\right]_{V_{CE} = \text{constant}}$$

Terms α and β are related as: $\alpha = \dfrac{\beta}{1+\beta}$ and

$$\beta = \frac{\alpha}{1-\alpha}$$

- A transistor can be used as an amplifier to increase voltage, current or power. Voltage gain of an amplifier can be defined as the ratio of small change in output voltage to small change in input voltage. Ratio of the small change in collector current to the small change in base current at constant collector-emitter voltage is called current gain.

  Voltage gain of amplifier is given by,

$$A_v = -\left(\frac{\beta_{ac} R_L}{r}\right)$$

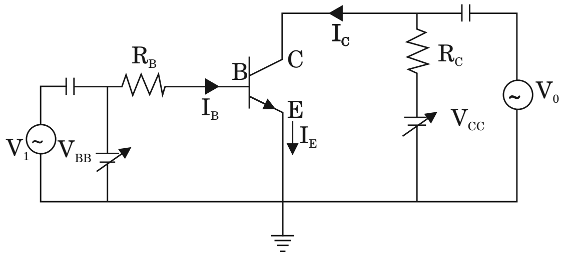


Fig.: C-E transistor amplifier

- A transistor can be used as a switch by analyzing the behavior of the base-biased transistor in CE configuration. When transistor works as a switch a low input to the transistor gives high output and a high input gives a low output. In this case the transistor does not remain in active state.

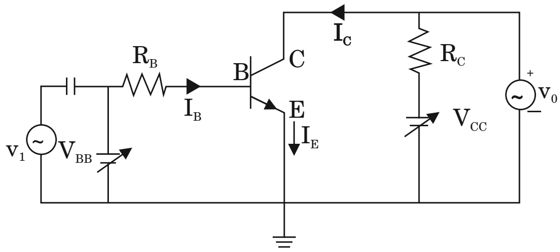


Fig.: Base-biased transistor in CE configuration to work as a switch

- ***Transistor oscillator:*** When we get ac output without any external input signal then the transistor works as an oscillator.

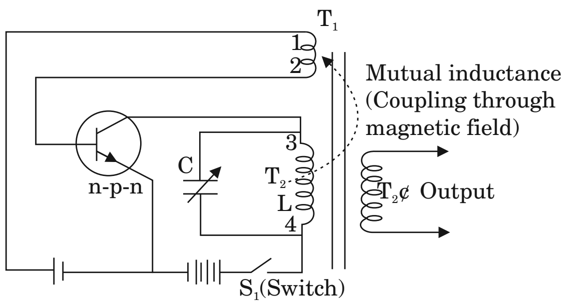
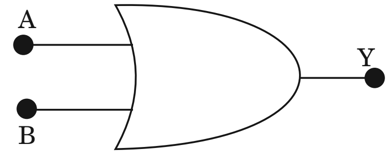


Fig.: Tuned collector oscillator

Frequency at which the oscillator will work is given by, $v = \dfrac{1}{2\pi\sqrt{LC}}$

- Logic gates are digital circuits which perform special; logic operations. These logic gates can be described as OR, AND, NOT, NAND, and NOR. Different logic gates are integrated in a single chip called Integrated circuits (IC).

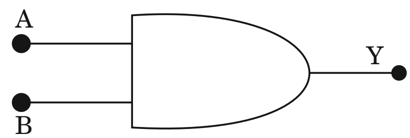
➢ Boolean expression for ***OR gate:*** Y = A + B



The truth table for OR gate is shown below:

A	*B*	*Output Y*
0	*0*	*0*
0	*1*	*1*
1	*0*	*1*
1	*1*	*1*

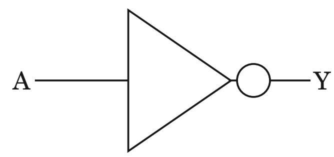
➢ Boolean expression for ***AND gate***: Y = A.B



The truth table for AND gate is shown below:

A	*B*	*Output Y*
0	*0*	*0*
0	*1*	*0*
1	*0*	*0*
1	*1*	*1*

➢ Boolean expression for ***NOT gate:*** $Y = \overline{A}$



The truth table for NOT gate is shown below:

A	*Output Y*
0	*1*
1	*0*

- ***Integrated circuits:*** When a entire circuit (including all passive components and active devices) is fabricated on a single chip or block of a semiconductor then it is known as integrated circuit(IC). The most widely used technology for making IC's is monolithic Integrated circuit.

Exercise

1. The majority charge carries in p-type semiconductor are

(*a*) Electron (*b*) Protons

(*c*) Holes (*d*) Neutrons

2. A p-type semiconductor can be obtained by adding

(*a*) Arsenic to pure silicon

(*b*) Gallium to pure silicon

(*c*) Antimony to pure germanium

(*d*) Phosphorous to pure germanium

3. The valency of an impurity added to germanium crystal in order to convert it into a p-type semiconductor is

(*a*) 6 (*b*) 5

(*c*) 4 (*d*) 3

4. In a semiconductor. the concentration of electrons is $8 \times 10^{14}/cm^3$ and that of the holes is $5 \times 10^{12}/cm^3$. The semiconductor is

(*a*) P-type (*b*) N-type

(*c*) Intrinsic (*d*) PNP-type

5. The valency of the impurity atom that is to be added to germanium crystal so as to make it a N-type semiconductor is

(*a*) 6 (*b*) 5

(*c*) 4 (*d*) 3

6. Silicon is a semiconductor. If a small amount of As is added to it, then its electrical conductivity

(*a*) Decreases

(*b*) Increases

(*c*) Remains unchanged

(*d*) Zero

7. To obtain P-type Si semiconductor, we need to dope pure Si with

(*a*) Aluminium

(*b*) Phosphorous

(*c*) Oxygen

(*d*) Germanium

8. A N-type semiconductor is

(*a*) Negatively charged

(*b*) Positively charged

(*c*) Neutral

(*d*) None of these

9. Semiconductor is damaged by the strong current due to

(*a*) Lack of free electron

(*b*) Excess of electrons

(*c*) Excess of proton

(*d*) None of these

10. PN-junction diode works as an insulator, if connected

(*a*) To A.C.

