SMART SKILLS

ACADEMIC SESSION 2020-2021

PHYSICS

CLASS XII

INDEX

Page no

SYLLABUS

CLASS XII (2020-21)
(THEORY)

Time: 3 hrs. **Max Marks: 70**

		No. of Periods	Marks
Unit–I	**Electrostatics**	**24**	**16**
	Chapter–1: Electric Charges and Fields		
	Chapter–2: Electrostatic Potential and Capacitance		
Unit-II	**Current Electricity**	**18**	
	Chapter–3: Current Electricity		
Unit-III	**Magnetic Effects of Current and Magnetism**	**22**	**17**
	Chapter–4: Moving Charges and Magnetism		
	Chapter–5: Magnetism and Matter		
Unit-IV	**Electromagnetic Induction and Alternating Currents**	**20**	
	Chapter–6: Electromagnetic Induction		
	Chapter–7: Alternating Current		
Unit–V	**Electromagnetic Waves**	**04**	**18**
	Chapter–8: Electromagnetic Waves		
Unit–VI	**Optics**	**27**	
	Chapter–9: Ray Optics and Optical Instruments		
	Chapter–10: Wave Optics		
Unit–VII	**Dual Nature of Radiation and Matter**	**08**	**12**
	Chapter–11: Dual Nature of Radiation and Matter		
Unit–VIII	**Atoms and Nuclei**	**15**	
	Chapter–12: Atoms		
	Chapter–13: Nuclei		
Unit–IX	**Electronic Devices**	**12**	**7**
	Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits		
Total		**150**	**70**

A: March-April-May

Unit I: Electrostatics

Electric Charges; Conservation of charge, 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 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, electrical potential energy of a system of two point charges and of electric dipole in an electrostatic field.

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

Unit II: Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity, 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.

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.

B: JULY

Unit II: Current Electricity (To be continued)

Potentiometer - principle and its 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 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. Force between two parallel current-carrying conductors-definition of ampere. Torque experienced by a current loop in uniform 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. 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 ferro - magnetic substances, with examples. Electromagnets and factors affecting their strengths. Permanent magnets.

C: August

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.

D: September

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

Wave optics: Wave front and Huygens 'Principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle.

Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light. Diffraction due to a single slit, width of central maximum. Resolving power of microscopes and astronomical telescopes. Polarisation, plane polarised light; Brewster's law, uses of plane polarised light and Polaroids.

E: October

Unit VII: Dual Nature of Matter and Radiation

Dual nature of 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.

Unit VIII: Atoms & Nuclei

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum.

Composition and size of nucleus, 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.

F: November

Unit IX: Electronic Devices

Energy bands in solids (Qualitative ideas only) conductor, insulator and semiconductor; 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.

PRACTICALS

The record, to be submitted by the students, at the time of their annual examination, has to include:

- Records of at least 12 Experiments (with 6 from section A and 6 from section B) to be performed by the students.
- Records of at least 6 Activities [with 3 each from section A and section B) to be performed by the students.
- The Report of the project, to be carried out by the students

Evaluation Scheme for Practical Examination:

Two experiment one from each section	(7+7) Marks
Practical record (experiments & activities)	5 Marks
One activity from any section	3 Marks
Investigatory Project	3 Marks
Viva on experiments & activities and project	5 Marks
Total	30 Marks

SECTION A

Experiments

1. To determine resistivity of two/three wires by plotting a graph of potential difference versus current.
2. To find resistance of a given wire using meter bridge and hence determine the specific resistance of its material
3. To verify the laws of combination (series and parallel) of resistances using a metre bridge.
4. To compare the EMF of two given primary cells using potentiometer.
5. To determine the internal resistance of given primary cell using potentiometer.
6. To determine resistance of a galvanometer by half-deflection method and to find its figure of merit.

Activities

1. To measure the resistance and impedance of an inductor with or without iron core.
2. To assemble the components of a given electrical circuit.
3. To study the variation in potential drop with length of a wire for a steady current

SECTION B

1. To find the value of v for different values of u in case of a concave mirror and to find the focal length.
2. To find the focal length of a convex mirror, using a convex lens
3. To find the focal length of a convex lens by plotting graphs between u and v or between 1/u and 1/v.
4. To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and angle of deviation.
5. To determine refractive index of a liquid by using convex lens and plane mirror

6. To draw the I-V characteristics curve of a p-n junction in forward bias and reverse bias.

Activities

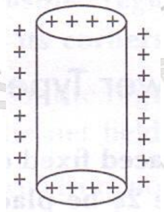
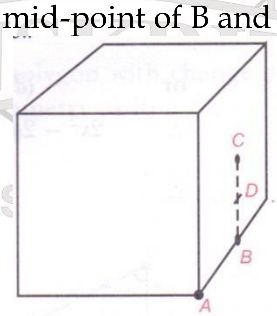
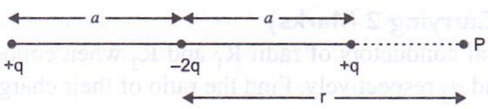
1. To identify a diode, an LED, a transistor, and IC, a resistor and a capacitor from mixed collection of such items.
2. To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab.
3. To study the nature and size of the image formed by (i) convex lens (ii) concave mirror, on a screen by using a candle and a screen.

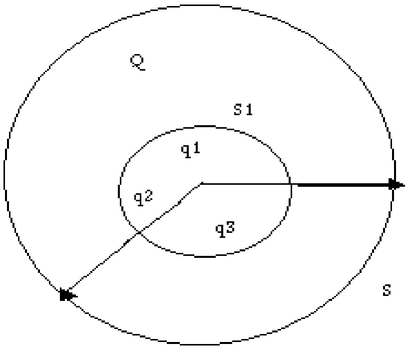
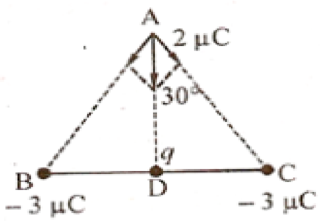
Suggested Investigatory Projects

1. To study factors on which the internal resistance/EMF of a cell depends
2. To study the variations, in current flowing, in a circuit containing an LDR, because of a variation (a) in the power of the incandescent lamp, used to illuminate the LDR. (Keeping all the lamps at a fixed distance). (b) in the distance of incandescent lamp (of fixed power) used to illuminate the LDR.
3. To find the refractive indices of (a) water (b) oil (transparent) using a plane mirror, an equi convex lens and an adjustable object needle.
4. To design an appropriate logic gate combination for a given truth table.
5. To investigate the relation between the ratio of (i) output and input voltage and (ii) number of turns in the secondary coil and primary coil of a self-designed transformer.
6. To investigate the dependence of the angle of deviation on the angle of incidence, using a hollow prism filled, one by one, with different transparent fluids.
7. To estimate the charge induced on each one of the two identical Styrofoam (or pith) balls suspended in a vertical plane by making use of Coulomb's Law.
8. To study the factors on which the self-inductance of a coil depends by observing the effect of this coil, when put in series with resistor/bulbs in a circuit fed up by an AC source of adjustable frequency.
9. To study the earth's magnetic field using a tangent galvanometer

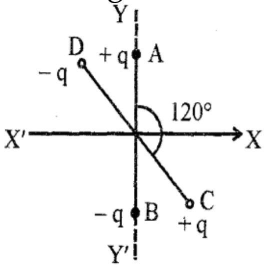
CHAPTER 1: FIELD AND FLUX

Assignment

	What is the value of minimum force acting between two charges placed at 1 m apart from each other (a) Ke^2 (b) Ke (c) Ke/4 (d) $Ke^2/2$
2	Charge on a conducting metal sphere present at : - (a) On the surface of sphere (b) Inside the sphere (c) Outside the sphere (d) both inside and outside of sphere
3	A glass rod acquires charge by rubbing it with silk cloth. The charge on glass rod is due to : (a) Friction (b) Conduction (c) Induction (d) Radiation
4	Four charges + 8Q, - 3Q +5Q and -10Q are kept inside a closed surface. What will be the outgoing flux through the surface. (a) 26 V-m (b) 0 V-m (c) 10 V-m (d) 8 V-m
5	An electrostatic field line is a continuous curve, that is , a field line cannot have sudden breaks. Why not?
6	A metallic spherical shell has an inner radius $R_1$and an outer radius R_2. A charge Q is placed at the centre of the spherical cavity. What will be surface charge density on (i) the inner surface, and (ii) the outer surface?
7.	Sketch the electric field lines for a uniformly charged hollow cylinder shown in fig. 
8.	What will be the total flux through the faces of the cube with side length a if a charge q is placed at (a) A: a corner of the cube (b) B: mid-point of an edge of the cube (c) C: centre of a face of the cube (d) D: mid-point of B and C. 
9.	Figure shows a configuration of the charge array of two dipoles.  Obtain the expression for the dependence of potential on r for r>>a for a point P on the of this array of charges.

10.	Four charges +q, +q, -q and –q are placed respectively at the four corners of a square of side a. Find the magnitude and direction of the field at the centre of the square.
11	Two spherical conductors B and C having equal radii and carrying equal charges repel with a force F. A third uncharged similar sphere is brought in contact with B, then brought in contact with C and finally removed away. Find new force between B and C.
12.	a) A charged particle is free to move in an electric field. Will it always move along an electric line of force? b) Why do the electrostatic field lines not form closed loops?
13.	Sketch the lines of force for 1) a dipole 2) a point charge q ($q<0$) 3) two equal positive charges near each other.
14	Two point charges 4Q and Q are separated by 1m in air. At what point on the line joining the charges is the electric field intensity zero? What happens when the charge Q becomes negative?
15.	Two point charges, q_1 and q_2, are located at points (a, o, o) and (o, b, o) respectively. Find the electric field, due to both these charges, at the point, (o, o, c).
16.	The flux of the electrostatic fields, through the closed spherical surface S,' is found to be four times that through the closed sphere 'S1'. Find the magnitude of the charge Q . Given, q_1= 1 µC,q_2=-2µC and q_3=9.854 µC 
17.	3 point charges of 2µC,-3µC and -3µC are kept at the vertices A, B and C respectively of an equilateral triangle of side 20 cm. What should be the sign and magnitude of charge to be placed at the mid point of the side BC so that the charge at A remains in equilibrium? 
18.	An electric dipole is held in uniform electric field. (i) Using suitable diagram, show that it does not undergo any translatory motion. (ii) Derive an expression for the torque acting on this dipole.

<table>
<tr><td></td><td>b) An electric dipole of length 2cm, when placed with its axis making an angle of 60^0 with uniform electric field, experiences a torque of $8\sqrt{3}$Nm. Calculate the potential energy of the dipole, if it has a charge of ±4nC .</td></tr>
<tr><td>19.</td><td>Two small identical electric dipoles AB and CD , each of dipole moment p are kept at an angle of 120˚ as shown. What is the resultant dipole moment of the combination? If this system is subjected to an electric field E along +X direction, what will be the magnitude and direction of the torque acting on this?

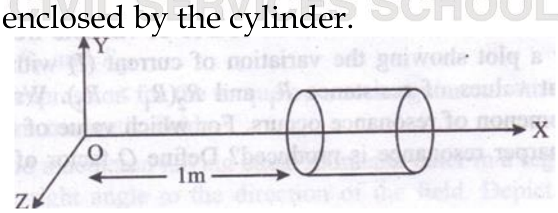


</td></tr>
<tr><td>20.</td><td>A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q. A charge q is placed at the centre of the shell.

a) What is the surface charge density on the 1) inner surface 2) outer surface of the shell ?

b) Write the expression for the electric field at a point x (> r_2)from the centre of the shell.</td></tr>
<tr><td>21.</td><td>Charges of magnitudes 2q and –q are located at points (a,0,0) and (4a,0,0). Find the ratio of the flux of electric field, due to these charges, through concentric spheres of radii 2a and 8a centered at the origin.</td></tr>
<tr><td>22.</td><td>(a) " The outward electric flux due to charge +Q is independent of the shape and size of the surface which endorses it". Give two reasons to justify this statement.

(b) Two identical circular loops 1 and 2 of radius r each have linear charge densities -λ and +λ C/m respectively. The loops are placed coaxially with their centres $R/\sqrt{3}$ distance apart. Find the magnitude and direction of the net electric field at the centre of loop 1.</td></tr>
<tr><td>23.</td><td>A hollow cylindrical box of length 1m and area of cross-section 25cm² is placed in a three dimensional coordinate system as shown in the figure . The electric field is the region is given by E= 50xi, where E is NC^{-1} and x is the metres Find (i) Net flux through the cylinder (ii) Charge enclosed by the cylinder.



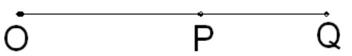
</td></tr>
<tr><td>24.</td><td>(a) If two similar large plates, each of area A having surface charge densities +σ and -σ are separated by a distance d in the air find the expression for

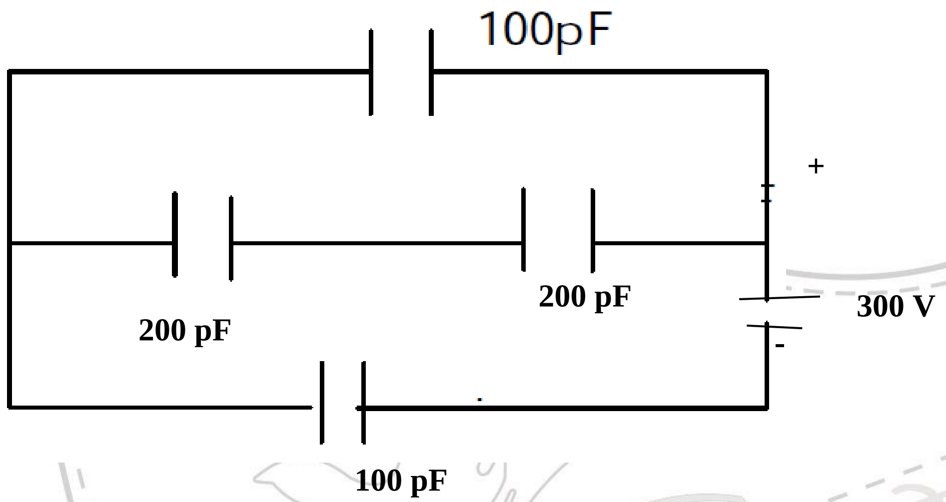
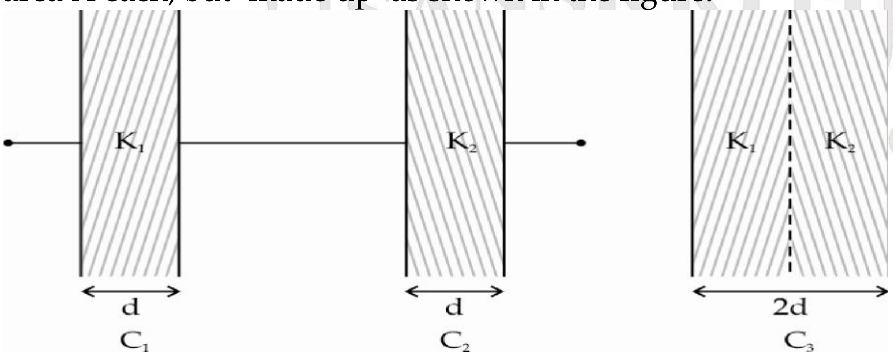
(i) Field at points between the two plates and on outer side of the plates. Specify the direction of the field in each case.</td></tr>
</table>

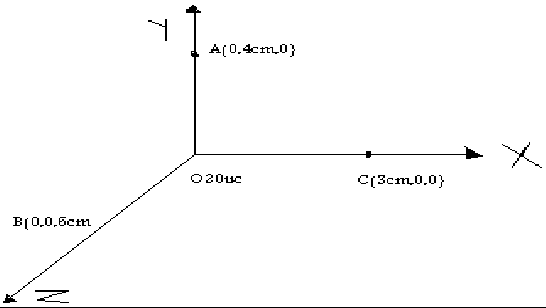
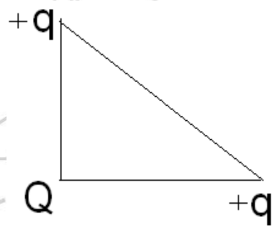
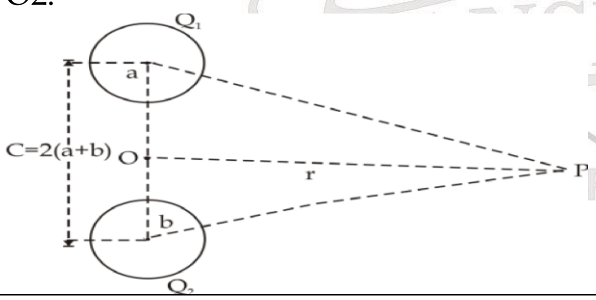
	(ii) the potential difference between the plates (iii) The capacitance of the capacitor so formed. (b) Two metallic spheres of radii R and 2R are charged so that both of these have same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why?
25.	Two uniformly large parallel thin plates having charge densities +σ and – σ are kept in the X-Z plane at a distance d apart. Sketch an equipotential surface due to the electric field between the plates. If a particle of mass m and charge ' –q' remains stationary between the plates, what is magnitude and direction of this field?
26	A point charge (+Q) is kept in the vicinity of uncharged conducting plate. Sketch electric field lines between the charge and the plate.

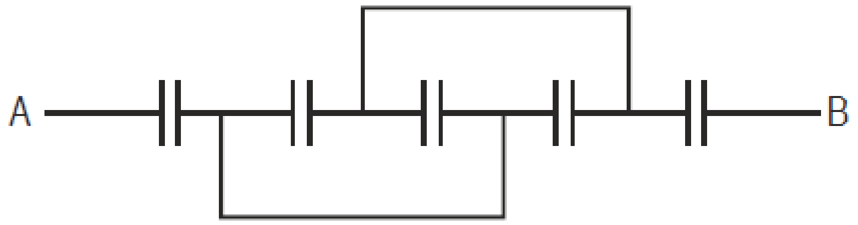
CHAPTER 2: POTENTIAL AND CAPACITANCE

Assignment

1	Electric field is always : (A) Parallel to equipotential surface (B) Perpendicular to equipotential surface (C) It can be perpendicular and parallel as well (D) It does not depends on distribution of charge
2	On reducing potential across a capacitor, its capacitance : (A) Decreases (B) Increases (C) Remains constant (D) First increases then decreases
3	Two conducting spheres A and B of radii a & b respectively are at the same potential. The ratio of surface charge densities of A and B is (a)a/b (b) b/a (c) b^2/a^2 (d) a^2/b^2
4	When charge is supplied to a conductor, its potential depends upon (a) the amount of charge (b) Geometry & size of conductor (c) both (a) & (b) (d) none
5	Why is there no work done in moving a charge from one point to another on an equipotential surface?
6.	Do free electrons travel to region of higher potential or lower potential?
7.	Calculate potential on the axis of a ring due to charge Q uniformly distributed along the ring of radius R.
8.	A parallel plate capacitor is filled by a dielectric whose relative permittivity varies with the applied voltage (U) as $\varepsilon = \alpha U$, where $\alpha = 2V^{-1}$. A similar capacitor with no dielectric is charged to U_0=78V. It is then connected to the uncharged capacitor with the dielectric. Find the final voltage on the capacitors?
9.	A uniform electric field of 2 kNC^{-1} is in the x-direction. A point charge of 3 μC initially at rest at the origin is released. What is the kinetic energy of this charge at x = 4m?
10.	A point charge q is placed at O as shown in the figure.  Is V_P-V_Q +ve or –ve when (i) q>0, (ii) q<0? Justify your answer.
11.	What is a dielectric? What is meant by dielectric polarization? What is the effect on capacitance of a capacitor when a dielectric of width't' is placed between the two plates of parallel plate capacitor?
12.	A parallel plate capacitor is charged at certain potential difference. When 3mm thick slab is introduced between plates in order to maintain the same potential difference, the distance between plates is increased by 2.4mm. Find the dielectric constant of the slab?

13	A parallel plate 50µF capacitor is charged to 200V. If the distance between plates is doubled, what will be the new potential difference between plates and the change in energy stored?
14	The given figure shows a network of four capacitors connected to a 300Vsupply. Calculate the total charge and energy stored in the network. 
15.	Derive an expression for the energy stored in a parallel plate capacitor. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced by half and the space between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance of parallel plate capacitor in this case.
16.	Three point charges of q, -4q and +2q are placed at three vertices of an equilateral triangle of side 10cm. where $q = 1.6\times10^{-10}\ C.$ Calculate the work done to dissociate the system.
17.	The capacitors C1, and C2, having plates of area A each, are connected in series, as shown. Compare the capacitance of this combination with the capacitor C3, again having plates of area A each, but 'made up' as shown in the figure. 
18.	Derive an expression for the total work done in rotating a dipole of dipole moment p through an angle θ in a uniform electric field E. For what angle between p and E will the potential energy of the electric dipole be half of its maximum value?