(*b*) In forward bias

(*b*) In reverse bias

(*d*) None of these

11. The PN-junction diode is used as

(*a*) An amplifier (*b*) A rectifier

(*c*) An oscillator (*d*) A modulator

12. In a junction diode, the holes are due to

(*a*) Protons

(*b*) Neutrons

(*c*) Extra electrons

(*d*) Missing of electrons

13. In PN-junction, avalanche current flows in circuit when biasing is

(*a*) Forward (*b*) Reverse

(*c*) Zero (*d*) Excess

14. Avalanche breakdown is due to

(*a*) Collision of minority charge carrier

(*b*) Increase in depletion layer thickness

(*c*) Decrease in depletion layer thickness

(*d*) None of these

15. The potential barrier, in the depletion layer, is due to

(*a*) Ions (*b*) Holes

(*c*) Electrons (*d*) Both (*b*) and (*c*)

16. Function of a rectifier is

(*a*) To convert ac into dc

(*b*) To convert dc into ac

(*c*) Both (*a*) and (*d*)

(*d*) None of these

17. The maximum efficiency of full wave rectifier is

(*a*) 100% (*b*) 25.20%

(*c*) 40.2% (*d*) 81.2%

18. Zener diode is used as
(*a*) Half wave rectifier
(*b*) Full wave rectifier
(*c*) ac voltage stabilizer
(*d*) dc voltage stabilizer

19. When NPN transistor is used as an amplifier
(*a*) Electrons move from base to collector
(*b*) Holes move from emitter to base
(*c*) Electrons move from collector to base
(*d*) Holes move from base to emitter

20. In an NPN transistor the collector current is 24 mA. If 80% of electrons reach collector its base current in mA is
(*a*) 36 (*b*) 26
(*c*) 16 (*d*) 6

21. Least doped region in a transistor
(*a*) Either emitter or collector
(*b*) Base
(*c*) Emitter
(*d*) Collector

22. The transistors provide good power amplification when they are used in
(*a*) Common collector configuration
(*b*) Common emitter configuration
(*c*) Common base configuration
(*d*) None of these

23. In a PNP transistor the base is N-region. Its width relative to the P-region is
(*a*) Smaller (*b*) Larger
(*c*) Same (*d*) Not related

24. NPN transistors are preferred to PNP transistors because they have
(*a*) Low cost
(*b*) Low dissipation energy
(*c*) Capability of handling large power
(*d*) Electrons having high mobility than holes

25. An amplifier has a voltage gain $A_V = 1000$. The voltage gain in dB is
(*a*) 30 dB (*b*) 60 dB
(*c*) 3 dB (*d*) 20 dB

26. The minimum potential difference between the base and emitter required to switch a silicon transistor 'ON' is approximately
(*a*) 1V (*b*) 3V
(*c*) 5V (*d*) 4.2V

27. A logic gate is an electronic circuit which
(*a*) makes logic decisions
(*b*) allows electrons flow only in one direction
(*c*) works binary algebra
(*d*) Alternates between 0 and 1 values

28. How many NAND gates are used to form an AND gate
(*a*) 1 (*b*) 2
(*c*) 3 (*d*) 4

29. The Boolean equation of NOR gate is
(*a*) $C = A + B$ (*b*) $C = \overline{A + B}$
(*c*) $C = A.B$ (*d*) $C = \overline{A . B}$

30. A gate in which all the inputs must be low to get a high output is called
(*a*) A NAND gate (*b*) An inverter
(*c*) A NOR gate (*d*) An AND gate

31. The output of OR gate is 1
(*a*) If both inputs are zero
(*b*) If either or both inputs are 1
(*c*) Only if both input are 1
(*d*) If either input is zero

32. Which of the following logic gate is an universal gate
(*a*) OR (*b*) NOT
(c) AND (d) NOR

Answer Keys

1. (*c*)	**2.** (*b*)	**3.** (*d*)	**4.** (*b*)	**5.** (*b*)	**6.** (*b*)	**7.** (*a*)	**8.** (*c*)	**9.** (*b*)	**10.** (*c*)
11. (*b*)	**12.** (*d*)	**13.** (*b*)	**14.** (*a*)	**15.** (*a*)	**16.** (*a*)	**17.** (*d*)	**18.** (*d*)	**19.** (*a*)	**20.** (*d*)
21. (*b*)	**22.** (*b*)	**23.** (*a*)	**24.** (*d*)	**25.** (*a*)	**26.** (*a*)	**27.** (*a*)	**28.** (*b*)	**29.** (*b*)	**30.** (*b*)
31. (*b*)	**32.** (*d*)								

Solutions

1. In P-type semiconductor, holes are the majority charge carriers.
2. A P-type semiconductor can be obtained by adding Gallium to pure silicon
3. The valency is 3 of an impurity
4. Since, $n_e > n_h$.
   $\therefore$ The semiconductor is N-type.
5. The valency of the impurity is 5.
6. Impurity increases the electrical conductivity.
7. Aluminium is trivalent impurity
8. N-type semiconductors are neutral because neutral atoms are added during doping.
9. When a strong current passes through the semiconductor it heats up the crystal and covalent bonds are broken. Hence, because of excess number of tree electrons it behaves like a conductor.
10. In reverse bias no current flows.
11. It is used to convert ac into dc (rectifier)
12. In a junction diode, the holes are due to missing of electrons.
13. At a particular reverse voltage in PN-junction, a huge current flows in reverse direction known as avalanche current.
14. At high reverse voltage, the minority charge carries acquires very high velocities. These by collision break down the covalent bonds, generating more carriers. This mechanism is called Avalanche breakdown.
15. The potential barrier, in the depletion layer, is dul to ions.
16. $\text{ac} \longrightarrow \boxed{\text{Rectifier}} \longrightarrow \text{dc}$
17. For full wave rectifier

$$\eta = \frac{81.2}{1 + \frac{r_f}{R_L}}$$

$$\Rightarrow \eta_{max} = 81.2\% \ (r_f << R_L)$$

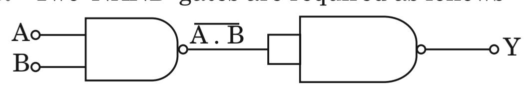
18. For a wide range of values of load resistance, the current in the zener diode may change but the voltage across it remains unaffected. Thus the output voltage across the zener diode is a regulated voltage
19. When NPN transistor is used as an amplifier, majority charge carrier electrons of N-type emitter move from emitter to base and then base to collector.
20. Given,

$$i_c = \frac{80}{100} \times i_e \Rightarrow 24 = \frac{80}{100} \times i_e \Rightarrow i_e = 30\text{mA}$$