19.	If N drops of same size, each having the same charge, coalesce to form a bigger drop. How will the following vary with respect to single small drop? (i) Total charge on bigger drop (ii) Potential on the bigger drop (iii) The capacitance on the bigger drop.
20.	A charge of 10 μc is brought from point A (0,4 cm,0) to C (3 cm,0,0) via point B (0,0,6 cm) in vacuum. Calculate the work done if the charge at origin is 20 μc. 
21	Three charges Q, +q and +q are placed at the vertices of a right angle isosceles triangle as shown. Find the magnitude of Q for which net electrostatic energy of the configuration is zero. 
22.	A 4μF capacitor is charged by a 200V supply. The supply is then disconnected and the charged capacitor is connected to another uncharged 2μF capacitor. How much electrostatic energy of the first capacitor is lost in the process of attaining the steady situation?
23.	Find the P.E. associated with a charge 'q' if it were present at the point P with respect to the 'set-up' of two charged spheres, arranged as shown. Here O is the mid-point of the line O1 O2. 
24.	Two identical parallel plate capacitors A and B are connected to a battery of V volts with the switch S closed. The switch is now opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric constant K. Find the ration of the total electrostatic energy stored in both capacitors before and after the introduction of the dielectric.

25.	Find the equivalent capacitance of the 5 identical capacitors connected as shown. Each capacitor is of 2 μF. 
26	Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel across a battery of 100V. If the energy stored in the two combinations is 0.045J and 0.25J respectively, determine the value of C_1 and C_2. Also calculate the charge on each capacitor in parallel combination.
27	(a) Plot a graph comparing the variation of potential V and electric field E due to a point charge Q as a function of distance R from the point charged. (b)Find the ratio of the potential differences that must be applied across the parallel and the series combination of two capacitors C_1 and C_2 with their capacitances in the ratio of 1 :2 so that the energy stored, in the two cases, becomes the same.

Practice Questions: Electrostatics

Short answer questions

1. (a) How does the energy of dipole change when it in rotated from unstable equilibrium to stable equilibrium in a uniform electric field ?
   b) Draw an equipotential surface for a dipole.

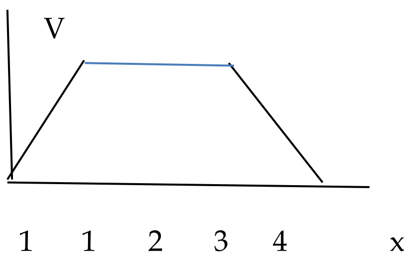
2. Name the physical quantity which is measured as V-m.

3. Work is done in taking a positive charge from the outer surface of a metallic sphere to another point outside the sphere, but no work is done in taking the charge from one point to another inside the sphere. Why?

4. In a certain volume 0.1 m^3 of space, electric potential is found to be 5V throughout. What is the electric field in the region?

5. Why does the electric field inside a dielectric decreases when it is placed in an external electric field?

6. What is equipotential surface? Draw an equipotential surface for an electric dipole. Electric charge is uniformly distributed on the surface of a spherical conductor. With the help of a graph, show how the value of potential varies:
   (a) on the surface (b) inside and (c) outside.
7. Just outside a conductor, electric field is perpendicular to the surface. Give reason.
8. How does capacity of an isolated conducting sphere depends on radius of sphere?
9. Assuming that capacitor is disconnected from the charging battery, explain how the (i) capacitance (ii) potential difference across plates and (iii) energy stored in parallel plate capacitor change, when a medium of dielectric constant K is introduced between the plates.
10. Draw the graph showing the variation of potential with the charge given to conductor. Name the quantity given by slope of the curve.
11. The variation of V with distance x is shown in fig. Construct a graph showing variation of E with x



12. A sphere S_1 of radius r_1 encloses a charge q . If there is another concentric sphere S_2 of radius r_2 ($r_2 > r_1$) and there be n additional charges between S_1 and S_2, find the ratio of the electric flux through S_1 and S_2.
13. A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge Q. A charge q is placed at the centre of the shell. What is the surface charge density on the inner and outer surfaces of the shell?
14. Two identical point charges are kept at a distance r from each other. A third point charge q is placed on the line joining the above two charges , such that all the three charges are in equilibrium. What is the sign , magnitude and position of the third charge?
15. Two point charges of unknown magnitude and sign are placed at a distance d apart . The electric field intensity is zero at a point , not between the charges but on the line joining them. Write two essential conditions for this to happen.
16. What is the angle between the directions of the electric field at any i) axial point ii) equatorial point , due to an electric dipole?
17. Two charges each of +Q units are placed at certain distance. A third unknown charge is placed between them. At what position and for what value of charge, will the system be in equilibrium?
18. Draw a diagram to show lines of force in a plane containing two equal point charges of opposite signs separated by a small distance. Giving reason, indicate on the diagram a point where a small positive charge experience a force parallel to the line joining the two charges.

Long answers questions :

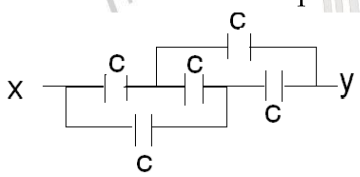
1. Derive an expression of potential energy of a system of two charge particles.
2. Derive an expression of energy stored in a parallel plate capacitor. What is the form of this energy and wherefrom it comes?
3. Define capacitance. How do the charge, potential, electric field and energy changes when a dielectric slab is introduced between plates of charged capacitors with the battery remaining connected.
4. Derive an expression for the capacitance of a parallel plate capacitor with a dielectric slab between the plates. Assume that the thickness of the slab is less than its plate separation.

5. Define electric dipole moment. What is the S.I. unit of dipole moment of an electric dipole? Show the orientation of the dipole in the field for which the torque is i) maximum ii) half the maximum value iii) Zero.
6. An electric dipole of dipole moment P is held in a uniform electric field E. How much work is required in turning the electric dipole, from the position of most stable equilibrium to the position of most unstable equilibrium?
7. Derive an electric potential at a point at a distance r from the center of electric dipole if the line joining the point to the center of dipole makes an angle θ with the dipole moment.
8. Two capacitors with capacity C_1 and C_2 are charged to potential V_1 and V_2 respectively and then connected in parallel. Calculate the common potential across the combination, the charge on each capacitor, the electrostatic energy stored in the system and the change in the electrostatic energy from its initial value.
9. A charge is distributed uniformly over a ring of radius a. Obtain an expression for the electric intensity at a point on the axis of the ring. Hence show that for point at large distances from the ring, it behaves like a point charge.

Numericals :

1. A 10 mC charge is at the centre of a square of side 10 cm. Find the work done in moving a charge of 1 micro Coulomb between 2 diagonally opposite points on the square.
2. An electric charge of 8.85×10^{-13} C is placed at the center of the sphere of radius 1m. What is the total electric flux linked with the sphere ? How will the electric flux change if another equal and opposite charge is introduced at a distance of i) 0.5 m from the center ii) 1.5 m from the centre
3. The ratio of capacitances of two capacitors is 1:4 and their equivalent capacitance is 16 µF when connected in series. Find the capacitance of each capacitor?
4. 10 µF capacitor is charged by a 30 dc supply and then connected across an uncharged 50 µF capacitor. Calculate (i) the final potential difference across the combination ; and (ii) the initial and final energies. How will you account for the difference in energies?
5. A uniform electric field of magnitude 300 N/C exist along +ve x direction. Let A (0,0), B (2,0) and C (0,1) be the points. Distances are measured in meters. Find potential difference between (i) A and B (ii) A and C (iii) B and C.

6. A conducting spherical bubble of radius r and thickness t (t<< r) is charged to potential V. Now it collapses to form a spherical droplet. Find the potential of the droplet.
7. Three hollow concentric spheres A, B and C having radii a, b, and c (a<b<c) have uniform surface charge densities + σ, - σ, and + σ respectively. Compute the electric potential at the surface of each sphere.
8. Three point charges of 1nC, 2 nC, and 3 nC are placed at three corners of an equilateral triangle of side √3m. Find the potential at a point equidistant from each charge.
9. X and Y are two identical parallel plate connected in series with a cell of potential difference 12V. X has air and Y has dielectric medium of K= 5 between the plates.
   (i) Calculate potential difference between the plates of X and Y.
   (ii) What is the ratio of electrostatic energy stored in X and Y
10. Five identical capacitors, each of capacitance C are connected between points X and Y as shown in the figure. If the equivalent capacitance of the combination between X and Y is 5mF. Calculate the capacitance of each capacitor.



11. A $500\mu C$ charge is placed at the center of a square of side 10cm. find the work done in moving a charge of $10\mu C$ between two diagonally opposite points on the square.
12. A charge placed at a certain distance on the axial line of a short dipole experiences a force of 32N. What will be the force on the test charge if the distance of the charge is doubled?
13. A uniformly charged conducting sphere of 2.5m in diameter has a surface charge density of $100\mu C/m^2$. calculate the
   (i) Charge on the sphere.
   (ii) Total electric flux passing through the sphere.

MCQ :

1. If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium , then the value of q is :

   a) Q/2 b) - Q/2
   b) Q/4 d) - Q/4

2. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire , then in equilibrium , the ratio of the magnitudes of the electric fields at the surfaces of the spheres A and B is

   a) 2:1 b) 1:4
   b) 4:1 d) 1:2

3. A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P at a distance R/2 from the centre of the shell is :

   a) $2Q / (4\pi\epsilon_o R) - 2q / (4\pi\epsilon_o R)$
   b) $2Q / (4\pi\epsilon_o R) + q / (4\pi\epsilon_o R)$
   c) $2Q / (4\pi\epsilon_o R)$
   d) $2(q+Q) / (4\pi\epsilon_o R)$

4. There is an electric field in the X-direction. If the work done in moving a charge of 0.2 C through a distance of 2m along a line making an angle of 60° with the x- axis is 4 J , then what is the value of E?

   a) $\sqrt{3}$ N/C b) 4 N/C
   c) 5 N/C d) 20 N/C

5. A cpacitor of capacitance C is charged to a potential V and is placed inside a closed surface . The electric flux through the closed surface is

   a) CV/ε_o b) $2CV/\varepsilon_o$
   c) $CV/2\varepsilon_o$ d) zero

6. Identical charges –q are placed at each corner of a cube of side b . Then , the electrostatic potential energy of charge + q placed at the centre of the cube is

   a) $-4\sqrt{2}q^2/\pi\varepsilon_o b$ b) $8\sqrt{2}q^2/\pi\varepsilon_o b$

   c) $-4q^2/\sqrt{3}\pi\varepsilon_o b$ d) $8\sqrt{2}q^2/4\pi\varepsilon_o b$

7. A 4 μF capacitor is charged to 400 V. If its plates are joined through a resistance of 2 kΩ , then heat produced in the resistance is :

   a) 0.16 J b) 0.32 J
   c) 0.64 J c) 1.28 J

8. A capacitor of capacitance C_1 is charges upto a potential V and then connected in parallel to an uncharged capacitor of capacitance C_2 . The final potential difference across each capacitor will be :

a) $C_2 V / C_1 + C_2$ b) $C_1 V / C_1 + C_2$

c) $(1 + C_2/ C_1) V$ d) $(1 - C_2/ C_1) V$

9. Equipotential surfaces associated with an electric field , which is increasing in magnitude along the X-direction , are

a) Planes parallel to Y-Z plane
b) Planes parallel to X-Y plane
c) Planes parallel to X-Z plane
d) Coaxial cylinders of increasing radii around the x-axis.

10. The electrostatic capacitance depends on

a) Nature of the conductor
b) Size of the conductor
c) Thickness of the conductor
d) None of these

11. Three capacitors of 2 μF , 3 μF and 6 μF are connected in series to a 10 V source. The charge on the 3 μF capacitor is

a) 5 μC b) 10 μC

c) 12 μC d) 15 μC

12. 27 small drops , each having charge q and radius r coalesce to form a big drop . How many times will the charge and the capacitance become?

a) 3,27 b) 27,3 c) 27,27 d) 3,3

13. A uniform electric field pointing in positive x direction exists in a region. Let A be the origin , B be the point on the x-axis at x = 1 cm. Then the potentials at points A,B and c satisfy :

a) $V_A < V_B$ b) $V_A > V_B$ c) $V_A < V_c$ d) $V_A > V_c$

14. A positively charged glass rod is brought near an uncharged pith ball pendulum. The pith ball is

a) Attracted towards the rod.
b) Repelled away from the rod
c) Not affected by the rod
d) Attracted towards the rod , touches it and is then thrown away from it.

15. Electric field varies as r^{-1} due to

   a) A point charge

   b) A quadrupole

   c) An infinite line charge

   d) An infinite plane sheet of charge

16. A capacitor of capacitance 10 μF was originally charged to 10 V. Now , the potential difference is increased to 20 V. The increase in potential energy is

   a) 4×10^{-4} J b) 10×10^{-4} J c) 15×10^{-4} J d) 5×10^{-4} J

17. A solid sphere and a hollow sphere of equal diameters are raised to the same potential. Then,

   a) Hollow sphere has more charge

   b) Both have equal charge

   c) Only hollow sphere has charge

   d) Solid sphere has more charge

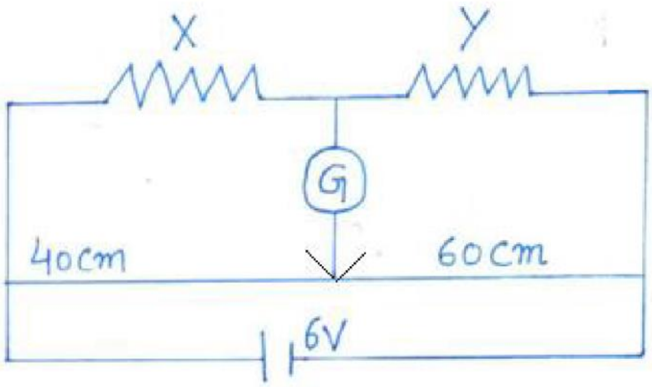
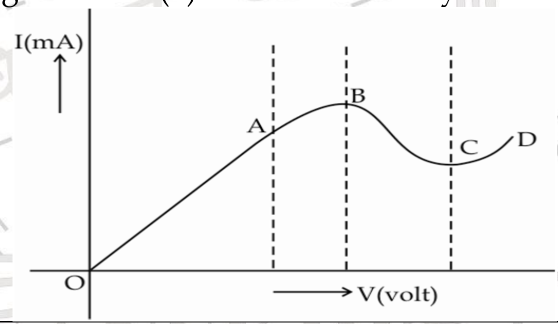
Answers:

1. d	2. a	3. b	4. d	5. d
6. c	7. b	8. b	9. a	10. b
11. b	12. b	13. b	14. D	15. c
16. c	17. b			

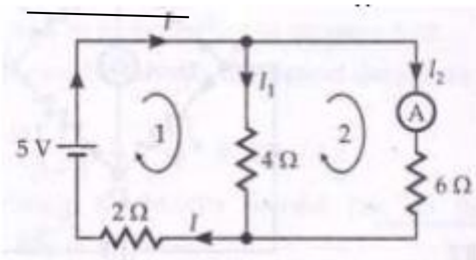
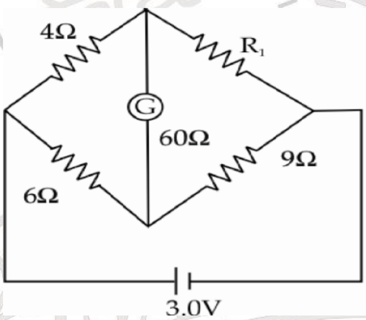
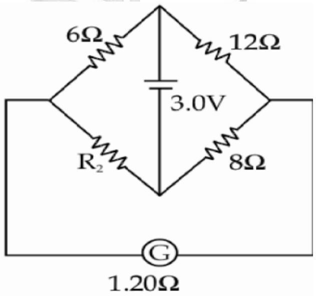
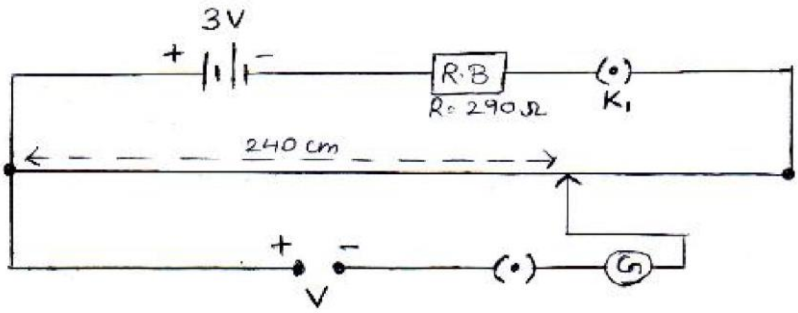
Chapter No 3: Current Electricity

Assignment

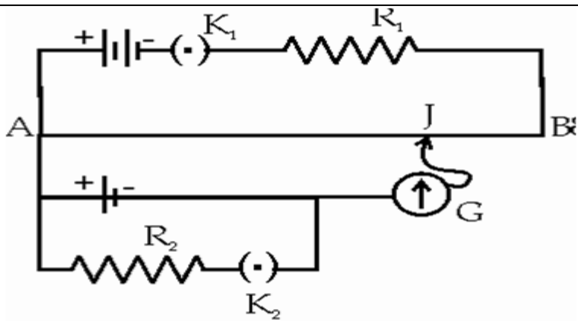
1	Kirchhoff's II law for the electric network is based on: (a) Law of conservation of charge (b) Law of conservation of energy (c) Law of conservation of angular momentum (d) Law of conservation of mass
2	How much work is required to carry a 6μC charge from the negative to the positive terminal of a 9V battery? (a) 54 × 10-3 J (b) 54 × 10-6 J (c) 54 × 10-9 J (d) 54 × 10-12 J
3	Two resistors of resistance R1 and R2 having R1 >R2 are connected in parallel. For equivalent resistance R, the correct statement is (a)R > (R1 + R2) (b) R1 < R < R2 (c) R2 < R <(R1 + R2) (d) R < R1
4	The temperature coefficient of resistance for a wire is 0.00125 / °C. At 27°K its resistance is 1ohm. The temperature at which the resistance becomes 2 ohm is (a) 1154 K (b) 1100 K (c) 1400 K (d) 1127 K
5	In an experiment on meter bridge, if the balancing length AC is 'x' What would be its value, when the radius of the meter bridge wired AB is doubled? Justify your answer.
6	Two wires A and B of the same material and having same length, have their cross sectional areas in the ratio 1:6. What would be the ratio of heat produced in these wires when same voltage is applied across each?
7	Draw a graph to show a variation of resistance of a metal wire as a function of its diameter keeping its length and material constant.
8	In the given circuit, a metre bridge is shown in the balanced state. The metre bridge wire has a resistance of 1 Ω cm-1. Calculate the unknown resistance X and the current drawn from the battery of a negligible internal resistance if the magnitude of Y is 6 Ω. If at the balancing point, we interchange the position of galvanometer and the cell, how it will affect the position of the galvanometer?

	
9	Two metallic wires of the same material and same length but different cross-sectional areas are joined together (i) in series (ii) in parallel, to source of EMF. In which of the two wires will the drift velocity of electron be more in each of the two cases and why?
10	Define the term 'mobility' of charge carriers. Write its S.I. unit.
11	The length of a potentiometer wire is 5m. It is connected to a battery of constant EMFf. For given leclanche cell, the position of zero galvanometer deflection is obtained at 100cm. If the length of potentiometer wire be made 8m instead of 5m, calculate the length of wire for zero deflection in galvanometer for same cell.
12	Name the material whose V-I characteristics is shown in figure. Identify the region over which (a) resistance is negative and (b) Ohms law is obeyed. 

13	Two cells of emf E_1 and E_2 have internal resistance r_1 and r_2. Deduce an expression for equivalent emf of their parallel combination.
14	A potential difference of V volt is applied to a conductor of length L, and diameter D. How will the drift velocity of electrons and resistance of conductor change when (i) V is doubled (ii) L is halved and (iii) D is halved , where in each case, the other two factors remains same. Give reason in each case.
15	The ends of a resistor are connected to 19 identical cells each of internal resistance 0.1Ω in series. The current is found to be 2A. When the number of reduced to 15 and an additional resistance 9.5Ω is connected in series to given resistor, the current reduced to half. Calculate the resistance of given resistor and emf of each cell?

16	You are required to find the internal resistance of a primary cell in the laboratory. Draw a circuit diagram of the apparatus you will use to determine it. Explain the principle of the experiment. Give the formula used.
17	1) State the two Kirchhoff's rules used in electric networks. How are these rules justified ? 2)What does the ammeter A read in the circuit? What if the positions of the cell and ammeter are interchanged? 
18.	A battery of emf 3V and internal resistance r is connected in series with a resistor of 55Ω through an ammeter of resistance 1Ω. The ammeter reads 50mA. Calculate the value of r.
19	A potentiometer wire of length 1.0m has a resistance of 15Ω. It is connected to a 5V battery in series with a resistance of 5Ω. Determine the EMF of the primary cell which gives a balance point at 60cm.
20	The galvanometer, in each of the two given circuits, does not show any deflection. Find the ratio of the resistors R1 and R2, used in these two circuits. 
21.	Calculate the value of the unknown potential V for the given potentiometer circuit. The total length (400 cm) of the potentiometer wire has a resistance of 10 Ω and the balance point is obtained at a length of 240 cm 

22.