By using $i_e = i_b + i_c$

$\Rightarrow i_b = 30 - 24 = 6$ mA

21. In a transistor, base is least doped.
22. The transistor provide good power amplification when they are used in common emitter configuration.
23. The width of the base is always smaller.
24. Because they have electrons having high mobility than holes.
25. Voltage gain = 10 $\log_{10}$ 1000 dB
    = 30 dB
26. The minimum potential difference between the base and emitter is 1V.
27. A logic gate is an electronic circuit which makes logic decisions.
28. Two 'NAND' gates are required as follows-



$$Y = \overline{\overline{AB} \cdot \overline{AB}} = AB$$

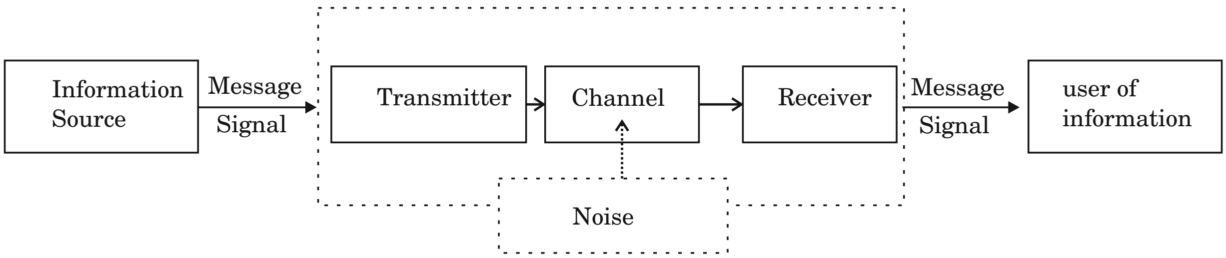
29. The Boolean equation of NOR gate is $C = \overline{A + B}$
30. A gate in which all the inputs must be low to get a high output is called an inverter.
31. The output of OR gate is Y = A + B
32. 'NOR' gates are considered as universal gates, because all the gates like AND, OR NOT can be obtained by using only NOR gates.

CHAPTER 15

Communication System

Communication

- Communication is a two way process in which exchange of information takes place either in verbal or written form.
- ***Elements of communication system:*** There are three essential elements of communication transmitter, medium/channel and receiver.
  Communication System



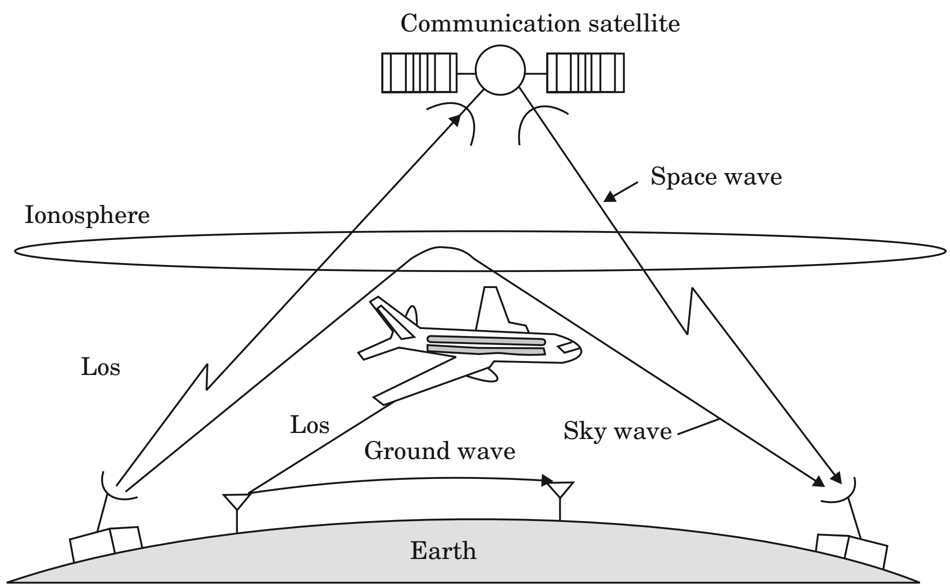
Transmitter transmits the signals through channel which is a physical medium and the receiver receives the signals.

The two basic types of communication modes are point-to-point and broadcast.

- ***Transducer:*** A device which transforms the energy from one form into another. Example: Loudspeaker.
- ***Signal:*** An information transformed into electrical form for suitable transmission is termed as signal. Signals can be of two types: analog or digital.
- ***Noise:*** The unwanted signals which have a tendency to create the disturbancein the transmission and processing of message is called noise.
- ***Transmitter:*** The device that processes the incoming message signal in order to make it suitable for transmission through a channel and subsequent reception is known as transmitter.
- ***Receiver:*** In order to extract the appropriate message signals from the received signals at the channel output, receiver is used.
- ***Attenuation:*** When signals are propagated through a medium, some of their strength is lost which is known as attenuation.
- ***Amplification:*** The process of increasing the amplitude and the strength of a signal using an electronic circuit is called amplification.
- ***Range:*** The largest distance between a source and a destination is called range up to which the signal is received with sufficient strength.
- ***Bandwidth:*** The range of frequency over which an equipment operates or the portion of the spectrum occupied by the signal is called bandwidth.
- ***Repeater:*** A combination of transmitter and receiver is the repeater which amplifies the signals picked up from the transmitter and then retransmits those signals to the receiver. In order to extend the range of the communication system, the repeaters are used.
- ***Bandwidth of signals:*** The difference between the upper and lower frequencies of the signals is termed as bandwidth of signals. The different bandwidths of the different kinds of signals is shown in the following table:

Types of Signals	*Bandwidth*
Speech signal	*2800 Hz*
Music signal	*20 KHz*
Video signal	*4.2 MHz*
TV signal	*6 MHz*