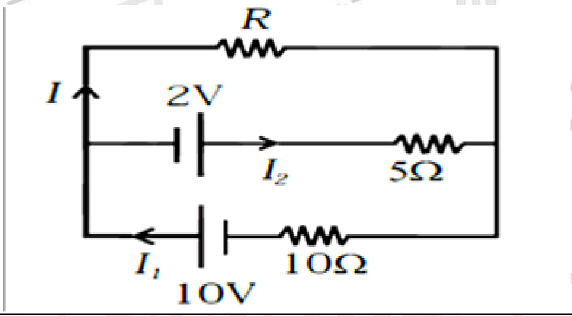
For the circuit shown here, would the balancing length increase, decrease or remain the same, if
(i) R1 is decreased
(ii) R2 is increased
without any other change, (in each case) in the rest of the circuit. Justify your answers in each case.

23.

Give an example of a material each for which temperature coefficient of resistivity is (i) positive, (ii) negative.
A cell of emf 'ξ' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.
It is found that when R= 4Ω, the current is 1A and when R is increased to 9 Ω, the current reduces to 0.5A. Find the values of the emf ξ and internal resistance r.

24.

Two cells of E.M.F. 10 V and 2 V and internal resistances 10 Ω and 5 Ω respectively, are connected in parallel as shown. Find the effective voltage across R.



25.

The potential difference across a resistor 'r' carrying current 'I' is Ir.
(i) Now if the potential difference across 'r' is measured using a voltmeter of resistance 'Rv', show that the reading of voltmeter is less than the true value.
(ii) Find the percentage error in measuring the potential difference by a voltmeter.
(iii) At what value of Rv, does the voltmeter measures the true potential difference?

Chapter 3: Current Electricity

Short Answer Questions:

1. Write the condition under which the potential difference between the terminals of a battery exceeds its emf.
2. Give two reasons why manganin is used for making standard resistors?
3. The order of the coloured rings on the carbon resistor is red, yellow, blue and gold. What is the resistance of the carbon resistor?
4. How would the drift velocity of electrons in a metallic conductor vary when

   (a) the temperature of the conductor is increased?
   (b) The applied potential difference is decreased, keeping the temperature constant.
5. A metallic wire of length l is stretched so that its length becomes three times. Assuming there is no change in its density on stretching, explain how the following factors vary in the conductor:
   (a) Resistance (b) resistivity
6. Define relaxation time.
7. Define resistivity of the material. Plot its variation with the temperature in case of metal and semiconductor.
8. Draw a circuit diagram to determine the unknown resistance of a metallic conductor using a metre bridge.
9. 'n' identical cells each of emf E and internal resistance r are connected in series to resistor R.
   i) Deduce an expression for the internal resistance r of one cell in terms of the current I flowing through the circuit.
   ii) How does the internal resistance of the cell vary with temperature?
10. When current flows through a coil of heater heat produced is Q_1. Now the coil is cut into two equal parts and only one part is connected to same power supply. Heat produced is Q_2. Find Q_1/Q_2.
11. Why is a potentiometer preferred over a voltmeter for determining the emf of a cell?
12. Draw variation of resistivity with temperature for Si, C, Cu and Nichrome.
13. Two wires of equal lengths, one of copper and the other of magananin have the same resistance. Which wire is thicker?
14. A cell of EMF E and internal resistance r is connected across a variable external resistance R. Plot graphs to show variation of (i) E with R (ii) terminal potential difference of cell V with R.
15. A heating element using nichrome connected to a 230V supply draws an initial current of 3.2A which settles after a few seconds at a steady state value 0f 2.8A. What is the steady temperature of the heating element if the room temperature is 27^0C.? temperature coefficient of resistance of nichrome averaged over the temperature range involved is $1.7 \times 10^{-4}/^0C$

Long Answer Questions :

1. Using Kirchhoff's laws derive the condition for balance in a Wheatstone's bridge.

2. Draw a circuit diagram of a meter bridge used to determine the resistance of wire. Give the formula used.
3. Two metallic wires of the same material and same length but different cross-section are joined together in i) series ii) parallel , to a source of emf . In each of these cases, in which of these two wires, will the drift velocity of electrons be more? Why?
4. With the help of a circuit diagram, describe a method to find the internal resistance of a primary cell.
5. Define mobility. Prove that the current flowing in a conductor is proportional to the drift velocity of free electrons.
6. A conductor of length l is connected to a d.c. source of potential V. If the length of the conductor is tripled by stretching it , keeping V constant , explain how do the following factors vary in the conductor
   (a) drift speed of electrons
   (b) resistance
   (c) resistivity.

Numericals :

1. Two heaters are marked 200V,300W and 200V,600W. If the heaters are combined in series and the combination is connected to a 200V d.c. supply, which heater will produce more heat?
2. The e.m.f. of a cell measured using a potentiometer is found to be 1.20 V, whereas an accurate voltmeter connected across the terminals of the cell reads 1.10 V. Calculate the ratio of the resistance of the voltmeter to the internal resistance of the cell.
3. Two resistances of 4 Ω and 8Ω connected in parallel is placed in right gap of a meter bridge and a known resistance of 6 Ω is placed in the left gap. Where is the balance point on the wire of meter bridge from right end of wire?
4. The four arms of a Wheat stone bridge have the following resistances: AB=100Ω, BC = 10 Ω, CD = 5Ω and DA= 60 Ω. The galvanometer of 15Ω resistance is connected across BD. A potential difference of 10V is maintained across AC.
   (a) State two laws used to find the current in different branches of circuit.
   (b) Calculate the current through galvanometer.
5. A cell of emf 1.1 V and internal resistance 0.5 ohm is connected to a wire of resistance 0.5 ohm. Another cell of same emf is connected in series but the current in the wire remains the same. Find the internal resistance of the second cell.

6. An electric heater and a bulb are rated at 500W-220V and 100W-220V respectively. Both are connected in series to a 220 V a.c.mains . Calculate the power consumed by the I) heater II) the bulb.
7. A 24 volt battery of internal resistance 4 ohm is connected to variable resistor. At what value of the current drawn from the battery is the rate of heat produced in the resistor maximum?
8. In a potentiometer, a standard cell of E_1 = 2V and of negligible resistance maintains a steady current through the potentiometer wire. The balancing point of the cell E_2 is 100cm. When the cell E_2 is shunted by a resistance of RΩ, the balance point shifts to 50cm length of the potentiometer wire. Draw the circuit diagram used and determine the internal resistance of the cell E_2 .
9. When a resistance of 2 Ω is placed across the terminals of a battery the current is 0.5 A, when the resistance across the terminals is 5 Ω, the current is 0.25A. Find the emf of battery. 1.5V

Multiple choice questions

1. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 4/3 and 2/3 , then the ratio of the currents passing through the wire will be

   3 b) 1/3 c) 8/9 d) 2
2. A piece of copper and another of germanium are cooled from room temperature to 77 K. The resistance of
   a) Copper decreases and germanium increases
   b) Copper increases and germanium decreases
   c) Each of them increases
   d) Each of them decreases
3. The resistance of bulb filament is 100 Ω at a temperature of 100 ˚C. If its temperature coefficient of resistance be 0.005/˚C , its resistance will become 200Ω at a temperature of

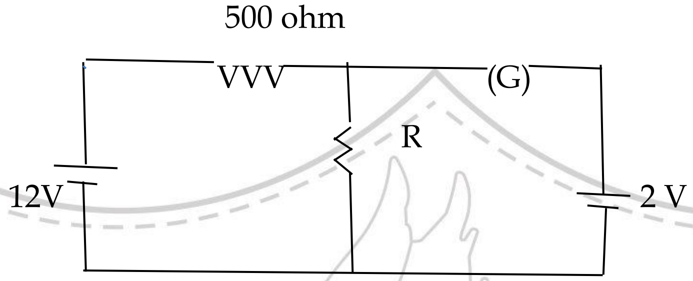
   500˚C b) 200˚C c) 300˚C d) 400˚C
4. An electric bulb is rated 220 V-100 W. The power consumed by it, when operated on 110 V will be

25 W b) 50 W c) 75 W d) 40 W

5. A heater coil is cut into two equal parts. Only one part is now used in the heater. The heat generated will now be

Doubled b) four times c) one-fourth d) halved

6. In the given circuit, the galvanometer G shows zero deflection. If the batteries A and B have negligible internal resistance , the value of the resistor R will be



a) 200 Ω b) 100 Ω c) 500 Ω d) 1000 Ω

7. In a metrebridge experiment , null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If X <Y , then where will be the new position of the null point from the same end , if one decides to balance a resistance of 4X against Y?

50 cm b) 80 cm c) 40 cm d) 70 cm

8. In a potentiometer experiment, the balancing length with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is

1 ohm b) 0.5 ohm c) 4 ohm d) 2 ohm

9. The resistivity of a potentiometer wire is 10^{-7} ohm-metre and its area of cross-section is $10^{-6}m^2$. When a current of I = 0.1 A flows through the wire , its potential gradient is

a) 10^{-2} V/m b) 10^{-4} V/m c) 0.1 V/m d) 10 V/m

10. The sensitivity of the potentiometer can be increased by

a) Increasing the length of the potentiometer wire
b) Decreasing the length of the potentiometer wire
c) Increasing the emf of the primary cell

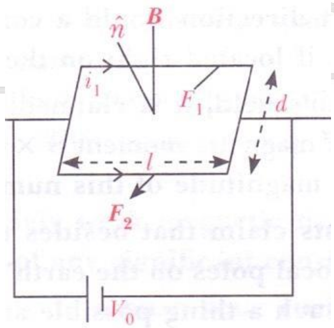
Increasing the potential gradient

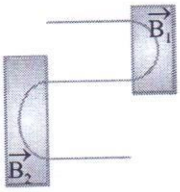
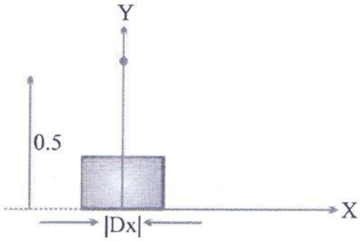
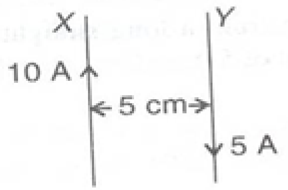
Answers:

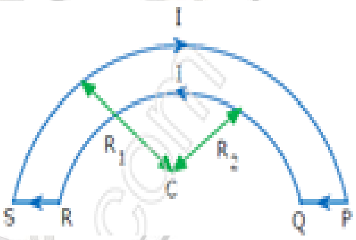
1. b	2. a	3. c	4. a	5. a
6. b	7. a	8. d	9. a	10. a

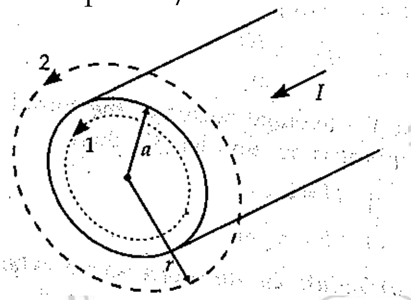
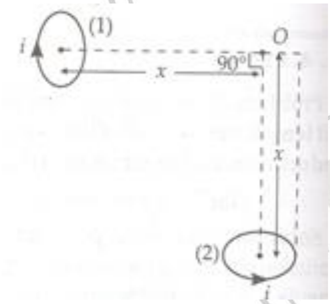
Chapter No. 4: Magnetic Effect of Current

Assignment

1	An electric current passes through a long straight copper wire. At a distance 5 cm from the straight wire, the magnetic field is B. The magnetic field at 20 cm from the straight wire would be (a)B/6 (b)B/4 (c)B/3 (d)B/2
2	The coil of a moving coil galvanometer is wound over a metal frame in order to (a) reduce hysteresis (b) increase sensitivity (c) increase moment of inertia (d) provide electromagnetic damping
3	Current sensitivity of a galvanometer can be increased by decreasing : (a) Magnetic field B (b) number of turns N (c) torsional constant K (d) Area A
4	A deuteron of kinetic energy 50 keV is describing a circular orbits of radius 0.5 m in a plane perpendicular to the magnetic field B. The kinetic energy of the proton that describes a circular orbit of same radius and inside same B is (a) 25 keV (b) 50 keV (c) 200 keV (d) 100 keV
5	A current is sent through a vertical spring from whose lower end a weight is hanging. How will the position of the weight be effected and why ?
6.	A uniform conducting wire of length 12a and resistance R is wound up as a current carrying coil in the shape of (i) an equilateral triangle of side a; (ii) a square of sides a and , (iii) a regular hexagon of sides a. The coil is connected to a voltage source V_0. Find the magnetic moment of the coils in each case.
7.	A rectangular conducting loop consists of two wires on two opposite sides of length l joined together by rods of length d. The wires are each of the same material but with cross-sections differing by a factor of 2. The thicker wire has a resistance R and the rods are of low resistance, which in turn are connected to constant voltage source V_0. The loop is placed in uniform a magnetic field B at 45° to its plane. Find t, the torque exerted by the magnetic field on the loop about an axis through the centres of rods? 
8	Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude B_1 and B_2. Its path in each region is a half circle (a) which field is stronger? (b) what are the directions of two fields? (c) Is the time

<table>
<tr><td></td><td>spend by the electron on the B_1, region greater than, less than, or the same as the time spent in B_2 region?

</td></tr>
<tr><td>9.</td><td>An element ΔI=Δx.i is placed at the origin and carries a large current I=10A. What is the magnetic field on the Y-axis at a distance of 0.5m. Δx= 1 cm.

</td></tr>
<tr><td>10.</td><td>Which one of the following will describe the smallest circle when projected with the same velocity ‘v’ perpendicular to the magnetic field B : (i) α- particle, and (ii) β-particle?</td></tr>
<tr><td>11.</td><td>A galvanometer with a coil of resistance 12.0 Ω show full scale deflection for a current of 25mA. How will you convert the meter into :
(i) an ammeter to a range 0 to 7.5 A
(ii) a voltmeter to range 0 to 10.0V.
Determine the net resistance of the meter in each case. When an ammeter is put in a circuit does it read (slightly) less or more than the actual current in the original circuit? When a voltmeter is put across a part of the circuit, does it read (slightly) less or more than the original voltage drop?</td></tr>
<tr><td>12.</td><td>Two long parallel straight wires X and Y separated by a distance of 5 cm in air carry currents of 10A and 5A respectively in opposite direction. Calculate the magnitude and direction of the force on a 20 cm length of the wire Y. Also Find the magnetic field at a point midway between the wires.

</td></tr>
<tr><td>13</td><td>An α- particle and a proton are released from the centre of the cyclotron and made to accelerate.
(i) Can both accelerate at the same cyclotron frequency? Give reasons to justify your answer.</td></tr>
</table>

	(ii) When they are accelerated in turn, which of the two will have higher velocity at the exits slit of the dees?
14.	(a) Draw a label led diagram of a moving coil galvanometer. Prove that in a radial magnetic field, the deflection of the coil is directly proportional to the current flowing in the coil. (b) A galvanometer can be converted into a voltmeter to measure upto (i) V volt by connecting a resistance R_1 series with the coil (ii) V/2 volt by connecting a resistance R_2 in series with coil Find R in terms of R_1 and R_2 required to convert – it into a voltmeter that can read upto '2V' volt.
15.	Write the expression of the magnitude F of the force between two straight parallel current carrying conductors kept at a distance d apart. Use this expression and the sign conventions that the force of attraction is assigned a negative sign and force of repulsion is assigned a positive sign. Draw the graph showing dependence of F on (i) I_1I_2 when d is kept constant (ii) d when the product I_1I_2 is maintained at a constant positive value (iii) d when the product I_1I_2 is maintained at a constant negative value
16.	Two wires loops PQRSP formed by joining two semi-circular wires of radii R_1 and R_2 carries a current I as shown in the figure. What is the magnetic of the magnetic induction at the centre C.? 
17	Two Concentric circular coils X and Y of radii 16 cm and 10 cm respectively lie in the same vertical plane containing the north to south direction. Coil X has 20 turns and carries a current of 16A : Coil Y has 25 turns and carries a current of 18A. The sense of the current in X is anticlockwise, and clockwise in Y, for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coil at their centre.
18.	A coil of n turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.
19	A straight wire of length L, carrying current I, stays suspended horizontally in mid-air in a region where there is a uniform magnetic field B. The linear density of the wire is λ. Find the magnitude and direction of this magnetic field.
20.	(a) A long straight wire AB carries a current I. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current. What is the force experienced by the proton and what is its direction?

	(b) Use an expression for the force per unit length between two infinitely long parallel current carrying conductors to define S.I. Unit of current.
21.	(i) A straight thick long wire of uniform cross-section of radius 'a' is carrying a steady current I. Use Ampere's circuital law to obtain a relation showing the variation of the magnetic field (R_r) inside and outside the wire with distance r, ($r \leq a$) and ($r>a$) of the field point from the centre of its cross-section. Plot a graph showing the variation of field B with distance r. (ii) Calculate the ration of magnetic field at a point a/2 above the surface of the wire to that a point a/2 below its surface. What is the maximum value of the field of this wire. 
22.	Two small identical circular loops, marked (i) and (2), carrying equal currents, are placed with the geometrical axes perpendicular to each other as shown in Fig. Find the magnitude and direction of the net magnetic field produced at the point O 
23.	Describe qualitatively the path of a charged particle moving in : (a) A uniform electrostatic field, with initial velocity (i) parallel to the field, (ii) Perpendicular to the field, (iii) At an arbitrary angle with the field direction. (b) a uniform magnetic field, with initial velocity (i) parallel to (or along) the field, (ii) perpendicular to the field, (iii) at an arbitrary angle with the field. (c) a region with uniform electrostatic and magnetic fields parallel to each other, with initial velocity (i) parallel, (ii) perpendicular , (iii) at an arbitrary angle with the common direction of the field.
24.	Give reasons for the following : (1) Why do we prefer phosphor-bronze alloy for the suspension wire of a moving coil galvanometer?

	(2) Why is it that while using a moving coil galvanometer as a voltmeter a high resistance in series is required whereas in an ammeter a shunt is used? (3) Why are the pole pieces of galvanometer made concave? (4) Why is a cyclotron not suitable for accelerating electrons? (5) Why two wires carrying currents in opposite directions repel each other? (6) Why do we need radial magnetic field in a moving coil galvanometer?
25.	(a) State Biot-Savart's law and express this law in the vector form. (b)Two identical circular coils, P and Q each of radius R, carrying currents 1A and √3A respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils.
26.	Two identical loops P and Q each of radius 5cm are lying in perpendicular planes such that they have a common centre as shown in fig. Find the magnitude and direction of the net magnetic field at the common centre of the two coils; of they carry currents equal to 3A and 4A respectively.

Practice Questions: Magnetic Effect of Current

Short Answer Questions:

1. Define SI unit of magnetic field intensity.
2. Define magnetic field intensity at a point
3. A current is sent through a vertical spring from whose lower end a weight is hanging. How will the position of the weight be effected and why?
4. A current is sent through a vertical spring from whose lower end a weight is hanging. How will the position of the weight be effected and why?
5. An electron is projected into a uniform electric field at right angle to the field. The electron suffers deflection. How will you decide whether the given field is electric or magnetic?
6. A charged particle moving with a uniform velocity v enters a region where uniform electric and magnetic fields E and B are present. It passes through the region without any change in its velocity. What can we conclude about the 1) relative directions about E and B? 2) magnitudes of E and B ?
7. An electron doesn't suffer a deflection while passing through a region. Is it necessary there is no magnetic field in that region?
8. A proton and an alpha particle of the same velocity enter a region of uniform magnetic field, acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths. How will the Kinetic Energy of the particles be affected? 2:1
9. What is the importance of the soft iron core and a radial magnetic field in a moving coil galvanometer?
10. An ammeter and a milliammeter are converted from the same galvanometer. Out of the two, which has a higher resistance?
11. (a) How much is the flux density at the center of a long solenoid?
    (b) Does the time spent by a proton inside the dee of a cyclotron depend upon the 1) radius the circular path 2) the velocity of the proton?
    (c) Does an electric charge moving parallel to a magnetic field experience a force
12. An electron and a proton, moving parallel to each other in the same direction with equal momenta, enter into a uniform magnetic field which is at right angles to their velocities. Trace their trajectories in the magnetic field
13. Two wires of equal lengths are bent in the form of two loops. One of the loops is square shaped whereas the other loop is circular. These are suspended in a uniform magnetic field and the same current is passed through them. Which loop will experience greater torque? Give reasons.
14. What do you mean by shunt? Write the function of shunt in galvanometer
15. Write the expression for force acting on a moving charge in magnetic field. Under what conditions force can be maximum and minimum.

16. A proton and an alpha particle moving with the same speed enter a region of uniform magnetic field. Proton enters normal to the field direction and alpha enters along a direction at 30^0 with the field. What would be the ratio of their angular frequencies?
17. An electron is moving with velocity V along the axis of a long straight solenoid carrying current I. What will be the force acting on the electron due to the magnetic field of the solenoid?
18. Two short magnets P and Q are placed one over another with their magnetic axes mutually perpendicular to each other. It is found that the resultant field at the point on the prolongation of the magnetic axis of P is inclined at 30^o with this axis. Compare the magnetic moments of the two magnets.

19. Write the expression for the force acting on a charged particle of charge q moving with velocity is in the presence of magnetic field B. Show that in the presence of this force.

(a) The K.E. of the particle does not change. (b) Its instantaneous power is zero.

20. An $\propto$ - particle and a proton are moving in the plane of paper in a region where there is uniform magnetic field B directed normal to the plane of paper. If two particles have equal linear momenta, what will be the ratio of the radii of their trajectories in the field?

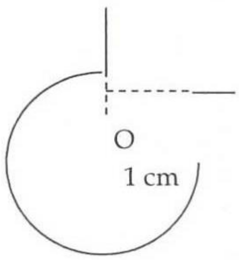
21. Discuss the motion of a charged ion beam under the combined influence of an electric and a magnetic field, acting mutually perpendicular as well as perpendicular to the direction of motion of ion beam. Hence, explain the principle of a "velocity selector". Where it is used?

Long Answer Questions :

1. What type of magnetic field is used in a moving coil galvanometer? How can you convert a galvanometer into ammeter and a voltmeter?
2. State Ampere's circuital law. Obtain an expression for the magnetic field along the axis of a long carrying current long solenoid.
3. Obtain an expression for the frequency of revolution of a charged particle moving in a direction perpendicular to a uniform magnetic field. How does the time period of the circulating ions in a cyclotron depend on i) the speed ii) the radius of the path of ions.
4. Give principle construction and working of cyclotron.
5. Give principle construction and working of a moving coil galvanometer.
6. Obtain an expression for the magnetic moment of an electron moving in a circular orbit having angular momentum L.
7. Derive an expression for the force acting on a current carrying conductor placed in a uniform magnetic field. Write the condition for which force will have (i) maximum (ii) minimum value.
8. Two circular coils X and Y having radii R and R/2 respectively are placed in horizontal plane with their centers coinciding with each other. Coil X has a current I flowing through it in the clockwise sense. What must be the current in coil Y to make the total magnetic field at the common centre of the two coils be zero?
9. State Biot- Savart law. Using this obtain an expression for the magnetic field at the centre of a circular coil of n number of turns each of radius r and carrying a current I in anticlockwise direction
10. Obtain an expression for torque on a current carrying coil placed in the magnetic field.
11. Using Biot-Savart Law obtain the magnetic field, at an axial point, distance Z from the center of a circular coil of radius **a,** carrying a current I. Hence compare the magnitudes of the magnetic field of this coil at its center and at an axial point for which Z = √3 **a**

Numerical:

1. In the following fig. find the magnetic field at the point O when a current of 5A is passed through the conductor.



2. A straight wire of mass 200g and length 1.5m carries a current of 2A. It is suspended in mid air by a uniform horizontal magnetic field B. what is the magnitude of the magnetic field?
3. A very long straight conductor is carrying a current of 1A. What is the force per unit length on it when it is placed on a horizontal table and the direction of current is i) east to west ii) south to north.
4. An element l= x i is placed at the origin and carries a large current i=10 A . What is the magnetic field on the Y- axis at a distance of 0.5 m? x=1cm.
5. If the current sensitivity of a galvanometer is increased by 50%, the resistance of the galvanometer also increases to two times its initial value. How will the voltage sensitivity of the galvanometer be affected?
6. A magnetic field of 100 G (1G= 10^{-4} T) is required which is uniform in a region of linear dimension about 10 cm and area of cross-section about 10^{-3} m^2. The maximum current-carrying capacity of a given coil of wire is 15A and the number of turns per unit length that can be wound round a core is at most 1000 turns m^{-1}. Suggest some appropriate design particulars of a solenoid for the required purpose. Assume the core is not ferromagnetic.
7. A short bar magnet has pole strength of 48 Am, which are 25cm apart. 1) what is the magnetic moment of the magnet? 2) What torque is required to hold this magnet at an angle of 30 with a uniform field of flux density 0.15 T?
8. A uniform magnetic field of 1.5T exists in a cylindrical region of radius 10 cm, its direction parallel to the axis along east to west. A wire carrying current of 7 A in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if,
   (a) the wire intersects the axis.
   (b) The wire is turned from N-S to northeast –southwest direction.
   (c) The wire is the N-S direction is lowered from the axis by a direction of 6 cm.
9. If the current sensitivity of a moving coil galvanometer is increased by 20%, its resistance also increases by 1.5 times. How will the voltage sensitivity of galvanometer be affected?
10. A galvanometer with a coil of resistance 12Ω shows a full scale deflection for a current of 2.5 mA. Calculate the value of resistance required to convert it into (a) an ammeter of range 0 to 7.5A and (b) a voltmeter of range 0 to 10V. Draw the diagrams to show how you will connect this resistance to the galvanometer in each case.
11. An electron moving with a velocity of 10^7 m/s enters along straight solenoid along the axis having a magnetic field of 1T. What will be the force acting on the electron due to magnetic field of solenoid?

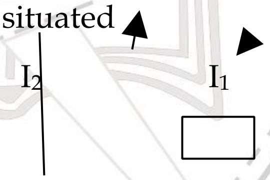
Multiple choice questions

1. A wire of certain length is bent to form a circular coil of a single turn. If the same wire is bent into a coil of smaller radius so as to have two turns, then magnetic field produced at the centre by the same value of current is
   a) One quarter of its value in first case
   b) One half of its value in first case
   c) Two times its value in first case
   d) Four times its value in first case

2. A charged particle enters a magnetic field H with its initial velocity making an angle of 45 ˚ with H. The path of the particle will be
   a) a straight line b) a circle
   c) an ellipse d) helical

3. Two parallel beams of positrons moving in the same direction will
   a) repel each other
   b) will not interact with each other
   c) attract each other
   d) be deflected normal to the plane containing the two beams

4. A rectangular loop carrying a current I_1 is situated



near a long straight wire carrying a steady current I_2. The wire is parallel to one of the sides of the loop and is in the plane of the loop as shown. Then the current loop will
   a) remain stationary
   b) move towards the wire
   c) move away from the wire
   d) rotate about an axis parallel to the wire

5. A galvanometer having a resistance of 8 ohm is shunted by a wire of resistance 2 ohm. If the total current is 1 A , the part of it passing through the shunt is
   a) 0.2 A b) 0.25 A c) 0.5 A d) 0.8 A

6. A long solenoid carrying a current produces a magnetic field B along its axis. If the current is doubled and the number of turns per cm is halved , then the new value of the magnetic field is

a) B b) 2B c) 4B d) B/2

7. A beam of electrons passes undeflected through mutually perpendicular electric and magnetic fields. If the electric field is switched off and the same magnetic field is maintained , the electrons move
   a) In an elliptical orbit
   b) In a circular orbit
   c) Along a parabolic path
   d) Along a straight line

8. A current loop of area 0.01 m^2 and carrying a current of 10 Ampere is held perpendicular to a magnetic field of intensity 0.1 Tesla. The torque in Nm acting on the loop is
   a) 0 b) 0.001 c) 0.01 d) 1.1

9. A long hollow copper pipe carries a current. Then , the magnetic field produced is
   a) Both inside and outside the pipe
   b) Neither inside nor outside the pipe
   c) Outside the pipe only
   d) Inside the pipe only

10. If a current passes though a spring , the spring will
    a) expand b) compress c) remain the same

11. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter
    a) a low resistance in parallel
    b) a high resistance in parallel
    c) a high resistance in series
    d) a low resistance in series

Answers:

1. d	2. d	3. c	4. b	5. d
6. a	7. b	8. a	9. c	
10. b	11. c			

Moving Coil Galvanometer

M C G is an instrument used for detection and measurement of small electric current.
Principle- Its working is basedon the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque.

Theory & working- Suppose a current carrying coil is suspended freely in the radial magnetic field produced by concave poles of the horse shoe magnet.
Since the field is radial, the plane of the coil always remains parallel to the field B. The magnetic forces on sides P Q & S R are equal, opposite & collinear therefore their resultant is zero. The side PS experiences a normal inward force while side Q R experiences an equal normal outward force. The 2 forces are equal and opposite but their action lines are different therefore they form a couple and exert a torque.

$\tau =$ F x perpendicular distance

$=$ NIbB x a sin90°

$=$ NIBA

The torque τ deflects the coil through an angle α . A restoring torque is set up in the coil due to elasticity.

τ (restoring) α α or τ (restoring) = k α where k is the torsion constant of the springs i.e. torque required to produced unit angular twist.

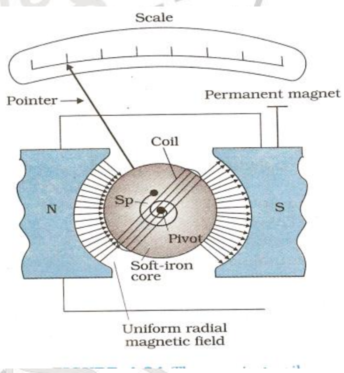
τ (restoring) = τ deflecting (at equilibrium)

$k\ \alpha = NIBA$

$\alpha = \frac{NBA}{K} I$

Or α α I (Linear Scale)

$I\ \alpha\ \alpha = \frac{K}{NBA}\alpha = G\alpha$ where $G = \frac{K}{NBA}$



G- galvanometer constant or current reduction facto

Figure of merit of a Galvanometre

It is defined as the current which produces a deflection of one scale division in the galvanometer.

$$G = \frac{I}{\propto} = \frac{K}{NBA}$$

Sensitivity of a Galvanometer- A galvanometeris said to be sensitive if it shows large scale deflection even when a small current is passed through it or a small voltage is applied across it.

Current Sensitivity—It is defined as the deflection produced in the galvanometer when a unit current flows through it.

$$I_s = \frac{\alpha}{I} = \frac{NBA}{K}$$

Voltage Sensitivity

$$V_s = \frac{\alpha}{V} = \frac{\alpha}{IR} = \frac{NBA}{KR}$$

$V_s = I_s / R$

Factors on which the sensitivity depends –

1. N (The value of N cannot be increased beyond certain limit. It will make galvanometer bulky & increase its R).
2. B (increase by using strong horse shoe magnet or placing soft iron core within the coil.)
3. A (increase within limit)
4. K (K made small by using suspension wire and springs of phosphore bronze.)

Advantages of moving coil galvanometer:

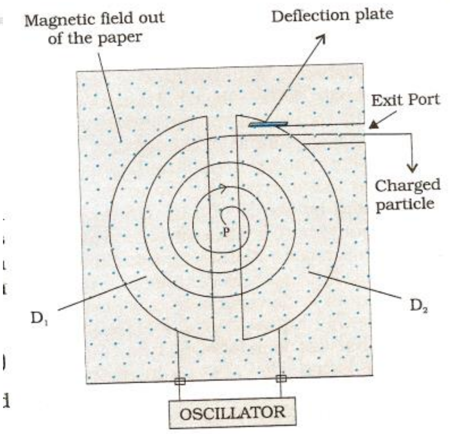
1. As the deflection of the coil is proportional to the current passed through it, so a linear scale can be used to measure the deflection.
2. A moving coil galvanometer can be made highly sensitive by increasing N, B, A and decreasing k.
3. As the coil is placed in a strong magnetic field of a powerful magnet, its deflection is not affected be external magnetic fields. This enables us to use the galvanometer in any position.
4. As the coil is wound over a metallic frame, the eddy currents produced in the frame bring the coil to rest quickly.

Disadvantages of moving coil galvanometer:

1. The main disadvantage is that it's that its sensitiveness cannot be changed at will.
2. All types of moving coil galvanometers are easily damaged by overloading. A current greater than that which the instrument is intended to measure will burn out its hair-springs or suspension.

Cyclotron

It is a device used to accelerate charged particles like proton, deuteron, x particle etc to very high energies. It was invented by Lawrence and Livingston.



Principle- A +vely charged particle can be accelerated to a sufficiently high energy by making it to pass through electric field time and again with the use of strong magnetic field.

Theory & working- Suppose a +ve ion, (proton) enters the gap between the two dees and finds dee D_1 to be –ve . It gets accelerated towards dee D_1. As it enters D_1,
It does not experience any electric field due to shielding effect of metallic dee. Due to perpendicular magnetic field, it describes the circular path.
Magnetic force on charge q= centripetal force

$q\,v\,B \sin 90° = mv^2/r$

$r = mv/qB$

At the instant the proton comes out of dee D_1, it finds dee D_2 -ve. It now gets accelerated towards D_2. It moves faster through D_2 and describes a larger semicircle.

Time taken by ion to describe a semicircle path $= t = \frac{\Pi r}{v}$

$$t = \frac{\Pi m}{Bq} = \text{constant}$$

Time period $= T = 2t = \frac{2\Pi m}{qB}$

Frequency of Revolution $= f_c = 1/T = qB/2\Pi m$

Cyclotron frequency is independent of both the velocity of the particle and the radius of the orbit.
Finally high energy accelerated proton is ejected through a window by a deflecting voltage and hits the target.

Maximum K.E. of the +ve ion- Let Vo is the max. velocity acquired by the ion & r_o be the max. radius. Then

$\frac{MVo^2}{r_o} = q\,Vo\,B$ or $Vo = \frac{qB r_o}{m}$

$$K.E._{max} = \frac{1}{2} m Vo^2 = \frac{1}{2} m \left(\frac{qBr_o}{m}\right)^2 = \frac{q^2 B^2 r_o^2}{2m}$$

Limitations of Cyclotron-

1. Acc. To Einstein' s special theory of relativity

$$\mathbf{m = \frac{m_o}{\sqrt{1-v^2/c^2}}}$$

$$\mathbf{\& \; T = \frac{2\Pi m}{Bq} = \frac{2\Pi}{Bq} \; \frac{m_o}{\sqrt{1-v^2/c^2}}}$$

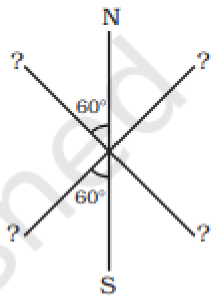
As V increases , t increases & ion will not arrive the gap between the two dees at the instant when polarity is reversed and hence will not accelerate further.

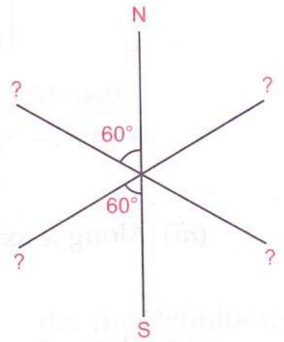
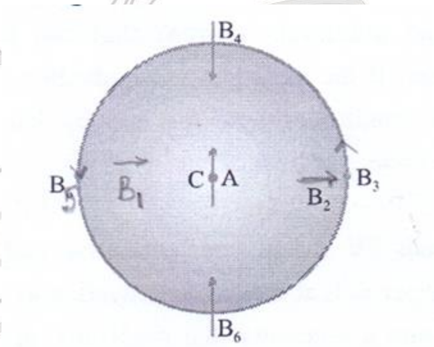
2. Eletrons cannot be accelerated by cyclotron . The mass of the electron is small a small increase in energy makes it moves with a very high speed. This throws the electrons out of step with oscillating field.
3. Neutron, being electrically neutral cannot be accelerated in a cyclotron.

Uses of Cyclotron-

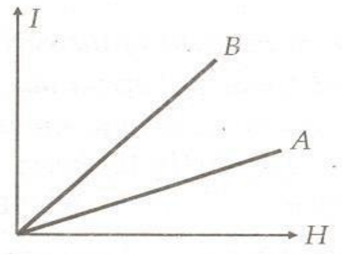
1. The high energy particles produced in a cyclotron are used to bombard nuclei to carry out nuclear reaction.
2. It is used to implant ions into solids to synthesise new materials.
3. It is used to produce radio active isotopes which are used in hospitals for diagnosis and treatment.

Chapter No.5: Magnetism and Matter
Assignment

1	In a permanent magnet at room temperature (a) magnetic moment of each molecule is zero. (b) the individual molecules have non-zero magnetic moment which are all perfectly aligned. (c) domains are partially aligned. (d) domains are all perfectly aligned.
2	A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16K, the magnetisation will be (a) 32 /3 Am^{-1} (b) 2 /3 Am^{-1} (c) 6 Am^{-1} (d) 2.4 Am^{-1}
3	The primary origin(s) of magnetism lies in (a) atomic currents. (b) Pauli exclusion principle. (c) polar nature of molecules. (d) intrinsic spin of electron.
4	Three identical bar magnets are rivetted together at centre in the same plane as shown in Fig. 5.1. This system is placed at rest in a slowly varying magnetic field. It is found that the system of magnets does not show any motion. The north-south poles of one magnet is shown in the Fig. 5.1. Determine the poles of the remaining two. 
5.	A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. (i) In which direction will it move? (ii) What will be the direction of its magnetic moment?
6.	A bar magnet of magnetic moment *m* and moment of inertia *I* (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to length. Let T be the period of oscillations of the original magnet about an axis through the mid-point, perpendicular to length, in a magnetic field B. What would be the similar period 'T' for each piece?
7.	Three identical bar magnets are revetted together at centre in the same plane as shown in fig. This system is placed at rest in a slowly varying magnetic field. It is found that

<table>
<tr><td></td><td>the system of magnets does not show any motion. The north-south poles of one magnet is shown in the fig. Determine the poles of the remaining two.

</td></tr>
<tr><td>8.</td><td>A small magnetized needle A placed at a point O. The arrow shows the direction of its magnetic moment. The other arrow shows different positions(and orientation of the magnetic moment) of another identical magnetized needle B.
(a) In which configuration is the system not in equilibrium?
(b) In which configuration is the system in (i) stable and (ii) unable equilibrium?
(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

</td></tr>
<tr><td>9.</td><td>a)How does the (i) pole strength and (ii) magnetic moment of each part of a bar magnet change if it is cut into two pieces (i) transverse to its length (ii) along its length?
b) What happen if an iron bar magnet is melted? Does it retain its magnetism?
Define the terms retentivity and coercivity.</td></tr>
<tr><td>10.</td><td>True value of dip at a place is 45^0. The plane of the dip circle is turned through 60^0 from the magnetic meridian. Find the apparent value of dip.</td></tr>
<tr><td>11</td><td>A magnetic compass needle of magnetic moment $60Am^2$ is placed at a place. The needle points towards the geographical north. Using the data given below, find the value of declination at that place. Horizontal component of earth's magnetic field = $40x10^{-6}$ Wb m^{-2} and torque experienced by the needle = $12x10^{-3}$ Nm.</td></tr>
</table>

12	A compass needle pivoted about the horizontal axis and free to move in the magnetic meridian is observed to point along the (A) Vertical direction at a place A (B) Horizontal direction at a place B. What are the values of (i) angle of dip and (ii) horizontal component of earth's field at this place? Where will this place be on earth?
13.	Identify the magnetic type of the material. A specimen of this material is kept in a non-uniform magnetic field. Draw the modified field pattern. (a) The susceptibility of a magnetic material is -0.085 (b) The susceptibility of a magnetic material is 0.9853. (c)The relative magnetic permeability of a magnetic material is 800.
14.	How will a dia-, para- and a ferromagnetic material behave when kept in a non-uniform external field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide its suitability for making (i) a permanent magnet (ii) an electromagnet. Which of these two characteristics should have high or low values for each of these two types of magnets?
15.	A magnetized needle suspended freely in a uniform magnetic field experiences a torque but no net force. An iron nail near a bar magnet, however experiences a force of attraction in addition to torque. Why?
16.	A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0A in the same direction east to west. The earth's magnetic field at the place is 0.39G, and the angle of dip is 35° The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?
17.	Specimens of a i) Copper , ii) Aluminium and iii)Mercury cooled to 4.2 K, are kept in a magnetic field . Draw the modified field pattern.
18.	a) Differentiate clearly between the geographic and the magnetic meridian. Name and define the magnetic element of earth's magnetic field associated with the difference between these two planes. Where does this magnetic element have a higher value near equator or near the poles? b) A magnetic needle, perfectly balanced about a horizontal axis, is free to swing in a plane of the magnetic meridian. In this equilibrium position, the needle makes an angle α with the vertical direction at that place. What is the angle of dip at the place? What would be the relation between horizontal component B_H and the total magnetic field B_E of the earth?
19.	The following figure shows the variation of intensity of magnetization versus the applied magnetic field intensity, H for two magnetic material A and B.

	 (a) Identify the materials A and B. (b) For the material A, plot the variation of intensity of magnetization verses temperature . Justify your answer?
20.	An electron moves around the nucleus in a hydrogen atom of radius 0.51 Å, with a velocity of 2×10^6 m/s. Calculate the following: (i) the equivalent current due to orbital motion of electron (ii) the magnetic field produced at the centre of the nucleus (iii) the magnetic moment associated with the electron.
21.	A solenoid of 500 turns / m is carrying a current of 3A. Its core is made of iron which has a relative permeability of 5000. Determine the magnitudes of the magnetic intensity, magnetization and the magnetic field inside the core.
22.	Two identical magnetic dipoles of magnetic moments 1.0 Am^2 each are placed at a separation of 2m with their axes perpendicular to each other. What is the resultant magnetic field at a point mid-way between the dipoles?
23.	Name and define the magnetic elements of Earth's magnetic field at a place. Derive an expression for the angle of dip in terms of the horizontal component and the resultant magnetic field of the earth at a given place.
24.	(a) A small compass needle to magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. The moment of inertia of the needle about the axis is I. The needle is slightly disturbed from its stable position and then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period. (b) A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the value of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.
25.	Explain the origin of paramagnetism. State Curie's law. How does it get modified for ferromagnetic substances?