- ***Bandwidth of transmission medium:*** Free space, wire, fibre optic cable and optical fibre are the common transmission media. The bandwidths are different for various transmission media.
- ***Propagation of Electromagnetic Waves:*** In radio waves communication, the EM waves are radiated at the transmitter by antenna.
- ***Ground wave propagation:*** The ground wave propagation is also termed as surface wave propagation.The radio waves are travelled along the earth surface in this type of propagation. It is necessary for the antenna to be of a size which is comparable to the wavelength of the signal so that the signals can be radiated with high efficiency. As the frequency increases, the attenuation also increases.
- ***Sky wave propagation:*** It is used for long distance communication in the frequency range from few MHz to 40MHz. It uses the phenomenon of bending of EM waves so that they are diverted towards the earth is similar to total internal reflection in optics.
- ***Space wave propagation:*** For long distance transmission, antennas are used to radiatesignals into space. In order to travel from transmitting antenna to the receiving antenna, space wave takes the straight line path.They are useful for line-of-sight (LOS) communication and satellite communication.
- The range d_T of an antenna of height h_T that radiates electromagnetic waves is given by $\sqrt{2Rh_T}$; R = radius of the earth.
- To find out the maximum distance of line of sight (d_M) between antennas with heights hT and h_R:
  $d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$



Modulation

- ***Modulation*** is the process by which a low frequency is superimposed on a high frequency carrier signal so that the low frequency can be transmitted to long distance.
- ***Demodulation:*** The reverse process of modulation is called as demodulation in which the information from the carrier wave is retrieved at the receiver.
- ***Need of Modulation:***

➢ As there is a need of a very large antenna for low frequency signals, signals from different stations mixes up and the attenuation is large, so the modulation is needed.

➢ The size of antenna is given by $\frac{\lambda}{4}$ and low frequency implies larger wavelength so the size of antenna is not achievable.

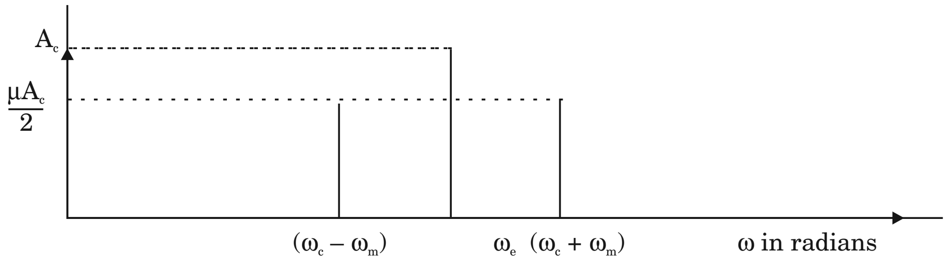
➢ There are 4 types of modulation: Amplitude modulation, Frequency modulation, Pulse modulation and Phase modulation

- ***Amplitude Modulation:*** The alteration of the amplitude of the carrier in accordance with the information signal is amplitude modulation. The following expression represent the AM of a carrier wave having amplitude and frequency f_c:

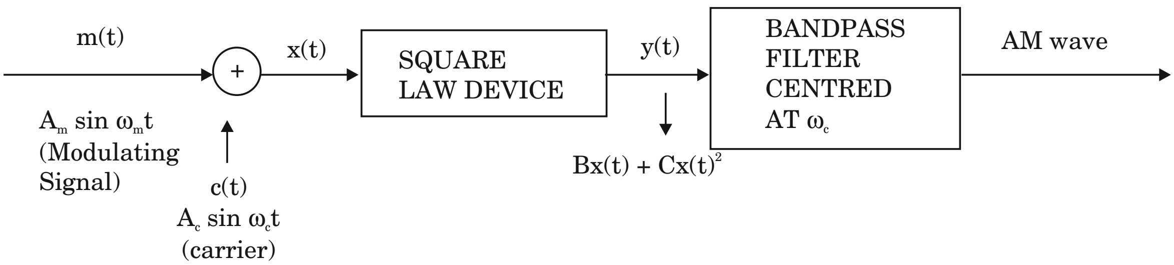
$$C_m(t) = A_c A \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2} \cos(\omega_c + \omega_m)t$$

The amplitude of the modulating wave is A_m and the frequency is f_m.

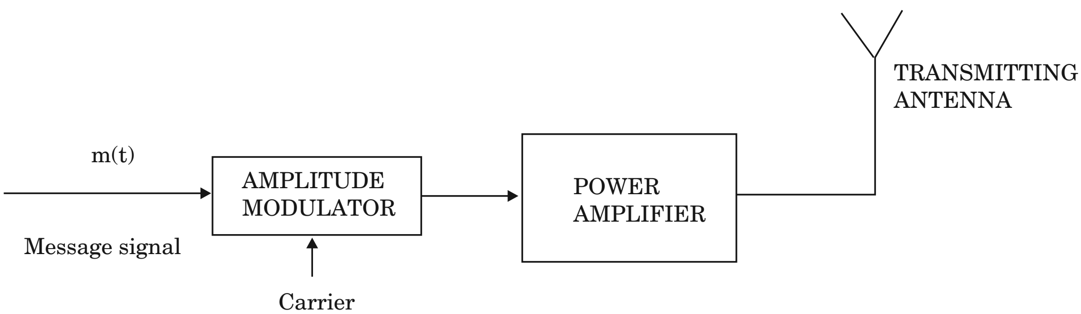
Modulation index $\mu = \frac{A_m}{A_c}; \mu \leq 1$.



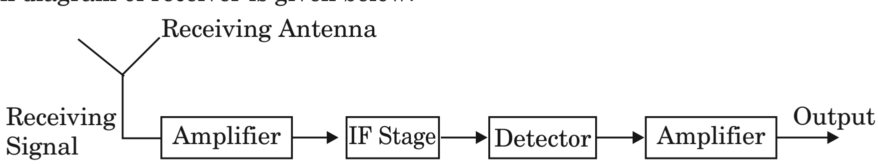
- ***Production of AM wave:*** The following block diagram shows the production of AM wave:



The block of transmitter is as follows:



- ***Detection of AM wave:*** Detected signals need modification as they may not be strong enough to use. The block diagram of receiver is given below:



EXERCISE

1. Which of the following is the disadvantage of FM over AM?
   (a) Larger bandwidth requirement
   (b) Larger noise
   (c) Higher modulation power
   (d) Low efficiency
2. An AM wave has 1800 watt of total power content, For 100% modulation the carrier should have power content equal to
   (a) 1000 watt (b) 1200 watt
   (c) 1500 watt (d) 1600 watt
3. An antenna is a device
   (a) That converts electromagnetic energy into radio frequency signal
   (b) That converts radio frequency signal into electromagnetic energy
   (c) That converts guided electromagnetic waves into free space electromagnetic waves and vice versa
   (d) None of these
4. Indicate which one of the following system is digital?
   (a) Pulse position modulation
   (b) Pulse code modulation
   (c) Pulse width modulation
   (d) Pulse amplitude modulation
5. The waves used in telecommunication are
   (a) IR (b) UV
   (c) Microwave (d) Cosmic rays
6. In an FM system a 7 kHz signal modulates 108 MHz carrier so that frequency deviation is 50 kHz. The carrier swing is
   (a) 7.143 (b) 8
   (c) 0.71 (d) 350
7. Consider telecommunication through optical fibres. Which of the following statements is not true?
   (a) Optical fibres may have homogeneous core with a suitable cladding
   (b) Optical fibres can be of graded refractive index
   (c) Optical fibres are subject to electromagnetic interference from outside
   (d) Optical fibres have extremely low transmission loss
8. The phenomenon by which light travels in an optical fibres is
   (a) Reflection
   (b) Refraction
   (c) Total internal reflection
   (d) Transmission
9. Advantage of optical fibre
   (a) High bandwidth and EM interference
   (b) Low bandwidth and EM interference
   (c) High band width, low transmission capacity and no EM interference
   (d) High bandwidth, high data transmission capacity and no EM interference
10. In frequency modulation
    (a) The amplitude of modulated wave varies as frequency of carrier wave
    (b) The frequency of modulated wave varies as amplitude of modulating wave
    (c) The amplitude of modulated wave varies as amplitude of carrier wave
    (d) The frequency of modulated wave varies as frequency of modulating wave
    (E) The frequency of modulated wave varies as frequency of carrier wave
11. Audio signal cannot be transmitted because
    (a) The signal has more noise
    (b) The signal cannot be amplified for distance communication
    (c) The transmitting antenna length is very small to design
    (d) The transmitting antenna length is very large and impracticable
    (e) The signal is not a radio signal
12. In which of the following remote sensing technique is not used?
    (a) Forest density (b) Pollution
    (c) Wetland mapping (d) Medical treatment
13. For sky wave propagation of a 10 MHz signal, what should be the minimum electron density in ionosphere?
    (a) $\sim 1.2 \times 10^{12}\ m^{-3}$ (b) $\sim 10^{6}\ m^{-3}$
    (c) $\sim 10^{14}\ m^{-3}$ (d) $\sim 10^{22}\ m^{-3}$
14. What should be the maximum acceptance angle at the aircore interface of an optical fibre if n1 and n2 are the refractive indices of the core and the cladding, respectively?
    (a) $\sin^{-1}(n_2 / n_1)$ (b) $\sin^{-1}\sqrt{n_1^2 - n_2^2}$
    (c) $\left[\tan^{-1}\frac{n_2}{n_1}\right]$ (d) $\left[\tan^{-1}\frac{n_1}{n_2}\right]$
15. In short wave communication waves of which of the following frequencies will be reflected back by the ionospheric layer, having electron density 10^{11} per m^3
    (a) 2 MHz (b) 10 MHz
    (c) 12 MHz (d) 18 MHz

16. In an amplitude modulated wave for audio frequency of 500 cycle/second, the appropriate carrier frequency will be
(a) 50 cycles/sec (b) 100 cycles/sec
(c) 500 cycles/sec (d) 50,000 cycles/sec

17. Range of frequencies allotted for commercial FM radio broadcast is
(a) 88 to 108 MHz (b) 88 to 108 kHz
(c) 8 to 88 MHz (d) 88 to 108 GHz

18. The velocity factor of a transmission line x. If dielectric constant of the medium is 2.6, the value of x is
(a) 0.26 (b) 0.62
(c) 2.6 (d) 6.2

19. The process of superimposing signal frequency (i.e. audio wave) on the carrier wave is known as
(a) Transmission (b) Reception
(c) Modulation (d) Detection

20. A step index fibre has a relative refractive index of 0.88%. What is the critical angle at the core cladding interface?
(a) 60° (b) 75°
(c) 45° (d) None of these

21. Through which mode of propagation, the radio waves can be sent from one place to another
(a) Ground wave propagation
(b) Sky wave propagation
(c) Space wave propagation
(d) All of them

22. A laser beam of pulse power 10^{12} watt is focussed on an object are 10^{-4} cm^2. The energy flux in watt/cm^2 at the point of focus is
(a) 10^{20} (b) 10^{16}
(c) 10^{8} (d) 10^{4}

23. The carrier frequency generated by a tank circuit containing 1 nF capacitor and 10 μH inductor is
(a) 1592 Hz (b) 1592 MHz
(c) 1592 kHz (d) 159.2 Hz

24. For television broadcasting, the frequency employed is normally
(a) 30-300 MHz (b) 30-300 GHz
(c) 30-300 KHz (d) 30-300 Hz

25. Maximum useable frequency (MUF) in F-region layer is x, when the critical frequency is 60 MHz and the angle of incidence is 70°. Then x is
(a) 150 MHz (b) 170 MHz
(c) 175 MHz (d) 190 MHz

26. The attenuation in optical fibre is mainly due to
(a) Absorption
(b) Scattering
(c) Neither absorption nor scattering
(d) Both (a) and (b)

27. The maximum distance upto which TV transmission from a TV tower of height h can be received is proportional to
(a) $h^{1/2}$ (b) h
(c) $h^{3/2}$ (d) h^2

28. A laser beam is used for carrying out surgery because it
(a) Is highly monochromatic
(b) Is highly coherent
(c) Is highly directional
(d) Can be sharply focussed

29. Laser beams are used to measure long distances because
(a) They are monochromatic
(b) They are highly polarised
(c) They are coherent
(d) They have high degree of parallelism

30. An oscillator is producing FM waves of frequency 2 kHz with a variation of 10 kHz. What is the modulating index?
(a) 0.20 (b) 5.0
(c) 0.67 (d) 1.5

Answer Keys

1. (*a*)	**2.** (*b*)	**3.** (*c*)	**4.** (*b*)	**5.** (*c*)	**6.** (*a*)	**7.** (*c*)	**8.** (*c*)	**9.** (*d*)	**10.** (*b*)
11. (*d*)	**12.** (*d*)	**13.** (*a*)	**14.** (*b*)	**15.** (*a*)	**16.** (*d*)	**17.** (*a*)	**18.** (*b*)	**19.** (*c*)	**20.** (*d*)
21. (*d*)	**22.** (*b*)	**23.** (*c*)	**24.** (*a*)	**25.** (*c*)	**26.** (*d*)	**27.** (*a*)	**28.** (*d*)	**29.** (*d*)	**30.** (*b*)

Solutions

1. Frequency modulation requires much wider channel (7 to 15 times) as compared to AM.

2. $P_t = P_c\left(1+\frac{m_a^2}{2}\right)$; Here ma = 1

$$\Rightarrow \quad 1800 = P_c\left(1+\frac{(1)^2}{2}\right)$$

$$\Rightarrow \quad P_c = 1200\text{W}$$

3. An antenna is a metallic structure used to radiate or receive EM waves.

4. Pulse code modulation is a digital system.

5. In telecommunication, microwaves are used.

6. Carrier swing

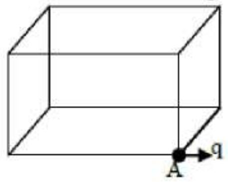
$$= \frac{\text{Frequency deviation}}{\text{Modulating frequency}} = \frac{50}{7} = 7.143$$

Physics Sample Paper - 1

DIRECTIONS for the question: *Mark the best option:*

Question No. : 1

The total flux through the faces of the cube with side of length 'a' if a charge q is place at corner A of the cube is:-



A) $\frac{q}{8\epsilon_0}$ B) $\frac{q}{4\epsilon_0}$ C) $\frac{q}{2\epsilon_0}$ D) $\frac{q}{\epsilon_0}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 2

Electric field lines provides information about

A) Field strength B) Direction C) Nature of charge D) All of these

DIRECTIONS for the question: *Mark the best option:*

Question No. : 3

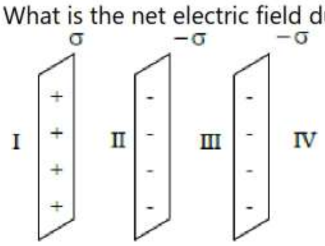
Unit of electric dipole moment is:-

A) Newton B) Coulomb C) Farad D) Debye

DIRECTIONS for the question: *Mark the best option:*

Question No. : 4

What is the net electric field due to informally charged infinite sheet in region – III?



A) $\frac{\sigma}{\epsilon_0}$ B) $\frac{\sigma}{2\epsilon_0}$ C) $\frac{2\sigma}{\epsilon_0}$ D) $\frac{\sigma}{4\epsilon_0}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 5

Which of the following is true about electrostatic force?

A) It is non-conservative B) It is always attractive C) It is weaker than gravitational force
D) It depends on nature of the medium

DIRECTIONS for the question: *Mark the best option:*

Question No. : 6

When a charged sphere A of charge "q" is touched with another identical charged sphere B of charge '2q', what is the net charge on both spheres after some time?

A) 3q B) 3q/2 C) q D) 4q

DIRECTIONS for the question: *Mark the best option:*

Question No. : 7

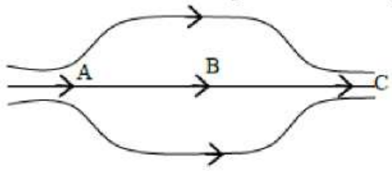
Two forces of magnitude 'F' are acting on a charge q perpendicularly, which is the resultant force on charge 'q'?

A) $F/2$ B) $F/\sqrt{2}$ C) $F\sqrt{2}$ D) $F\sqrt{3}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 8

Which of the following is correct for given filed lines?



A) $E^A > E^B > E^C$ B) $E^A = E^B < E^C$ C) $E^A = E^B > E^C$ D) $E^A = E^B = E^C$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 9

Two charges of magnitudes – 2Q and +Q are located at points (a, 0) & (4a, 0) respectively. What is the electric flux due to these charges through a sphere of radius '3a' with its centre at the origin?

A) Q/ϵ_0 B) $-Q/\epsilon_0$ C) $2Q/\epsilon_0$ D) $-2Q/\epsilon_0$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 10

What is the electric flux due to electric dipole enclosed inside a closed spherical surface?

A) $\frac{\sigma}{\epsilon_0}$ B) $\frac{q}{\epsilon_0}$ C) Zero D) $\frac{\sigma}{2\epsilon_0}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 11

What is the dimensional formula for electric field:

A) $[ML^2T^{-3}A^{-1}]$ B) $[MLT^{-3}A^{-1}]$ C) $[MLT^{-3}A^{-2}]$ D) $[MLT^{-2}A^{-1}]$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 12

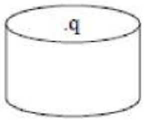
Which of the following is correct for electric field due to uniformly charged infinite length of wire of charge density λ?

A) $\frac{\lambda}{2\pi E_0 r}$ B) $\frac{\lambda}{4\pi E_0 r}$ C) $\frac{2\lambda}{\pi E_0 r}$ D) $\frac{\lambda}{8\pi E_0 r}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 13

What is the electric flux due to this charge configuration through hemisphere surface?



A) $\frac{q}{E_0}$ B) $\frac{q}{4E_0}$ C) $\frac{q}{2E_0}$ D) Zero

DIRECTIONS for the question: *Mark the best option:*

Question No. : 14

Electric field lines due to single positive charge is

A) Radially inwards B) Radially outwards C) Converging D) Diverging

DIRECTIONS for the question: *Mark the best option:*

Question No. : 15

What is the electric dipole moment of dipole of length 10cm & consisting of charges 100 ± μC?

A) 10^{-5}cm B) 2×10^{-5}cm C) 3×10^{-5}cm D) 4×10^{-5}cm

DIRECTIONS for the question: *Mark the best option:*

Question No. : 16

What is the correct expression for electric field due to uniformly charged circular ring of radius 'a' & at a distance x from its centre?

A) $\frac{1}{4\pi E_0}\frac{qx}{(x^2+a^2)^{3/2}}$ B) $\frac{1}{4\pi E_0}\frac{qx}{(x^2-a^2)^{3/2}}$ C) $\frac{1}{4\pi E_0}\frac{qx}{(x^2+a^2)^2}$ D) $\frac{1}{4\pi E_0}\frac{qx}{(x^2+a^2)}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 17

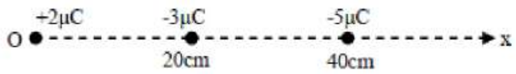
If a positive charge particle is moving in direction of electric field, it will

A) Accelerate B) Deaccelerate C) Stop moving D) Precess parabola

DIRECTIONS for the question: *Mark the best option:*

Question No. : 18

In which direction, force acts on the particle placed at origin in the given configuration



A) Left B) Right C) Upward D) Downward

DIRECTIONS for the question: *Mark the best option:*

Question No. : 19

What is the amount of charged carried by 12.5×10^8 electrons?