Practice Questions: Magnetism and Matter

Short Answer Questions:

1. The earth's core is known to iron. Yet, geologists do not regard this as a source of earth's magnetism, why?
2. A steel wire of length L has a magnetic moment M. It is then bent into a semicircular arc. Find the new magnetic moment.
3. Two identical thin bar magnets, each of length L and pole strength m are placed at right angles to each other, with the N-pole of one touching the South Pole of the other. Find the magnetic moment of the system.
4. What are the differences between electric and magnetic lines of forces?
5. State Gauss's law in magnetism.
6. A bar magnet falls through a metal ring. Will its acceleration be equal to g? Give reason.
7. Draw the curve showing the variation of susceptibility of a) paramagnetic b) diamagnetic material with temperature.
8. What happens if a bar magnet is cut 1) transverse to its length 2) along its length.
9. A magnetic dipole is situated in a magnetic field. What is its potential energy? If its rotated by 180˚, what amount of work will be done?
10. Why are elements with even atomic number more likely to be diamagnetic?
11. Two identical looking iron bars A and B are given, one of which is definitely known to be magnetized (we do not know which one). How would one ascertain whether or not both are magnetized? If only one is magnetized, how does one ascertain which one? (Use nothing else but the two bars A and B).
12. Does a paramagnetic sample display greater magnetization, for the same magnetic field, when cooled? Give reason.
13. What should be the orientation of a magnetic dipole in a magnetic field so that its P.E. is maximum?
14. What is hysteresis? What is the significance of the area under the hysteresis loop?
15. Define the terms i) magnetic intensity ii) magnetic induction iii) intensity of magnetization iv) magnetic permeability v) magnetic susceptibility.
16. Derive a relation between relative permeability and susceptibility.

17. Define the elements of the earth's magnetic field. Show them in a labeled diagram .
18. Horizontal component of Earth's magnetic field at a place is $\sqrt{3}$ times the vertical component. What is the value of angle of dip at this place?

Long Answer Questions:

1. Explain the origin of paramagnetism. State Curie's law. How does it get modified for ferromagnetic substances?
2. Define intensity of magnetization of a magnetic material. What is it's unit ? Two substances A & B have their relative permeabilities slightly greater and less than unity respectively. What do you conclude about A & B.
3. How will a diamagnetic and a paramagnetic material behave when kept in a non uniform external magnetic field? Name two main characteristics of a ferromagnetic material which help us to decide its suitability for making i) permanent magnet ii) an electromagnet. Which of these two characteristics should have high or low values for each of these two types of magnets?
4. State the law which gives the variation of intensity of magnetisation of a paramagnetic material with temperature. Does the intensity of magnetisation of a diamagnetic substance depend upon temperature?
5. How should a bar magnet be placed so that the net magnetic field is zero at some points on its axial line? On what factor does the distance of this point from the bar magnet depend?
6. A bar magnet is placed in a uniform magnetic field with its magnetic moment making an angle θ with the field.

I) Write an expression for the torque acting on the magnet and hence define its magnetic moment.

II) Write an expression for the potential energy of the magnet in this orientation. Hence obtain the orientation for which this energy becomes maximum.

7. Give some important properties of diamagnetic, paramagnetic and ferromagnetic substances.

Numericals:

1. A bar magnet has a coercivity 4×10^3 A/m. It is desired to demagnetize it by inserting it inside a solenoid 12 cm long and having 60 turns. What current should be sent through the solenoid?
   (8 A)
2. A compass needle whose magnetic moment is 60 Am^2 pointing north (geographical) at a certain place where the horizontal component of earth's magnetic field is 40 Wb/m^2 experiences a torque of 1.2×10^{-3} Nm. What is the declination of the place?
   (30˚)
3. The earth's magnetic field at the equator is 0.4G . Estimate the earth's dipole moment.
   (1.04×10^{23} Am^2)
4. A magnetic needle lying parallel to a magnetic field requires W unit of work to turn it through 60^0. find the torque needed to maintain the needle in this position.
5. A short bar magnet in horizontal plane has its axis along the magnetic north – south direction. Null points are found on the axis of the magnet. The earth's magnetic field at the place is 0.4G and angle of dip is zero. Find the total magnetic field on the normal bisector of magnet at the same distance as the null points from the magnet.
6. A magnetic needle completes 20 oscillations in 10 sec when placed in a uniform magnetic field. Moment of inertia of this needle is $10^{-5}kgm^2$ and magnetic moment is 0.1 A-m^2. Find the magnitude of magnetic field?
7. A solenoid of 5000 turns/m is carrying a current of 3A. It's core is made of made of iron which has a relative permeability of 5000. Determine the magnitude of magnetic intensity , intensity of magnetisation and magnetic field inside the coil.
8. Two thin bar magnets each of length l and pole strength m are placed perpendicular to each other. The N pole of one touches the S pole of the other. Find the magnetic moment of the system.
9. A magnetic compass needle of magnetic moment 60Am^2 is placed at a place. The needle points towards the geographical north. Using the data given below, find the

value of declination at that place. Horizontal component of earth's magnetic field=40×10^{-6} Wb m^{-2} and torque experienced by the needle = 12×10^{-3} Nm.

10. A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0A in the same direction east to west. The earth's magnetic field at the place is 0.39G, and the angle of dip is 35° The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?

Multiple choice questions

1. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60˚. The torque needed to maintain the needle in this position will be

   $\sqrt{3}$ W b) W c) $\sqrt{3}/2$ W d) 2 W

2. Materials suitable to make electromagnets should have
   a) High retentivity and high coercivity
   b) low retentivity and low coercivity
   c) High retentivity and low coercivity

   Low retentivity and high coercivity

3. A charged particle of charge q is moving in a circle of radius r with uniform speed v .The associated magnetic moment is given by

   qvr/2 b) qvr c)$qvr^2/2$ d) qvr^2

4. The work done in turning a magnet of magnetic moment M by an angle of 90˚ from the meridian is n times the corresponding work done to turn it through an angle of 60˚. The value of n is given by

   2 b) 1 c) 0.5 d) 0.25

5. For protecting sensitive equipment from an external magnetic field , it should be
   a) Placed inside an iron can
   b) Wrapped with insulated wire, through which current is passed
   c) Surrounded with fine copper gauze

   Placed inside an aluminium can

6. According to Curie's law , the magnetic susceptibility of a substance at the absolute temperature T is proportional to

   T b) T^2 c) 1/T d) $1/T^2$

7. Susceptibility is positive for

   a) Paramagnetic substances b) ferromagnetic substances

   c) non-magnetic substances d) diamagnetic substances

8. The best material for making the core of a transformer is

   a) Stainless steel b) mild steel

   c) hard steel d) soft iron

9. At a certain place , the angle of dip is 30˚ and the horizontal component of earth's magnetic field is 0.5 oersted. The eart's total magnetic field is

   √3 b) 1 c) 1/√3 d) ½

10. The area of the B-H hysteresis loop is an indication of

    a) Permeability of the medium

    b) Susceptibility of the substance

    c) Retentivity of the material

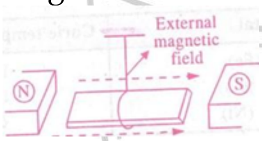
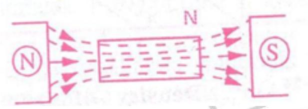
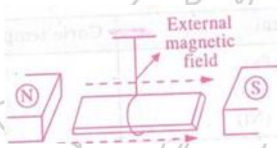
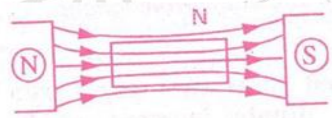
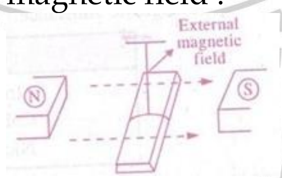
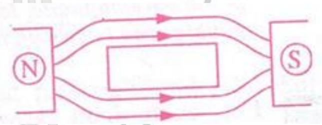
    Energy dissipated per unit volume of the substance per cycle.

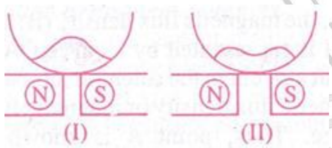
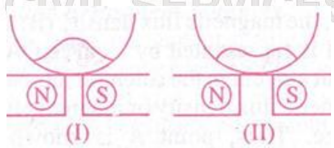
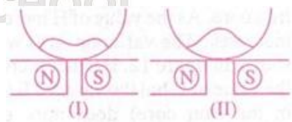
Answers:

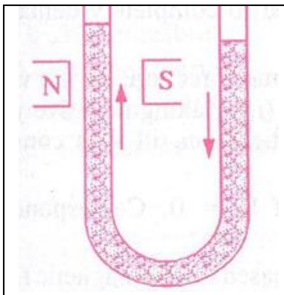
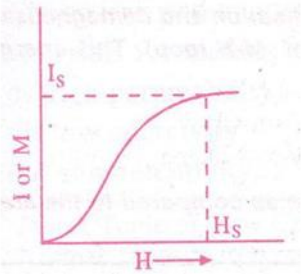
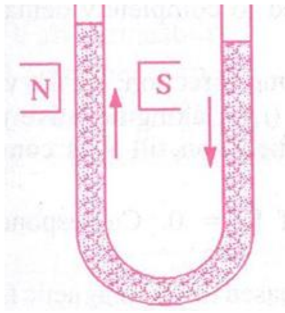
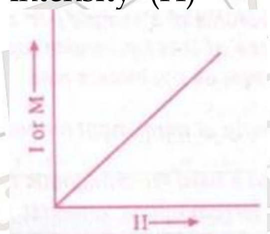
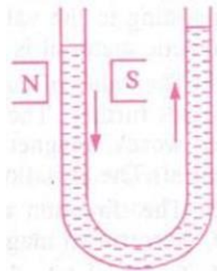
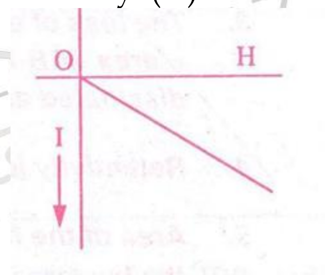
1. a	2. c	3. a	4. a	5. a
6. c	7. b	8. d	9. c	10. d

Study Materials

Classification of Magnetic Materials

Ferromagnetic materials	Paramagnetic Materials	Diamagnetic Materials
(a) They are strongly attracted by a magnet. (b) A freely suspended ferromagnetic rod quickly sets itself along the direction of external magnetic.  © When they are placed in a magnetic field lines prefer to pass through them.  This behaviour indicates that (i) Field within the sample Is much more than the magnetic intensity i.e. permeability is much more than unity. (B>>H or B/H >> 1or μ>>1). (ii) Flux density (B) inside a ferromagnetic material is much larger than in air. (iii) The sample gets strongly magnetised in the direction of magnetising field.	(a) They are weakly attracted by a magnet. (b) A freely suspended paramagnetic rod slowly sets itself along the direction of external magnetic field  © When they are placed in a magnetic field, most of the magnetic field lines prefer to pass through them.  This behaviour indicates that (i) Field within the sample Is more than the magnetic intensity i.e. permeability is much more than unity. (B>H or B/H > 1or μ>1). (ii) Flux density (B) inside a paramagnetic material is larger than in air. (iii) The sample gets weakly magnetised in the	(a) They are weakly repelled by a magnet. (b) A freely suspended diamagnetic rod slowly sets itself at right angle to the direction of external magnetic field .  © When they are placed in a magnetic field, the magnetic field lines do not prefer to pass through them  This behaviour indicates that (i) Field within the sample Is decreased to a very small value i.e. permeability is always less than unity. (B<H or B/H < 1or μ<1). (ii) Flux density (B) inside a diamagnetic material is less than in air. (iii) The sample gets weakly magnetised in the direction opposite to the

(iv) Magnetisation (M) has large positive value. (v) Susceptibility has a large positive value. $X_m = M/H$; M is large +ve, so $X_m >>1$ (d) They obey Curie's law. At a certain temperature i.e. Curie point or temperature, ferromagnetic properties disappear and material starts behaving as paramagnetic. (e) If a finely powdered ferromagnetic material in a watch glass is placed on closely spaced magnetic poles, the effect is observed. It shows that such materials move from weaker to stronger magnetic field.  (f) When a sample of ferromagnetic material in a very finely powdered form is placed in U- tube and magnetic field is applied across one limb, the level rises in that limb.	direction of magnetising field. (iv) Magnetisation (M) has small positive value. (v) Susceptibility has a small positive value $X_m = M/H$; M is small +ve, so $X_m >1$ (d) They obey Curie's law. They are badly affected with the rise in temperature. Due to rise in temperature, they lose magnetic property. (e) If a paramagnetic liquid in a watch glass is placed on closely spaced magnetic poles, and then on widely spaced magnetic poles, the effect is observed. In the first case, there is a rise in the middle but in the second case there is a depression in the middle. It shows that such materials move from weaker to stronger magnetic field.  (f) When a sample of paramagnetic liquid is put in U- tube and magnetic field is applied to across	direction of magnetising field. (iv) Magnetisation (M) has small negative value. (v) Susceptibility has a small negative value $X_m = M/H$; M is small -ve, so $X_m <0$ (d) They do not obey Curie's law. Normally their magnetic properties do not change with temperature. (e) If a diamagnetic liquid in a watch glass is placed on closely spaced magnetic poles and then widely spaced magnetic poles, the effct is obsevered as shown in figure. In the first case, there is a depression in the middle but in the second case there is a rise in the middle. It shows that such materials move from stronger to weaker magnetic field.  (f) When a sample of diamagnetic liquid is put in U- tube and magnetic field is applied across one limb, the level falls in that limb

 g) Intensity of magnetisation (I) or magnetisation (M) of ferromagnetism substance is large, positive and varies non linearly with the applied magnetic field intensity (H)  	one limb, the level rises in that limb.  g) Intensity of magnetisation (I) or magnetisation (M) of paramagnetic substance is small, positive and varies directly proportional to the applied magnetic field applied magnetic field intensity (H)  	 g) Intensity of magnetisation (I) or magnetisation (M) of a diamagnetic substance is small, negative and directly proportional to the applied magnetic field intensity (H) 

Magnetisation Curve (Hysteresis * loop)

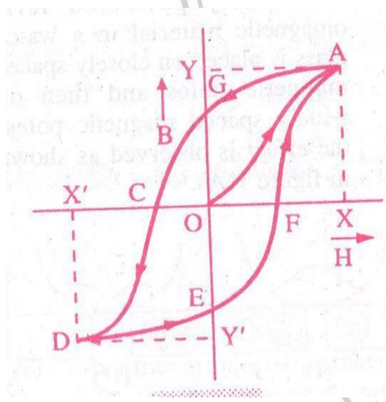
Consider a solenoid having ferromagnetic (Iron) core inside it. Current in it is to be increased and decreased in the following steps:

1. To start with, the iron core is placed in a solenoid having no current. Now, current flowing in the solenoid is increased in steps, so that the magnetic field inside the solenoid increase gradually. This magnetic field is known as magnetising field (H) as it magnetises the iron core. As the value of H increases, the magnetic flux density (B) also increases. The variation of B with H is represented by a curve OA as shown in figure. Further increase in current in the solenoid increases the value of H but the value of B (magnetic flux density or magnetic field in the iron core) does not change. Thus, point A is known as Saturation pointcorresponding to which B is maximum .
2. Now, reduce the value of current in the solenoid till the value of H becomes zero. The iron core placed inside the solenoid begins to demagnetise i.e., the value of B decreases along the path AG. When H =0,B 0 but B = OG . It shows that the magnetic

material (say iron core) retains magnetism even if the magnetising field (H) is reduced to zero.

The magnetism retained by the magnetic material even when the magnetising field is reduce to zero is called residual magnetism of the material. The property of magnetic material to retain magnetism even in the absence of the magnetising field is known as **retentivity** or **remanence.**

3. Now, reverse the direction of flow of the current in the solenoid, so that the magnetising field (H) acts in the opposite direction (say along negative x-axis). The magnetic field B becomes zero corresponding to the value of H = OC. The magnetising field (H) needed to completely demagnetise the magnetic material is known as **coercivity.**
4. The value of current in the solenoid is further increased in the same direction, so the value of H increases further. The value of B also increases in the reverse direction (i.e., along negative y – axis). In other words, magnetic material begins to magnetise in the opposite direction till it is completely magnetised. The variation of B with H is represented by the curve CD.



5. The direction of the current is again reversed till the value of H = O. Corresponding to H = O, the magnetisation of the material = OE.

6. To completely demagnetise the magnetic material, the current is increased till the magnetic field (B) becomes zero. The material is demagnetises along EF. On the further increase in the current in the solenoid, value of H increases. The variation of B with H is represented by FA.
The curve AGCDEFA is known a Hyateresis loop which is the result of a cycle of magnetisation and demagnetisation of the magnetic material.

Permanent Magnets
The magnets which retain their ferromagnetic properties for a long time at room temperature are called permanent magnets.

Steel is a common material used to make permanent magnets. It has high residual magnetism (retentivity). It has very high coercivity i.e. hysteresis loop is wide. Although area of hysteresis loop for steel is large yet it is of no importance because a permanent magnet is supposed to retain the magnetism and and is not required to undergo cycle of magnetisation and demagnetisation. Retentivity of steel is slightly smaller than that of soft iron but coercivity of soft iron but coercitivity of soft iron is very less which makes soft iron unfit for becoming permanent magnet. Many alloys are also used to make permanent magnets :
(i) Cobalt steel. It contains cobalt, tungsten, carbon and iron.
(ii) Alnico* It contains aluminium, nickel, cobalt, copper and iron. It is brittle.
(iii) Ticonal : It contains tin , cobalt, nickel and aluminium.
Permanent magnets are easily made by rubbing a ferromagnetic material say iron bar with a magnet in a particular fashion. Permanent magnets can also be made by placing hard

ferromagnetic bar in a current carrying solenoid. The magnetic field of solenoid, magnetises the ferromagnetic material.

Material for permanent magnet should have:

(i) high permeability

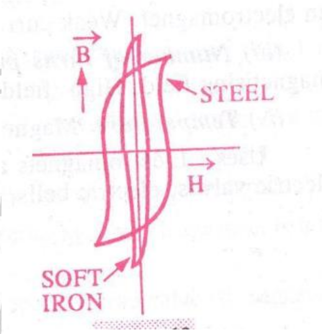
(ii) high coercivity

(iii) high retentivity

Electromagnets

A ferromagnetic material placed inside a current carrying solenoid acts as an electromagnet. Soft iron rod placed inside a current carrying solenoid behaves as an electromagnet.

Soft iron is a ferromagnetic substance and has **high permeability** and **low retentivity.** These properties of soft iron makes it suitable for making an electromagnet.



When the current in a solenoid is switched on, the soft iron rod placed inside it is magnetised at once. On the other hand, it ceases to be a magnet, as soon as current in the solenoid is switched off.

Cores of generators, motors and transformers are magnetised and demagnetised number of times, when a.c. flows through them. Hence, the materials having narrow hysteresis loops should be used to prepare these cores.

Silicon iron and mumetal (an alloy of Ni, Fe, Cu and Cr) are used to form cores of transformer. Materials for making electromagnets should have:

(i) high permeability

(ii) low coercivity

(iii) low retentivity

Factors deciding the strength of an electromagnet:

(i) Nature of material : Soft iron is best suited for an electro-magnet. Material of an electromagnet should have thin and long hysteresis loop. They should have low retentivity. The material should magnetise quickly. They should have high permeability. Silicon iron and mumetal are also used to make electromagnet.

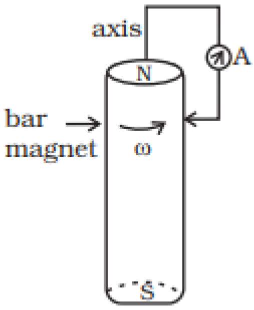
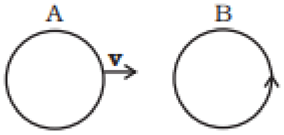
(ii) Electric current : Strength of current in the solenoid gives the required magnetising force to an electromagnet. Weak currents may not magnetise the sample properly.

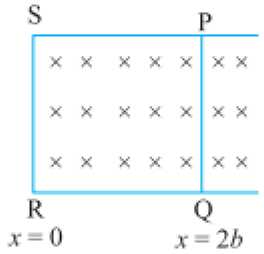
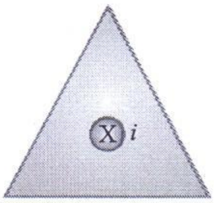
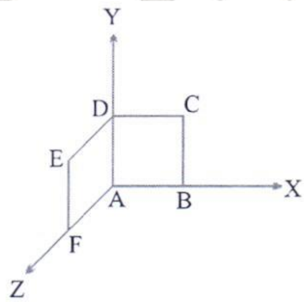
(iii) Number of turns per unit length of solenoid : Higher the number of turns, higher is the magnetising field. High field is required for strong electromagnets.