A) 2×10^{-10}C B) 3×10^{-10}C C) 4×10^{-10}C D) 5×10^{-10}C

DIRECTIONS for the question: *Mark the best option:*

Question No. : 20

A point charge q is rotated along a circle in the electric field, generated by another point charge Q. The work alone by electric field on rotating charge in one complete revaluation is,

A) zero B) Position C) Negative D) May be positive or negative

DIRECTIONS for the question: *Mark the best option:*

Question No. : 21

If the flow of electric field through a closed surface is zero

A) The electric field must be zero everywhere on the surface B) the electric filed may be zero everywhere on the surface
C) charges inside the surface must be zero D) charges in the vicinity of the surface must be zero

DIRECTIONS for the question: *Mark the best option:*

Question No. : 22

A non- conduction solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance from its centre

A) increase as r increases for $r < R$ B) decrease as r increase for $0 < r < \infty$ C) decrease as r increase for $R < r < \infty$
D) is discontinuous at $r = R$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 23

The magnitude of electric filed $\vec{E}$ in the annular region of a charged cylindrical capacity

A) is same through B) is higher near the outer cylinder than near the inner cylinder
C) varies as 1/r, where r is the distance from axis D) varies as $1/r^2$, where r is the distance from axis

DIRECTIONS for the question: *Mark the best option:*

Question No. : 24

Two charge particles each housing charge q and mass m are d distance about from each other. If the particles are in equilibrium under the gravitational and electric force, then determine the ratio q/m,

A) 10^{-8} B) 10^{-10} C) 10^{10} D) None

DIRECTIONS for the question: *Mark the best option:*

Question No. : 25

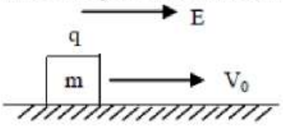
What is the magnitude of a point charge due to which the electric field 30 cm away has the magnitude 2 ?

A) 2×10^{-11}C B) 3×10^{-11}C C) 5×10^{-11}C D) 9×10^{-11}C

DIRECTIONS for the question: *Mark the best option:*

Question No. : 26

If a charge particle is projected on a rough horizontal surface with speed v_0 . what is the value of dynamic coefficient of friction, if K.E of system is constant



A) $\frac{qE}{mg}$ B) $\frac{qE}{m}$ C) $\frac{q}{g}$ D) None of these

DIRECTIONS for the question: *Mark the best option:*

Question No. : 27

Identify the correct statement in the following, Coulomb's law correctly described the electric force that.

A) Binds the electrons of an atom to nucleus B) Binds the protons & neutrons in nucleus of an atom
C) Binds atoms together to form molecules D) Binds atoms & molecules to form solids

DIRECTIONS for the question: *Mark the best option:*

Question No. : 28

At large distance, electric field due to point charge is proportional to:-

A) $\frac{1}{r}$ B) $\frac{1}{r^2}$ C) $\frac{1}{r^3}$ D) Independent of r.

DIRECTIONS for the question: *Mark the best option:*

Question No. : 29

For uniformly charged infinite sheet, direction of electric field is always.

A) Parallel to the sheet B) Perpendicular to the sheet C) Can be parallel or perpendicular D) None of the above

DIRECTIONS for the question: *Mark the best option:*

Question No. : 30

What will happen when we rub a glass rod with silk cloth?

A) Same of the electrons from glass rod are transferred to silk cloth.
B) Glass rod gets positively charge and silk cloth gets negatively charged.
C) New charge is created in the process of rubbing. D) both (a) & (b) correct

DIRECTIONS for the question: *Mark the best option:*

Question No. : 31

When a person combs his hair static electricity is sometimes generated by what process?

A) contact between comb and hair results in charge. B) Friction between comb and hair result in transfer of electrons.
C) Deduction between comb and hair. D) Induction between comb and hair.

DIRECTIONS for the question: *Mark the best option:*

Question No. : 32

no. of electrons present in -1C of charge is

A) 6×10^{18} B) 1.6×10^{19} C) 6×10^{19} D) 1.6×10^{18}

DIRECTIONS for the question: *Mark the best option:*

Question No. : 33

The force between two small charged spheres having charges of 1×10^{-7} and 2×10^{-7} C placed 20 Cm a part in air is

A) 4.7×10^{-2}N B) 4.5×10^{-3}N C) 5.4×10^{-2}N D) 5.4×10^{-3}N

DIRECTIONS for the question: *Mark the best option:*

Question No. : 34

Two point charge of +3μC and +4μC repel each other with a force of 10 N. If each is given an additional charge -6μC, the new force.

A) 2N B) 4N C) 5N D) 7.5N

DIRECTIONS for the question: *Mark the best option:*

Question No. : 35

Which of the following statement is true about electrical forces?

A) Electrical forces are produced by electrical charges B) Like charges attract, unlike charges repel.
C) Electric forces are weaker than gravitational forces
D) Positive and negative charges combine to produce a third type of charge.

DIRECTIONS for the question: *Mark the best option:*

Question No. : 36

Two insulated charged metallic spheres P and Q have their centres separated by a distance of 60cm. The radii of P and Q are negligible compared to distance of separation. Mutual force of electrostatic repulsion if the charge on each is 3.2×10^{-7}C is?

A) 5.2×10^{-4}N B) 2.5×10^{-3}N C) 1.5×10^{-3}N D) 3.5×10^{-4}N

DIRECTIONS for the question: *Mark the best option:*

Question No. : 37

Electric field at a point is

A) Continuous if there is no charge at that point B) Discontinuous if there is a charge at that point C) Always continuous
D) Both (a) and (b) are correct

DIRECTIONS for the question: *Mark the best option:*

Question No. : 38

If the charge on object is doubled then electric field becomes

A) Half B) Double C) Unchanged D) Thrice

DIRECTIONS for the question: *Mark the best option:*

Question No. : 39

A uniformly charged conduction sphere of 4.4m diameter has a surface charge density of 60μC m^{-2}. The charge on the sphere is

A) 7.3×10^{-3}C B) 3.7×10^{-6}C C) 7.3×10^{-6}C D) 3.7×10^{-3}C

DIRECTIONS for the question: *Mark the best option:*

Question No. : 40

Electric potential is a

A) Scalar B) Vector C) Tensor D) Both b & c are correct

DIRECTIONS for the question: *Mark the best option:*

Question No. : 41

Potential due to point charge q at infinite distance is

A) zero B) $\frac{q}{4\pi\varepsilon_0 r}$ C) $\frac{q}{4\pi\varepsilon_0 r^2}$ D) Infinity

DIRECTIONS for the question: *Mark the best option:*

Question No. : 42

What is expression for potential due to electric dipole at a point P making an angle θ with the centre of dipole and at a distance r from it?

A) $\frac{\beta}{4\pi\varepsilon_0 r^2}$ B) $\frac{\beta\sin\theta}{4\pi\varepsilon_0 r^2}$ C) $\frac{\beta\cos\theta}{4\pi\varepsilon_0 r^2}$ D) $\frac{\beta\cos\theta}{4\pi\varepsilon_0 r^3}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 43

What is the electrostatic potential inside a uniformly charged spherical shell, If charge q.

A) zero B) Constant C) $\frac{R}{4\pi\varepsilon_0 r}$ D) None of these

DIRECTIONS for the question: *Mark the best option:*

Question No. : 44

In the above question, how much work is required to separate two charges infinitely away from each other

A) 0.7J B) -0.7J C) 2.1J D) -2.1J

DIRECTIONS for the question: *Mark the best option:*

Question No. : 45

Find electric field between two metal plates 3mmm apart, connected to 18V battery

A) $6 \times 10^3 vm^{-1}$ B) $5 \times 10^3 vm^{-1}$ C) $3 \times 10^3 vm^{-1}$ D) $4 \times 10^3 vm^{-1}$

DIRECTIONS for the question: *Mark the best option:*

Question No. : 46

If potential energy between two charges is positive, the electrostatic force is

A) Attractive B) Repulsive C) Can be attractive or repulsing D) None of these

DIRECTIONS for the question: *Mark the best option:*

Question No. : 47

Current passes between two points when there is

A) Potential difference between two points B) No potential difference between two points C) Charge present
D) None of the above

DIRECTIONS for the question: *Mark the best option:*

Question No. : 48

If the charge on the capacitor is doubled, electric field inside it will become

A) half B) Four times C) Double D) No charge

DIRECTIONS for the question: *Mark the best option:*

Question No. : 49

If four capacitors of capacitance 10μF each are connected in series, which is the effective capacitance

A) 2.5μF   B) 20μF   C) 40μF   D) 5μF

DIRECTIONS for the question: *Mark the best option:*

Question No. : 50

Which of the following is potential difference dimensional formula

A) $[M^1L^2T^{-3}A^{-1}]$ B) $[M^2L^3T^{-2}A^{-1}]$ C) $[M^1L^3T^{-2}A^{-1}]$ D) $[M^2L^2T^{-3}A^{-2}]$

QNo:- 1 ,Correct Answer:- *A*

Explanation:-

QNo:- 2 ,Correct Answer:- *D*

Explanation:-

QNo:- 3 ,Correct Answer:- *D*

Explanation:-

QNo:- 4 ,Correct Answer:- *B*

Explanation:-

QNo:- 5 ,Correct Answer:- *D*

Explanation:-

QNo:- 6 ,Correct Answer:- *B*

Explanation:-

QNo:- 7 ,Correct Answer:- *C*

Explanation:-

QNo:- 8 ,Correct Answer:- *C*

Explanation:-

QNo:- 9 ,Correct Answer:- *D*

Explanation:-

QNo:- 10 ,Correct Answer:- *C*

Explanation:-

QNo:- 11 ,Correct Answer:- *B*

Explanation:-

QNo:- 12 ,Correct Answer:- *A*

Explanation:-

QNo:- 13 ,Correct Answer:- *C*

Explanation:-

QNo:- 14 ,Correct Answer:- *B*

Explanation:-

QNo:- 15 ,Correct Answer:- *A*

Explanation:-

QNo:- 16 ,Correct Answer:- *A*

Explanation:-

QNo:- 17 ,Correct Answer:- *A*

Explanation:-

QNo:- 18 ,Correct Answer:- *B*

Explanation:-

QNo:- 19 ,Correct Answer:- *A*

Explanation:-

QNo:- 20 ,Correct Answer:- *A*

Explanation:-

QNo:- 21 ,Correct Answer:- *D*

Explanation:-

QNo:- 22 ,Correct Answer:- *C*

Explanation:-

QNo:- 23 ,Correct Answer:- *B*

Explanation:-

QNo:- 24 ,Correct Answer:- *B*

Explanation:-

QNo:- 25 ,Correct Answer:- *A*

Explanation:-

QNo:- 26 ,Correct Answer:- *A*

Explanation:-

QNo:- 27 ,Correct Answer:- *B*

Explanation:-

QNo:- 28 ,Correct Answer:- *B*

Explanation:-

QNo:- 29 ,Correct Answer:- *B*

Explanation:-

QNo:- 30 ,Correct Answer:- *D*

Explanation:-

QNo:- 31 ,Correct Answer:- *B*

Explanation:-

QNo:- 32 ,Correct Answer:- *A*

Explanation:-

QNo:- 33 ,Correct Answer:- *B*

Explanation:-

QNo:- 34 ,Correct Answer:- *D*

Explanation:-

QNo:- 35 ,Correct Answer:- *A*

Explanation:-

QNo:- 36 ,Correct Answer:- *B*

Explanation:-

QNo:- 37 ,Correct Answer:- *D*

Explanation:-

QNo:- 38 ,Correct Answer:- *B*

Explanation:-

QNo:- 39 ,Correct Answer:- *D*

Explanation:-

QNo:- 40 ,Correct Answer:- *A*

Explanation:-

QNo:- 41 ,Correct Answer:- *A*

Explanation:-

QNo:- 42 ,Correct Answer:- *C*

Explanation:-

QNo:- 43 ,Correct Answer:- *B*

Explanation:-

QNo:- 44 ,Correct Answer:- *A*

Explanation:-

QNo:- 45 ,Correct Answer:- *A*

Explanation:-

QNo:- 46 ,Correct Answer:- *B*

Explanation:-

QNo:- 47 ,Correct Answer:- *A*

Explanation:-

QNo:- 48 ,Correct Answer:- *C*

Explanation:-

QNo:- 49 ,Correct Answer:- *A*

Explanation:-

QNo:- 50 ,Correct Answer:- *A*

Explanation:-