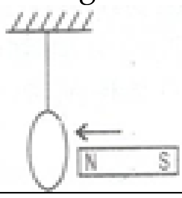
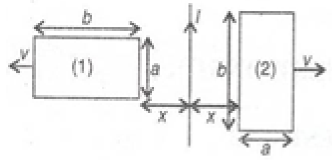
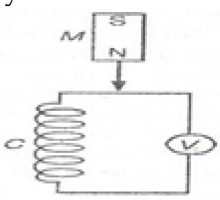
(iv)Temperature. Magnetism is lost at high temperatures. This fact was properly studied by Curie.

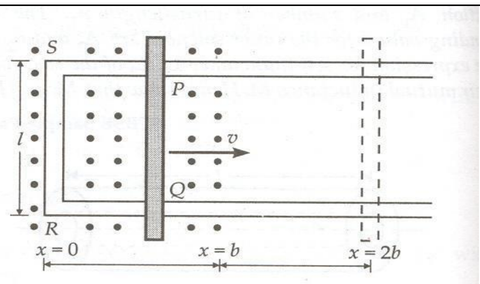
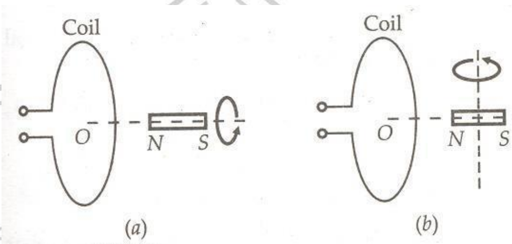
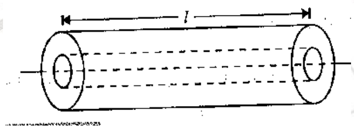
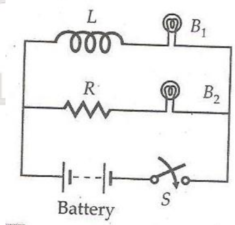
Uses : Electromagnets are usually found in lifting magnets, relays, controllers, circuit breakers, electric valves, electric bells, loud speakers, telephone diaphragms, motor brakes etc.

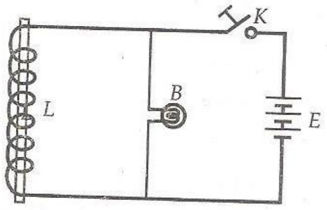
Chapter 6: Electromagnetic Induction
Assignment

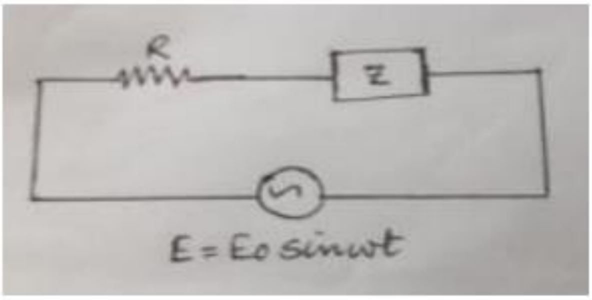
1	A cylindrical bar magnet is rotated about its axis . A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then a) a direct current flows in the ammeter A. (b) no current flows through the ammeter A. (c) an alternating sinusoidal current flows through the ammeter A with a time period $T=2\pi/\omega$. (d) a time varying non-sinusoidal current flows through the ammeter A 
2	There are two coils A and B as shown in Fig . A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that (a) there is a constant current in the clockwise direction in A. (b) there is a varying current in A. (c) there is no current in A. (d) there is a constant current in the counterclockwise direction in A. 
3	A metal plate is getting heated. It can be because (a) a direct current is passing through the plate. (b) it is placed in a time varying magnetic field. (c) it is placed in a space varying magnetic field, but does not vary with time. (d) a current (either direct or alternating) is passing through the plate.
4	In figure, the arm PQ is moved from x = 0 to x = 2b with constant speed V. Consider the magnet field as shown in figure. Write (i) direction of induced current in rod (ii) polarity induced across rod.

	
5	A conducting rod held horizontally along East-West direction is dropped from rest at certain height near Earth's surface. Why should there be an induced e.m.f. across the ends of the rod? Draw a graph showing the variation of e.m.f. as a function of time from the instant it begins to fall.
6.	A current carrying wire (straight) passes inside a triangular coil as shown in figure. The current in the wire is perpendicular to paper inwards. Find the direction of induced current in the loop if current in the wire is increasing with time. me. 
7.	A loop made of straight edges has six corners at A(0,0,0), B(1,0,0), C(1,1,0),D(0.1,0), E(0,1,1) and F(0,0,1) a magnetic field B = B_0(i+k)T is present in the region. Find the flux passing through the loop ABCDEFA? 
8.	A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, will the current increase or decrease? Explain.
9.	A long solenoid 'S' has 'n' turns per meter, with diameter 'a.' At the center of the coil we place a smaller coil of 'N' turns and diameter 'b' (where b<a). If the current in the solenoid increases linearly, with time, what is the induced emf appearing in the smaller coil. Plot graph showing nature of variation in emf, if current varies as a function mt^2 +C
10.	Consider a metallic pipe with an inner radius of 1 cm. If a cylindrical bar magnet of radius 0.8cm is dropped through the pipe, it takes more time to come down than it takes

	for a similar unmagnetised cylindrical iron bar dropped through the metallic pipe. Explain.
11	The induced emf is also called back emf. Why? Give the direction in which the induced current flows in the wire loop, when the magnet moves towards it as shown in the fig. 
12	The fig shows two identical rectangular loops (1) and (2) placed on a table along with a straight line current carrying conductor between them. (i) What will be the directions of the induced currents in the loops when they are pulled away from the conductor with same velocity v? (ii) Will the e.m.f. induced in the two loops be equal? Justify your answer. 
13.	A horizontal straight wire l0 m long is extending along east and west and is falling with a speed of 5.0 m/s at right angles to the horizontal component of the earth's magnetic field of strength 0.30×10^{-4} wb/m ^{2}. (a) What is the instantaneous value of the emf induced in the wire? (b) What is the direction of the emf? (c) Which end of the wire is at the higher potential?
14	Fig shows a bar magnet M falling under gravity through an air cored coil C. Plot the graph showing variation of induced e.m.f. (ε) with time (t). What does the area enclosed by the ε-t curve depict? Explain the shape of the graph. 
15.	Refer to Fig. The arm PQ of the rectangular conductor is moved from x = o to the right side. The uniform magnetic field is perpendicular to the plane and extends from x = 0 to x = b and is zero for x > b. Only the arm P Q possesses substantial resistance r. Consider the situation when the arm P Q is pulled outwards from x = o to x = 2 b and is then moved back to x = o with constant speed v. Obtain expressions for the flux, the induced emf, the force necessary to pull the arm and the power dissipated as Joule heat. Sketch the variation of these quantities with time.

	
16.	A cylindrical bar magnet is kept along the axis of a circular coil and near it as shown in Fig. Will there be any induced emf at the terminals of the coil, when the magnet is rotated (a) about its own axis, and (b) about an axis perpendicular to the length of the magnet? 
17.	A closed coil consists of 500 turns wound on a rectangular frame of area 4×10^4 Sq.m and has a resistance of 50 ohm. It is kept with its plane perpendicular to a uniform magnetic field of 0.2T. Calculate the amount of charge flowing through the coil if it is turned over (rotated through 180 °). Will this answer depend upon the speed with which the coil is rotated?
18	Fig. Shows two long coaxial solenoids, each of length 'l'. The outer solenoids has an area of cross-section A_1 and the number of turns/length n_1. The corresponding values for the inner solenoid are A_2 and n_2. Write the expression for self-inductance L_1, L_2 of the two coils and their mutual inductance M. Hence show that $M < \sqrt{L_1 L_2}$. 
19.	Fig. shows an inductor L and a resistor R connected in parallel to a battery through a switch. The resistance of R is the same as that of the coil that makes L. Two identical bulbs are put in each arm of the circuit.  i) Which of the bulbs lights up bright when S is closed? ii) Will the two bulbs be equally bright after some time? Give reason for your answer.
20.	In a step up transformer, transformation ratio is 100. The primary voltage is 200 V and input is 1000 watt. The number of turns in primary is 100. Calculate (1) Number of turns in the secondary

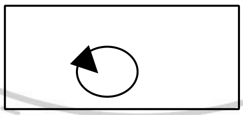
	(2) Current in the primary (3) The voltage across the secondary (4) Current in the secondary (5) Write the formula for transformation ratio?
21.	Two circular coils, one of radius r and the other of radius R are placed coaxially with their centres coinciding. For R >> r, obtain an expression for the mutual inductance of the arrangement.
22.	Why does metallic piece becomes very hot when it is surrounded by a coil carrying high frequency (H.F) alternating current? A capacitor is used in the primary circuit of an induction coil. Explain Why is choke coil needed in use of fluorescent tubes with ac mains? Why can we not use an ordinary resistor instead of choke coil?
23.	How does the self inductance of an air core coil change, when (i) the number of turns in the coil is decreased (ii) an iron rod is introduced in the coil. A copper coil L wounded on a soft iron core and a lamp B are connected to a battery 'E' through a tapping key K. When the key is closed, the lamp glows dimly. But when the key is suddenly opened, the lamp flashes for an instant to much greater brightness. Explain. 
24.	a) Why is electric power generally transmilted over long distances at high a.c. voltage? (b) An a.c. generator consist of a coil of 50 turns, area 2.5m 2 rotating at an angular speed of 60 rad/s in uniform magnetic field of B = 0.3 T between two fixed pole pieces. Given R = 500 Ω . (i) Find the maximum current drawn from the generator? (ii) What will be the orientation of the coil wrt. B to have max and zero magnetic flux? (iii) Would the generator work if the coils were stationary and instead the pole pieces rotated together with the same speed?
25.	(a)An alternating voltage E = Eo sinωt is applied to a circuit containing a resistor R connected in series with a black box. The current in the circuit is found to be I = Io sin (ωt + π/4).

	 State whether the element in the black box is a capacitor or inductor. (ii) Draw the corresponding phasor diagram and find the impedance in terms of R.

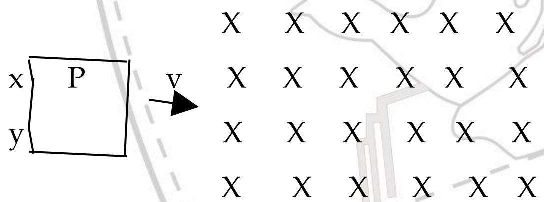
Practice Questions: Electromagnetic Induction

Short Answer Questions:

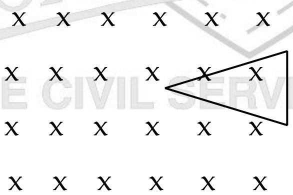
1. Name the phenomenon associated with the production of back e.m.f. in a coil due to change of electric current through the coil itself. Name and define the S.I. unit used for measuring this characteristic of the coil.
2. A bar magnet falls through a metal ring. Will its acceleration be equal to g? Give reason.
3. A sheet of metal is placed in a magnetic field which changes from zero to maximum value, the induced currents are set up in the direction shown in figure. What is the direction of magnetic field?



4. When the current flowing in an inductive circuit is switched off, will the induced current be in the direction of main current or in the opposite direction?
5. A B

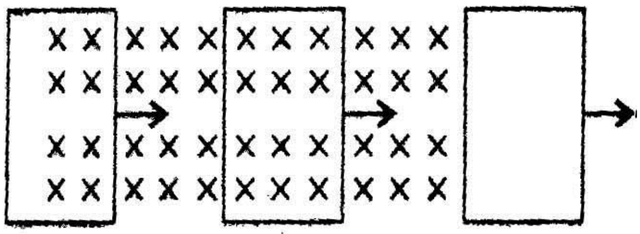


6. A rectangular coil P is moved from a point A to another point B with uniform velocity v, through a region of uniform magnetic field acting inwards as shown in the fig. Show graphically
   (a) The variation of magnetic flux associated with the coil with time.
   (b) Variation of induced emf across points x and y of the coil with time.
7. The fig. shows a planar loop to be moving out of a magnetic field. Mark the direction of induced current in the loop.

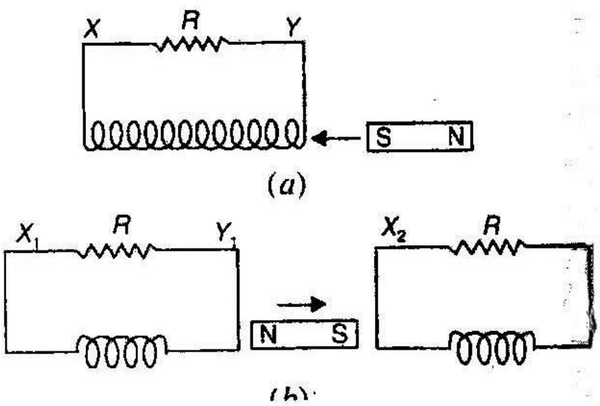


8. State Faraday's laws of electromagnetic induction. Name a practical device in which these laws are used.
9. How does induced charge depend upon the change in magnetic flux?
10. State Fleming's right hand rule.
11. A spark is produced in switch when the light is put off. Why?
12. Does the induced emf depend upon resistance?

13. A uniform magnetic field exists normal to the plane of the paper over a small region of the space. A rectangular loop of the wire is slowly moved with a uniform velocity across the field as shown



14. Draw the graph showing the variation of (i) magnetic flux linked with the loop and (ii) the induced e.m.f. in the loop with time.
15. Derive an expression for the induced emf set up in a coil when it is rotated in a uniform magnetic field with a uniform angular velocity. Explain how does the emf vary when the coil turns through an angle of 2Π ? What is the instantaneous value of induced emf when the plane of the coil makes an angle of 60^o with the magnetic lines.
16. What are the eddy currents? How are these minimized? Mention two applications of eddy currents.
17. Two identical lamps 1 and 2 are connected to an AC source of same end. The frequency of the ac supply is increased. What changes (if any) will take place in the Intensity of the light of the two lamps. Justify your answer.
18. Predict the direction of induced current in the resistance R in fig. (a) and fig (b) given below. Give reasons for your answer.



19. A rectangular coil of N turns, area A is held in a uniform magnetic field B. If the coil is rotated t a steady angular speed ω , deduce an expression for the induced emf in the coil at any instant of time.

20 .A coil of number turns N, area A is rotated at a constant angular speed ω in a uniform magnetic field B, and connected to a resistor R. Deduce expressions for:

(i) Maximum emf induced in the coil

(ii) Power dissipation in the coil.

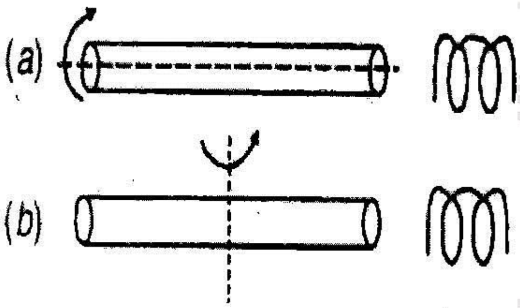
21. Two identical loops, one of copper and another of aluminum are rotated with the same speed in the same magnetic field. In which case, the induced

(a) emf. (b) current will be more and why?

22. Show that in the free oscillations of an LC circuit, the sum of the energies stored in the capacitor and the inductor is constant in time

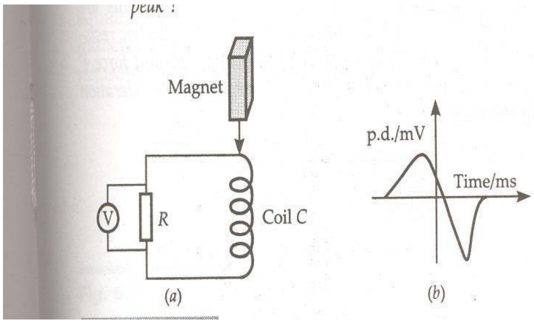
Long Answer Questions:

1. State Lenz's law. Derive an expression of magnetic field energy associated with an inductor of inductance L.
2. Distinguish between resistance, reactance and impedance.
3. What are eddy currents? Explain their uses. Also state their disadvantages.
4. What is meant by self-induction? Define self-inductance. Derive an expression for the self-inductance of a long solenoid.
5. Two circular coils one of small radius r_1 and the other of very large radius r_2 are placed co axially with centres coinciding. Obtain the mutual inductance of the arrangement.
6. What is motional emf? Deduce an expression for the induced emf set uo across the ends of a conductor moving in a magnetic field by using the concept of Lorentz force.
7. A cylindrical bar magnet is kept along with axis of a circular coil and near it as shown in the diagram. Will there be any induced e.m.f. at the terminals of the coil, when the magnet is rotated (a) about its own axis and (b) about an axis perpendicular to the length of the magnet?



8. A horizontal metal frame PQST moves with uniform velocity of 2m/s into uniform field of 10^{-2} T acting vertically downwards. PT = 10cm, PQ= 20cm and the resistance of the frame is 5 ohm. The sides QS and PT enter the field in a direction normal to the field boundary. What current flows lit the metal frame when QS just enters the field the whole frame is moving through the field QS just moves out of the field on the other side?

9. A bar magnet M is dropped so that it falls vertically through the coil. C. The graph obtained for voltage produced across the coil vs. time is shown in Fig..
   (a)Explain the shape of the graph.
   (b)Why is the negative peak longer than the positive peak?



Numericals :

1. When a current of 3A flows through a coil, a magnetic flux of 30 mWb is linked with the second coil. What is the mutual induction between the pair of coils?
2. A small square loop of side 2mm is placed inside and normal to the axis of a long solenoid. The solenoid has a total of 2000 turns of wire uniformly wound over its total length of 2m. If the current flowing in the solenoid wire changes from 1A to 3A in (Л/100) of a second. Calculate the emf induced in the square loop.
3. When 100V d.c. is applied across an inductor a current of 1 A flows through it. If the same inductor is connected to 100 V a.c. source , the current reduces to 0.5A. Why is the current reduced? Calculate the value of the reactance.
4. A wire in the form of a circular loop of radius 10 cm lies in a plane normal to a magnetic field of 100T. If the wire is pulled to take a square shape in the same plane in 0.1s. Find the average induced emf in the loop.
5. A pure inductor is first put across 220V, 50Hz supply and then across a 220V, 100Hz supply. Will the current draw be the same or different in both the cases? Explain.
6. Calculate the mutual induction between two coils when a current of 2A changes to 6A in 2 sec and induces an emf of 20mV In the secondary coil.
7. Self inductance of an air core inductor increases from 0.01 mH to 10 mH on introducing an iron core into it. What is the relative permeability of the core used?

Multiple choice questions

1. A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 rad/s. If the horizontal component of the earth's magnetic field is 0.2 x 10-4 T , then emf developed between the 2 ends of the conductor is

   a) 5 μV b) 50 μV c) 5 mV d) 50 mV

2. The self inductance of the motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz , it should be connected to a capacitance of

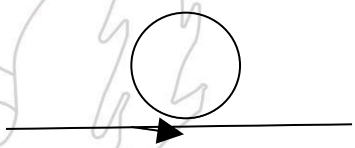
a) 4 μF b) 8 μF c) 1 μF d) 2 μF

3. In a transformer, number of turns in the primary is 140 and that in the secondary is 280. If current in primary is 4 A , then that in the secondary is
   a) 4 A b) 2 A c) 6 A d) 10 A

4. A metal ring is held horizontally and a bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is
   a) Equal to g b) less than g c) more than g d) either 'a'or 'c'

5. Two coils of self-inductance 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is
   a) 16 m H b) 10 mH c) 6 mH d) 4 mH

6. The current flows from A and B is shown. The direction of the induced current in the loop is
   a) Clockwise
   b) Anti-clockwise
   c) Straight line



None of these A B

7. The quantity that remains unchanged in a transformer is

Voltage b) current c) frequency d) none of these

8. Two coils are placed close to each other. The mutual inductance of the pair of coils depends on
   a) The rates at which currents are changing in the two coils
   b) Relative position and orientation of the two coils
   c) The material of the wires of the coils

The currents in the two coils

9. A straight conductor of length 0.4 m is moved with a speed of 7 m/s perpendicular to a magnetic field of intensity of 0.9Wb/m². The induced emf across the conductor is

5.04 V b) 1.26 V c) 2.52 V d) 25.2 V

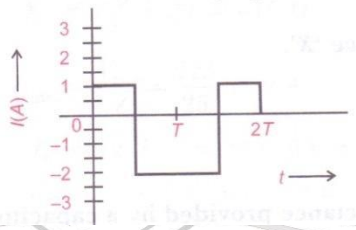
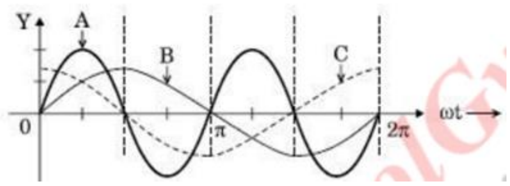
10. Use of eddy currents is done in the following except in
    a) Induction motor b) dynamo

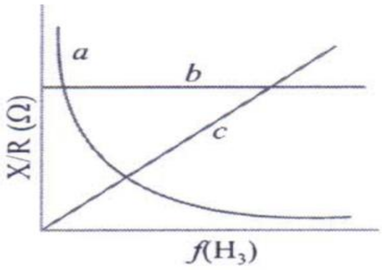
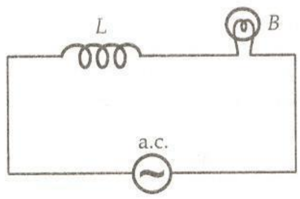
c) moving coil galvanometer d) electric brakes

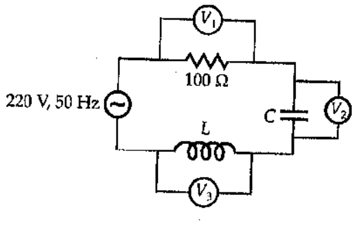
Answers:

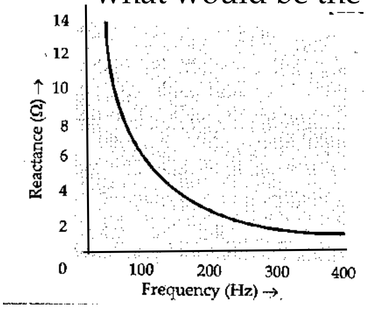
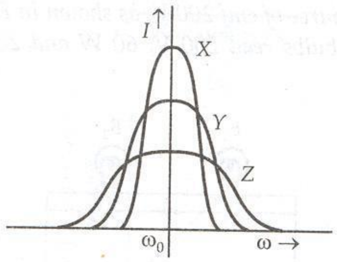
1. b	2. c	3. b	4. b	5. d
6. a	7. c	8. d	9. c	10. B

Chapter 7: Alternating Current
Assignment:

1	To reduce the reasonant frequency in an LCR series circuit with a generator (a) the generator frequency should be reduced. (b) another capacitor should be added in parallel to the first. (c) the iron core of the inductor should be removed. (d) dielectric in the capacitor should be removed.
2	An inductor of reactance 1 Ω and a resistor of 2 Ω are connected in series to the terminals of a 6 V (rms) a.c. source. The power dissipated in the circuit is (a) 8 W (b) 12 W (c) 14.4 W (d) 18 W
3	As the frequency of an ac circuit increases, the current first increases and then decreases. What combination of circuit elements is most likely to comprise the circuit? (a) Inductor and capacitor. (b) Resistor and inductor. (c) Resistor and capacitor. (d) Resistor, inductor and capacitor.
4	When an AC voltage of 220 V is applied to the capacitor C (a) the maximum voltage between plates is 220 V (b) the current is in phase with the applied voltage (c) the charge on the plates is in phase with the applied voltage (d) power delivered to the capacitor is zero
5.	The alternating current in a circuit is described by the graph shown in figure. Show rms current in this graph. 
6.	A device ‘X’ is connected to an a.c. source. The variation of voltage, current and power in one complete cycle is shown in figure. (a) Which curve shows power consumption over a full cycle? (b) What is the average power consumption over a cycle? (c) Identify the device ‘X’? 

7.	In given figure three curves a, b and c shows variation of resistance (R) capacitive reactance (X_c) and inductive (X_L) reactance with frequency. Identify the respective curves for these. 
8.	In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T then : (i) At what time is the energy stored completely electrical? (ii) At what time is the energy stored completely magnetic? (iii) At what time is the total energy shared equally between the inductor and capacitor?
9.	What is wattless current? Prove that an ideal inductor connected to an a.c. source does not dissipate any power.
10.	When 100 Volt d.c. is applied across an inductor, a current of IA flows through it. If the same inductor is connected across 100V A.C. source, the current reduces to 0.5 A .Why is the current reduced in the latter case? Calculate the value of the reactance of the circuit.
11.	An inductor 'L' of reactance X_L, is connected in series with a bulb 'B' to an a.c. source as shown in Fig.  Briefly explain how does the brightness of the bulb change, when (i) number of turns of the inductor is reduced and (ii a capacitor of reactance $X_C = X_L$ is included in series in the same circuit.
12	A series LCR- circuit is connected to an a.c source (220V-50Hz), as shown in fig,. If the voltage of the three voltmeter V_1, V_2 and V_3 are 65 V, 415V and 204V respectively. Calculate: (i) thecurrent in the circuit. (ii) the value of the inductor L, (iii) the value of capacitor C, and (iv) the value of C(for the same L) required to produce resonance.

	
13	(i) The primary of a transformer has 400 turns while the secondary has 2000 turns. If the power output from the secondary at 1100 V is 12.1 kW, calculate the primary voltage. (ii) If the resistance of the primary is 0.2 Ω and that of the secondary is 2.0 Ω and the efficiency of the transformer is 90%, calculate the heat losses in the primary and the secondary coils.
14.	A 100 mH inductor, a 25 microfarad capacitor and a 15 ohm resistor are connected in series to a 120 V source. Calculate (i) Impedance of the circuit at resonance (ii) Current at resonance (iii) resonant frequency
15.	a)What is the power dissipated in an a.c .circuit in which voltage and current are given by $V = 300\sin(\omega t+\Pi/2)$ and $I = 5\sin\omega t$ b) Plot a graph showing variation of impedance/Reactance of (i) a series LCR-circuit (ii) Inductive circuit (iii) Capacitive circuit with the frequency of the applied a.c. source.
16.	Define Q- factor . What is its significance? How can you increase the quality factor of a series resonant circuit?
17.	(a)An inductor L, a capacitor C and a resistor are connected in series in an a.c. circuit. What is meant by resonance of this circuit? Find the expression of resonance frequency. (b)In a series resonant circuit the AC voltage across R, L and C are 5V, 10 V and 10 V respectively, what is the AC voltage supplied to the circuit?
18.	Give reasons for the following : a) Why the coil of a deadbeat galvanometer is wound on a metal frame? b) Why do birds fly off a high tension wire when current is switched on? c) Why do alternating current measuring instruments have a non linear scale?
19.	The electric mains in a house are marked 220 V, 50 Hz. Write down the equation for instantaneous voltage. What is the peak value and the mean value of voltage?
20.	In the fig. given below shows how the reactance of a capacitor varies with frequency. (i) Use the information on graph to calculate the value of capacity of the capacitor. (ii) An inductor of inductance ‘L’ has the same reactance as the capacitor at 100Hz. Find the value of L.

	(iii) Using the same axes, draw a graph of reactance against frequency for the inductor given in part (ii) (iv) If this capacitor and inductor were connected in series to a resistor of 10 Ω, what would be the impedance of the combination at 300Hz. 
21	Three students X,Y,Z performed an experiment for studying the variation of alternating currents with angular frequency in a series LCR – circuit and obtained the graphs shown below. They all used a.c. sources of the same value.  What can we (qualitatively) conclude about the (I) capacitance values (II) resistance used by them? In which case will the quality factor be maximum? What can we conclude about nature of the impedance of the setup at the frequency ω_o?
22	When a circuit element 'X' is connected across an a.c. source, a current of $\sqrt{2}$ A flows through it and this current is in phase with the applied voltage. When another element 'Y' is connected across the same a.c. source, the same current flows in the circuit but it leads the voltage by $\Pi/2$ radians. (i) Name the circuit element X and Y. (ii) Find the current that flows in the circuit when the series combination of X and Y is connected across the same a.c. voltage. Plot a graph showing variation of the net impedance of this series combination of X and Y as a function of the angular frequency ω of the applied voltage
23	A resistor of 50ohm, an inductor of $(20/\Pi)$. H and a capacitor of $(5/\Pi)$ μF are connected in a series to a voltage source 230V, 50 Hz. Find the impedance of the circuit.

Practice Questions: Alternating Current

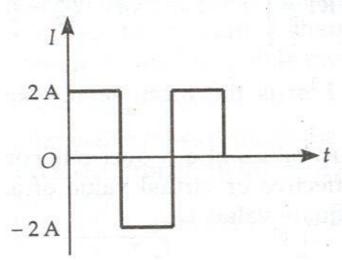
Short Answer Questions:

1. Mention two important causes of power loss in a transformer and how can the power loss due to these causes can be reduced?
2. Define Q-factor of a series LCR circuit. What is its significance?
3. An a.c. generator has a coil of N turns each of area A rotating with angular speed ω in a uniform magnetic field B.
   (i) what is the maximum e.m.f between its slip ring?
   (ii) What is the flux associated with the coil when the emf across it is zero.
4. An inductor L, a capacitor C and a resistor are connected in series in an a.c. circuit. What is meant by resonance of this circuit? Find the expression of resonance frequency.
5. What is wattless current?
6. Give the expression for the average value of the a.c. voltage $V = V_0 \sin\omega t$ versus the time interval t=0 t o t= Π/ω .
7. Draw a phasor diagram for a parallel combination of an inductance and a capacitance connected across an a.c. source.
8. Name the physical quantity which is measured as

(i) henry/s (ii) weber/ampere.

9. Soft iron is most suitable for making the cores of a transformer. Why?
10. An electric lamp is connected in series with a variable capacitor. What happens to brightness of lamp if source is alternating and capacitance is decreased?
11. An ideal inductor when connected in a.c. circuit does not produce heating effect yet reduces the current in the circuit. Why?
12. In a series LCR circuit. What is the potential drop across resistance when operating voltage is 220V, at resonance?
13. What is power factor of LCR series circuit at resonance?
14. Which value of a.c. do we measure with an a.c. ammeter?
15. What change will happen in the temperature of a metallic sphere moved in a magnetic field? Explain.
16. Plot a graph showing the variation of the net impedance of series combination of L,C and R as a function of the angular frequency of the applied voltage.

17. Calculate the rms value of the alternating shown in Fig.



18. An a.c. generator has a coil of N turns each of area A rotating with angular speed ω in a uniform magnetic field B.
(i)what is the maximum e.m.f between its slip ring?
(ii)What is the flux associated with the coil when the emf across it is zero.

19. Show that in an inductor , the voltage leads the current by Π/2.

Long Answer Questions :

1. Distinguish between the terms resistance, reactance and impedance of an a.c. circuit. Using a phasor diagram derive the expression for the impedance of an a.c. circuit. Find the expression for the resonant frequency.
2. Give principle construction and working of an a.c. generator.
3. What is meant by effective value of alternating current? Obtain a relation between it and its peak value.
4. Find the phase relation between current and emf if an a.c. circuit contains a pure inductor. Prove that a high frequency a.c. cannot pass through a pure inductor.
5. Find the phase relation between current and emf if an a.c. circuit contains a capacitor. Prove that d.c. cannot pass through a capacitor.
6. With the help of a diagram, explain the principle and working of a step-up transformer. Explain the use of transformer for long distance transmission of electrical energy. Why is its core laminated?
7. Sketch a graph showing the variation of inductive reactance, capacitive reactance and impedance of LCR series circuit with the frequency of applied voltage.
8. Define mean value of a.c. Derive the relation for the mean value of a.c.
9. An a.c. voltage is applied across a series combination of an inductor, capacitor and a resistor. Use the phasor diagram to obtain expressions for the impedance of the circuit , phase angle between the applied voltage and the resulting current in the circuit.
10. What is meant by L-C oscillations? Discuss qualitatively how these are produced. Show that an ideal inductor does not consume any power in an a.c. circuit.
11. Draw a plot showing the variation of the peak current with frequency of a.c.
12. State the condition under which resonance occurs in a series LCR circuit.
13. State the principle and explain the working with the help of labeled diagram of an i) a.c. generator and ii) a transformer.

14. An electric lamp having a coil of neglible inductance connected in series with a capacitor and an a.c. source is glowing with certain brightness. How does the brightness of the lamp change on reducing the 1) capacitance 2) frequency? Explain.
15. (a) Why the oil of a deadbeat galvanometer is wound on a metal frame?
    (b) Why do birds fly off a high tension wire when current is switched on?
    (c) Why do alternating current measuring instruments have a non linear scale?
16. Show that in an inductance , the voltage leads the current by Π/2.

Numericals :

1. A 200V variable frequency a.c. source is connected to a series combination of L= 5H, C= 80microfarad and R = 40 Ohms. Calculate a) angular frequency of the source to get maximum current in the circuit b) the current at resonance and c) power dissipation in the circuit.
2. A 60V, 10W electric lamp is to be operated on 100V,60hZ mains.
   A) Calculate the inductance of the coil required.
   B) If a resistor were to be used in place of the coil to achieve the same result, calculate its value.
   C) Which of the above ,(a) or (b) would be preferable and why?
3. The current in ampere in an inductor is given by I = 5+16t where t is in sec. The self induced emf in it is 10mV. Find the energy stored in the inductor and the power supplied to it at t= 1sec.
4. In a series LCR circuit the potential difference are : between the terminals of an inductance coil 60 V, between the terminals of a capacitor 30 V, between the terminals of a resistance coil 40 V. Find the supply voltage.
5. A circuit is set up by connecting L= 100mH , C=5μF & R= 100 ohm in series. An alternating emf of 150 2 volt , 500/∏ Hz is applied across this series combination. Calculate the impedance of the circuit. What is the average power dissipated in the resistor, the capacitor, the complete circuit.
6. An alternating voltage E = 200 sin 300t is applied across a series combination of a resistance of 10 ohm and an inductor of 800 mH. Calculate
   (a) impedance of the circuit
   (b) peak value of current in the circuit
   (c) power factor of the circuit.
7. The primary winding of a transformer has 500 turns and secondary has 5000 turns. If primary is connected to a.c. supply of 20V and 50Hz. What is the output across secondary?
8. A circuit is set up by connecting L= 100mH, C = 5μF and R = 100Ω in series. An alternating emf of (150√2) volts, (500/л) Hz is applied across this series combination. Calculate impedence of the circuit. What is average power dissipated in capacitor?
9. A capacitor of 50μF, a resistor of 10Ω, and an inductor L are connected in series with an a.c. source of frequency 50Hz. Calculate the value of L if phase angle between current and voltage is zero.

10. Obtain the resonant frequency of a series LCR circuit with L= 2H , C= 32 micro Farad and R= 10 ohm. What is the Q- value of the circuit?
11. A circular coil having 20 turns, each of radius 8cm is rotating about its vertical diameter with an angular speed of 50rad/s in a uniform horizontal magnetic field of magnitude 30mT. Obtain the maximum, average and rms values of the induced e.m.f. in the coil. If the coil forms a close loop of resistance 10Ω how much power is dissipated as heat in it?

Multiple choice questions

1. A. C cannot be measured by a d.c. ammeter because
   a) a.c. cannot pass through a.c. ammeter
   b) a.c. changes direction
   c) average value of current in a complete cycle is zero
   d) a.c. ammeter will get damaged
2. In an LCR-series a.c. circuit , the voltage across each of the components L,C and R is 50 V. The voltage across the L-C combination will be
   50 V b) $50\sqrt{2}$ V c) 100 V d) zero
3. In an LCR-series a.c. circuit, capacitance is changed from C to 2C . For the resonant frequency to remain unchanged, the inductance should be changed from L to
   4L b) 2L c) L/2 d) L/4
4. A 50 Hz a.c. source of 20 V is connected across aresistor R and a capacitor C in series. The voltage across R is 12 V. The voltage across C is
   8 V b) 10 V c) 16 V d) data given is insufficient

5. A capacitor
   a) Offers an easy path to a.c. but blocks d.c.
   b) Offers an easy path to d.c. but blocks a.c.
   c) Offers an easy path to a.c. and d.c.
   Blocks a.c
6. In an a.c. circuit , the maximum and minimum values of power factor are given by
   0 and 1 b) 1 and ∞ c) 0 and ∞ d) 0.1 and 1
7. An a.c. supply may be used directly for all these except for one. Identify the one , for which it cannot be used
   Heating b) lighting c) transforming voltage d) electroplating
8. An a.c. circuit having an L and C in series has a maximum current. If L= 0.5 H and C = 8 μF , then the angular frequency of a.c. voltage will be
   a) 500 b) 5×10^5 c) 4000 d) 5000
9. Wattless current is possible , only in
   a) A resistive circuit b) non-resistive circuit
   c) LR circuit d) LCR circuit

10. A coil and an electric bulb are connected in series with an a.c. source. On introducing a soft iron bar inside the coil, the intensity of the bulb will

    Increase b) decrease c) fluctuate d) remain the same

Answers:

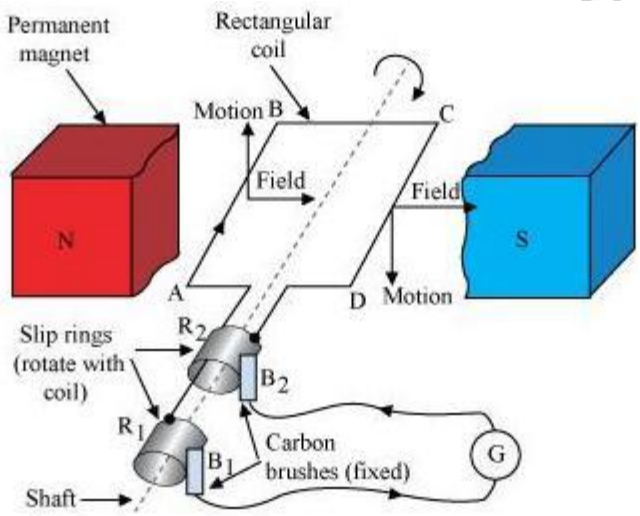
1. c	2. d	3. c	4. c	5. a
6. a	7. d	8. a	9. b	10. b

Study Materials

ALTERNATING CURRENT GENERATOR (A.C. DYNAMO)

An electric generator is a device used to convert mechanical energy into electrical energy.

Principle: It is based on the principle of the electromagnetic induction.
When a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an inducted e.m.f. is produced across it.
In an a. c. generator, mechanical energy is converted into electrical energy by virtue of electromagnetic induction.



Construction: The a. c. generator consists of the following parts:

1. **Armature:** A rectangular coil consisting of a large number of turns of copper wire wound over a soft iron core is called the armature. The soft iron core is used to increase the magnetic flux.
2. **Field magnet**: It is usually a strong permanent magnet having concave poles. The armature is rotated between the two poles of a magnet, so that axis of the arma-ture is perpendicular to the magnetic field lines.
3. **Slip rings**: The leads from the arms of the armature are connected to the two rings R_1 and R_2 separately. These rings help to provide movable contact and for this reason, they are called slip rings. As the armature and hence the leads rotate, the rings R_1 and R_2 also rotate about the central axis.
4. **Brushes**: The flexible metallic pieces B_1 and B_2, called brushes, are used to pass on the current from armature to the slip rings across which the external load resistance R is connected. As the slip rings rotate, the brushes provide movable contact by keeping themselves pressed against the rings.

Working: The working of the a.c. generator is illustrated with the help of five different positions of the armature ABCD at times t=0, T/4, T/2, 3T/4 and T respectively.

Direction of flow of current: Initially at t=0 the armature ABCD is vertical with arm AB up and CD down. During the motion of armature between t=0 to t= T/2, the arm AB moves down and CD moves up. The application of Flemings's right hand rule tells that the current in the armature will flow in the direction DCBA (from the end B to A in arm AB and the end D to C in the arm CD). On the other hand, during the motion of armature between t= T/2 to t=T, the motion of two arms is just opposite to that what happens during t=0 to t=T/2, i.e the arm AB moves up and CD moves down. Therefore, during this interval, the current in the armature will flow in the direction ABCD.

Magnitude of induced e.m.f: Whenever the armature is vertical, its arm AB and CD momentarily moves parallel to the field i.e the rate of change of magnetic flux through the armature becomes zero. Accordingly, as $d\O/dt$ is zero, the induced e.m.f. e= - $d\O/dt$ corresponding to the vertical positions of the armature is also zero. Thus, at time t=0, T/2 and T, the induced e.m.f. produced is zero. Whenever the armature is horizontal, the arm AB and CD move normally to the direction of magnetic field lines and hence they cut or intercept the magnetic field lines with maximum speed. Hence the rate of change of magnetic flux is fastest or maximum corresponding to horizontal positions. Thus, at times t= T/4 and 3T/4, the induced e.m.f. produced is maximum. Therefore the output e.m.f. across the load resistance R during a complete rotation of the armature will vary.
The expression for instantaneous e.m.f. developed across R is given by

$e = e_0 \sin \omega t$, which can be deduced as below:

Expression for instantaneous e.m.f. produced consider the coil (armature) of the a.c. generator consisting of n turns and placed in uniform magnetic field B, such that its axis of rotation is perpendicular to the direction of the field. Initially, at t=0 the coil is vertical with arm AB up and CD down.
In this position of the coil the component of the field normal to the plane of the coil is B cos θ. If A is area of the coil and n, the number of turns in the coil, then magnetic flux is linked with the coil in this position is given by

$$\O = n\,B\cos\theta\,(A)$$
$$= n\,B\,A\cos\theta$$
Or $$\O = n\,B\,A\cos\omega t$$

The effect of number on turns n in the coil is to increase the magnetic flux linked with the coil to n times.
Differentiating both sides w.r.t time we get

$$\frac{d\O}{dt} = \frac{d}{dt}(n\,B\,A\cos\omega t)$$

$$= n\,B\,A\frac{d}{dt}(\cos\omega t) = n\,BA\,(-\sin\omega t)\,(\omega)$$

$$= n\,B\,A\,\omega\sin\omega t$$

If e is the instantaneous induced e.m.f. produced in the coil, then

$$e = -\frac{d\O}{dt}$$

$$= -(-n\,B\,A\,\omega\sin\omega t) \text{ or } e = n\,B\,A\,\omega\sin\omega t$$

$$e = e_0\sin\omega t \qquad \text{where } e_0 = n\,B\,A\,\omega\sin\omega t$$

Thus, the induced e.m.f. produced is a function of time and therefore as the coil passes through different positions with the passage of time, e.m.f. produced changes with time.

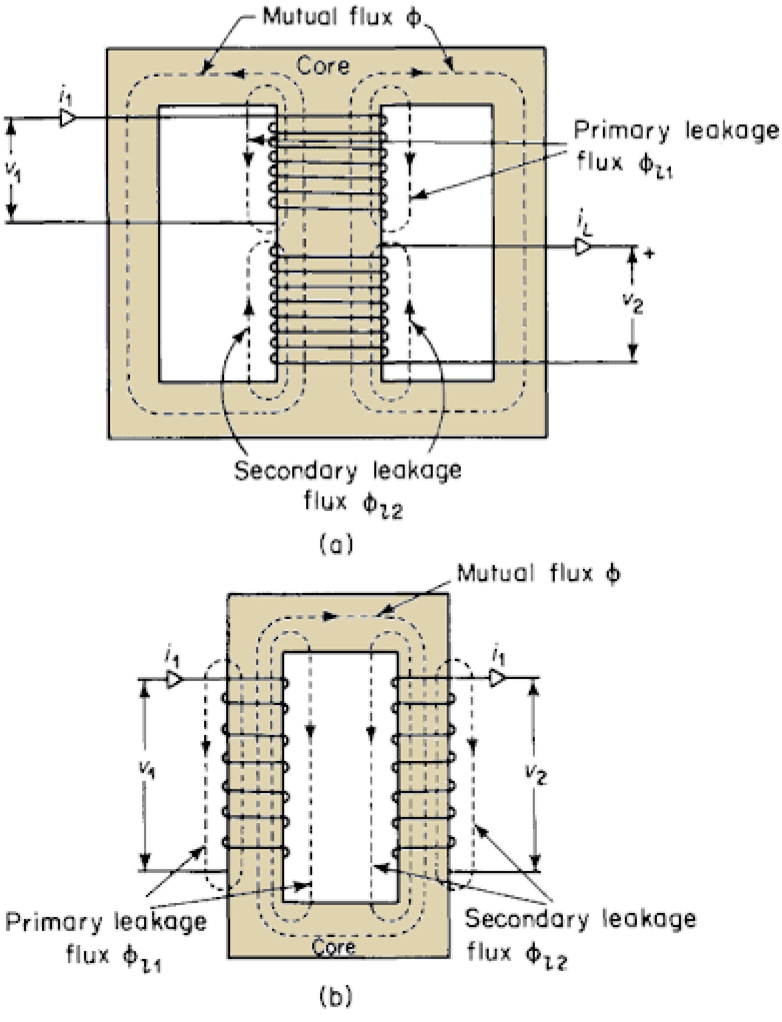
The e.m.f. would be zero from ωt=0 (when coil is vertical); positive maximum from ωt = π/2 (when coil is horizontal), zero from ωt = π (when the coil is vertical), negative maximum for ωt =3π/2 (when coil is horizontal) and again zero ωt =2 π (when the coil is vertical and return to its initial position). Thus graphically, the e.m.f. will vary with the time.

Transformer

It is device used for converting low alternating voltage into high voltage at low current and vice-versa.

Principle: It works on the principle of mutual induction i.e. if two coils are inductively coupled and when current or magnetic flux is changed through one of the two coils, and then induced e.m.f. is produced in the other coil.

Construction: It consists of two coils P and S wound on a soft iron core. The coils P and S are called the **primary coil** and the **secondary coil** respectively. The a.c. input is applied across the primary coil and the transformed output is obtained across the secondary coil. To minimize eddy currents, the soft iron core is laminated.



The transformers are of following two types:

Step-up transformer. In a step-up transformer, the number of turns in secondary coil (N_S) is greater than the number of turns in primary coil (N_P) i.e. $N_S > N_P$. The primary coil is made of a thick insulated copper wire, while the secondary coil is made of a thin insulated wire. It converts a ***low voltage at high current into a high voltage at lowcurrent***.

Step-down transformer. The number of turns in secondary coil (N_S) of a step-down transformer is less than that in primary coil (N_P) i.e. $N_S < N_P$. In a step down transformer, the primary coil is made of a thin wire and the secondary coil is made of a thick wire. It converts ***a high voltage at low current into a low voltage at high current***.

Theory. When an alternating e.m.f. is applied across the primary coil, the input voltage keeps on changing with time. Due to this, the magnetic flux through the primary coil also keeps on changing with time. The changing magnetic flux gets linked up with secondary coil through the laminated core, which in turn produces alternating e.m.f. across the secondary coil. The soft iron core is capable of coupling practically the whole of the magnetic flux produced in the primary coil with the secondary coil. If the magnetic field lines remain confined to the soft iron core, then all the field lines across the primary coil link up with each turn of secondary coil.

Therefore, the magnetic fluxes linked with two coils are simply proportional to their number of turns. If $Ø_P$ and $Ø_S$ are the values of magnetic flux linked with primary and secondary coils at any instant, then

$$\frac{Ø_S}{Ø_P} = \frac{N_S}{N_P}$$

Or

$$Ø_s = \frac{N_S}{N_P} Ø_P$$

Differentiating both sides w.r.t. we have

$$\frac{d\,Ø_S}{dt} = \frac{d}{dt}\left\{\frac{N_S Ø_P}{N_P}\right\}$$

Or $$\frac{d\,Ø_S}{dt} = \frac{N_S}{N_P} \times \frac{dØ_P}{dt}$$

According to Faraday's law of electromagnetic induction, the induced e.m.f. produced is given by

$$e = - dØ/dt.$$

Therefore, if e_p and e_s are the instantaneous values of induced e.m.f. produced in primary and secondary coils respectively, then

$$e_p = - dØ_p/dt$$
$$e_s = - dØ_s/dt$$

Using the above two expressions, equation becomes

$$\Rightarrow e_s = \frac{N_S}{N_P} e_P$$

The ratio $N_s/N_p = \kappa$ is called **transformation ratio**.

If we assume that there is no loss of energy, then

Instantaneous output power = instantaneous input power

i.e. $e_s\, I_s = e_p\, I_p$

Here, I_P and I_S are respectively the values of current in primary and secondary coils at the instant, when the respective values of the voltage across the two coils are e_P and e_P. Therefore,

$$e_S/e_p = I_P/I_s$$

Since in a step-up transformer, $e_S > e_p$, it follows that $I_S < I_P$. Thus, in accordance with the law of conservation of energy, a step-up transformer increases the voltage by decreasing the current. Similarly, a step-down transformer decreases the voltage by increasing the current. In other words, a transformer neither creates nor destroys the electric energy. It simplify transforms the voltages and currents, obeying the law of conservation of energy.

Need for laminated core. When a.c. input is applied across P-coil, the induced e.m.f. is produced in S-coil due to change of magnetic flux across it. In fact, magnetic flux changes through the soft iron core also and it produces induced e.m.f. in the iron core. The induced e.m.f. developed in the iron core produces current in the core in the form of closed loops, called eddy currents. Since resistance of the iron core is quite small, the magnitude of eddy currents is quite large. As a result, a large amount of heat is produced and it may damage the insulation of the copper windings.

To avoid it, a laminated iron core is used in a transformer. The laminated iron core is prepared by joining similar iron strips together after coating them with varnish.
As such, the induced e.m.f. produced in the core will cause eddy currents in each iron strip separately. Since an iron strip is quite thin and possesses very large resistance, the magnitude of eddy currents produced is quite small and hence only a small amount of heat is produced.

ENERGY LOSSES IN A TRANSFORMER

In practice, a number of types of energy losses occur in a transformer. Due to this, the efficiency of a practical transformer is never 1 or 100%. The various types of energy losses, which occur in a transformer, are as given below:

(i) **Flux losses**. The coupling of the primary and secondary coils is never perfect and whole of the magnetic flux produced in primary coil never gets linked up with the secondary coil.

(ii) **Copper losses**. Due to resistance of the windings of primary and secondary coils, some electrical energy is always converted into heat energy.

(iii) **Iron losses**. The varying magnetic flux produced eddy currents in the iron core, which also leads to the wastage of energy in the form of heat. It is minimised by using a laminated iron core.

(iv) **Hysteresis losses**. The alternating current flowing through the coils magnetises and demagnetises the iron core again and again. During each cycle of magnetisation, some energy is lost due to hysteresis, the energy lost during a cycle of magnetisation being equal to area of the heysteresis loop (in magnitude). However, the loss of energy can be minimised by selecting the material of core, which has a narrow hysteresis loop.

(v) **Humming losses**. Due to the passage of alternating current, the core of the transformer starts vibrating and produces humming sound. Thus, sine part (may be very small) of the electrical energy is wasted in the form of humming sounds produced by the vibrating core of the transformer.

On account of the energy losses given above, the output power of a transformer is always less than the input power *i.e.*

$$e_s I_s < e_p I_p$$

The efficiency of the transformer is given by

$$\eta = \frac{e_s I_s}{e_p I_p}$$

Hence, in practice, the efficiency of a transformer is never 100%

Chapter 8: Electromagnetic Waves

Assignment

1 One requires 11eV of energy to dissociate a carbon monoxide molecule into carbon and oxygen atoms. The minimum frequency of the appropriate electromagnetic radiation to achieve the dissociation lies in

(a) visible region (b) infrared (c) ultraviolet region (d) microwave region.

2 The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is

(a) c : 1 (b) c^2 : 1 (c) 1 : 1 (d) √c :1

3 A plane electromagnetic wave propagating along x direction can have the following pairs of E and B

(a) E_x , B_y (b) E_y , B_z (c) B_x, E_y (d) E_z , B_y

4 A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. The electromagnetic waves produced:

(a) will have frequency of 10^9 Hz
(b) will have frequency of 2×10^9 Hz
(c) will have a wavelength of 0.3 m
(d) fall in the region of radiowaves

5 A variable frequency a.c source is connected to a capacitor. How will the displacement current change with decrease in frequency?

6 Two students A and B prepare data about electromagnetic waves. Correct the table and rewrite it

	Direction of			Peak Value of	
Student	Electric field	Magnetic field	Propagation	Electric field	Magnetic field
A	Along X-axis	Along X-axis	Along Y-axis	E	B=cE
B	Along Y-axis	Along Z-axis	Along X-axis	E=cB	B

7 (a) How are electromagnet waves produced?
(b) How do you convince yourself that electromagnetic waves carry energy and momentum?.

8	E. M. Waves with wavelength i) λ_1 are used to treat muscular pain ii) λ2 are used by a FM radio station for broadcasting iii) λ_3 are used to detect fractures in bones iv) λ_4 are absorbed by the ozone layer of the atmosphere Identify and name the part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in decreasing order of magnitude
9	What is the main difference between characteristic X- rays and gamma rays?
10	Find the amplitude of the electric field in a parallel beam of light of intensity 2W/m^2.
11	What does electromagnetic waves consists of? On what factors does its velocity in vacuum depend?
12	A parallel plate capacitor with plate area A and separation d between the plates is charged by a constant current I. Consider a plane surface of area A/2 parallel to the plates and drawn symmetrically between the plates. Find the displacement current through this area.
13	A variable frequency A. C. Source is connected to a capacitor, will the displacement current increase or decrease with increase in frequency?
14	Which of the following statements are correct in relation to electromagnetic waves in an isotropic medium i) Energy due to electric field is equal to that due to magnetic field ii) Electric vector E and magnetic vector B are in phase iii) For a given amplitude of E vector, the intensity increases as the first power of frequency
15	The magnetic field in a plane electromagnetic wave is given by: By = $12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$ T. Calculate the (i) Energy density associated with the Electromagnetic wave (ii) Speed of the wave
16	Which part of electromagnetic spectrum does the wavelength 10-11m correspond to? The experimental observations have shown that, these rays (i) travels in vacuum with a speed of 3 X 108m/s (ii) exhibit the phenomenon of diffraction and can be polarized. What conclusion can be drawn about the nature of these rays from each of these observations?

Practice Questions: Electromagnetic Waves

Short Answer Questions

1. State the condition under which a microwave oven heats up a food item containing water molecules most efficiently.
2. What is the main difference between X-rays and gamma rays?
3. What is the role of ozone in the atmosphere?
4. State the reason why microwaves are best suited for long distance transmission of signals.
5. Can an e.m. wave be deflected by a magnetic or an electric field?
6. Write he following radiations in ascending order of their frequency: X- rays, microwaves, ultra violet rays and radio waves.
7. In an electromagnetic field, the amplitude of magnetic field is $3x\ 10^{-10}$ T. If the frequency of the wave is 10^{12} Hz, then find the amplitude of the associated electric field
8. Electromagnetic waves with wavelength

   λ_1 are used to treat muscular strain.

   λ_2 are used by a FM radio station for broadcasting.

   λ_3 are used to detect fracture in bones.

   λ_4 absorbed by the ozone layer of atmosphere.

Identify these rays. Arrange these wavelengths in decreasing order of magnitude.

9. Frequency of a wave is $6x10^{15}$ Hz. Which part of the e.m. spectrum it belongs to

10. Which of the following, if any, can act as a source of e.m. waves?
    a charge moving with a constant velocity
    a charge at rest
    a charge moving along a circular path.
    Give reason.

11. Name the components of E.M. spectrum
    (a) Whose range of wavelength varies from 10^{-14}m to 10^{-10}m.
    (b) Which can be produced by bombarding a target of high atomic number?
    (c) With a beam of fast moving electrons.
    (d) Which can be produced by the oscillating electrons in cavity?
    (e) Which can be used for sterilizing the surgical instruments?
    Arrange these in ascending order of frequency.

12. What is displacement current? State and explain Maxwell's modification of Ampere's Law.
13. Show that e.m. waves are transverse in nature.
14. State the properties of e.m.waves.
15. Write one property and one use of each if IR rays, UV rays, radio waves and microwaves , gamma rays.
16. Obtain an expression for the energy density of an e.m. wave. Show that the average energy density of the E field equals the average energy density of the B field .

Numerical:

1. A parallel plate capacitor consists of 2 circular plates of capacitances 1 micro farad is being charged at the rate of 5 V/s. What is the displacement current?
2. Identify the part of the e.m. spectrum to which waves of frequency 10^{20} Hz and 10^9 Hz belong . Find their velocity in glass of refractive index 1.5.
3. A plane monochromatic light wave lies in the visible region. It is represented by the sinusoidal variation with time by the following components of electric field : $E_X = 0$, $E_y = 4\sin[2\pi/\lambda\,(x-vt)]$ and $E_z = 0$

   (a)What is the direction of propagation of wave?

   (b)What is its amplitude?

   (c) Compute the components of magnetic field.
4. The magnetic field in a plane electromagnetic wave is given by

$$B_y = 2\times10^{-7}\sin\left(0.5\times10^{3}x+1.5\times10^{11}t\right)T$$

   (a)What are the frequency and the propagation vector (k) of the wave?

   (b) Write an expression for the electric field.

   (c) What is the direction of flow of energy (poynting vector).

Multiple choice questions

1 Electromagnetic waves are transverse in nature is evident by

(a) Polarization (b) interference (c) reflection (d) diffraction

2. Which of the following are not electromagnetic waves?

(a) Cosmic rays (b) γ-rays (c) β-rays (d) X-rays

3. Which of the following radiation has the least wavelength?

(a) α- rays (b) γ-rays (c) β-rays (d) X-rays

4. Infrared radiations are detected by

(a) Spectrometer (b) pyrometer

(c) nanometer (d) photometer

5. Fundamental particle in an electromagnetic wave is

(a) Photon (b) electron (c) phonon (d) proton

6. Which of the following is used to produce radio waves of constant amplitude?
   (a) Oscillator (b) FET (c) rectifier (d) amplifier

7. When a high energy UV photon beam enters an electric field, it will be
   (a) Accelerated (b) retarded (c) undeflected (d) none of these

8. 10cm is a wavelength corresponding to the spectrum of
   (a) Infrared (b) ultraviolet (c) microwaves (d) X-rays

9. The structure of solids is investigated by using
   (a) Cosmic rays (b) γ-rays (c) X-rays (d) infrared

10. Which radiations are used in treatment of muscle ache?
    (a) Infrared (b) ultraviolet (c) microwave (d) X-rays

1.a 2.c 3.b 4.b 5.a 6.a 7.c 8.c 9.b 10.a

Study Material

ELECTROMAGNETIC WAVES

Faraday's law of E.M.I. suggests that a magnetic field changing with time at a point in space produces an electric field at that point. On the other hand, Maxwell's concept of displacement current led to the conclusion that an electric field changing with time at a point in space produces an magnetic field at that point. The electric and magnetic field can propagate through space with velocity of light and were called E.M. waves.
The transverse time varying electric and magnetic fields propagating in space in a direction perpendicular to the direction of both the electric and magnetic fields are said to constitute **ELECTROMAGNETIC WAVES.**

PROPERTIES OF E.M. WAVES:

1. E.M. Waves are transverse in nature.
2. They are produced by accelerated charges particles.
3. In free space they travel with a velocity, c= $(\mu_0 €_0)^{-1/2}$ (where μ_0 and $€_0$ are absolute permeability and absolute permittivity of free space. In a material medium they travel with a velocity , v= $(\mu €)^{-1/2}$ (where $\mu$and € are permeability and permittivity of that medium.
4. They obey the principle of superposition.
5. The variation in the amplitudes of electric and magnetic fields in e.m. waves take place at the same time and at the same place in space. The ratio of electric and magnetic fields is always constant and is equal to the velocity of e.m. waves in that medium.
6. The energy in e.m. waves is divided equally between the electric and magnetic fields.

SOUCRCE OF E.M. WAVES:
An electric charge at rest has electric field in the region around it, but no magnetic field. A moving charge produces both electric and magnetic fields. If the current is constant the magnetic and electric fields will not change with time, hence no e.m. waves can be produced. If the charge is accelerated both magnetic and electric fields will change with space and time, it then produces electromagnetic waves. This shows that an accelerated charge emits electromagnetic waves.

HISTORY OF E.M. WAVES:
In 1865, Maxwell predicted the existence of e.m. waves. According to him an accelerated charge produces a time varying magnetic field which in turn produces a time varying electric field. The two fields so produced are mutually perpendicular to each other and are source of each other.
The mutually perpendicular time varying electric and magnetic fields constitute e.m. waves abd propagate in space in a direction perpendicular to both the direction of varying electric and magnetic fields.
In 1887, Hertz experimentally demonstrated the production of e.m. waves of wavelength 6m by using a spark oscillator and then detecting them successfully.
Seven year after in 1895 Jagdish Chander Bose produced e.m. waves of wavelength range 5mm to 25 mm.

In 1896 Marconi discovered that if one end of the spark gap is connected to an antenna and the other terminal is earthed the e.m. waves radiated upto few kilometres (He demonstrated the transmission of e.m. waves)

Electromagnetic Spectrum

The whole range of frequencies/wavelengths of the electromagnetic waves arranged in an order is known as the electromagnetic spectrum.

Electromagnetic spectrum consists of the following waves :

1. Radio waves 2. Micro waves 3. Infrared (i.e. IR) rays 4 Visible light
5. Ultra violet (i.e. UV) rays, 6. X-rays and 7. Gamma (i.e. ϒ) rays

1**. Radio waves** : Radio waves are produced by rapidly changing the electric current in LC circuit. The wavelength of a radio wave is the longest among all the electromagnetic waves, whereas the frequency of radio wave is the least among all the electromagnetic waves. Wavelength range of radio wave is from 15 cm to 2000 m.

Uses. Radio waves are mainly used for communication purpose. Radio waves are classified into many categories depending upon their frequency range. The classification of radio waves and their uses are given below:

(i) Very low frequency (VLF) radio waves : The frequency range of very low frequency radio waves is 10 kHz to 30 kHz. This type of radio waves is used for point to point short distance communication.

(ii) Low frequency (LF) radio waves : The frequency range of the low frequency waves is 30 kHz to 300 kHz. This type of radio waves is used for marine communication and navigation.

(iii) Medium frequency (MF) radio waves : The frequency range of the medium frequency radio waves is 300 kHz to 3000 kHz. These radio waves are used for amplitude modulated AM broadcasting.

(iv) High Frequency (HF) radio waves : The frequency of the high frequency radio waves is 3 MHz to 50 MHz. These radio waves are used for long distance communication.

(v) Very high frequency (VHF) radio waves: the frequency range of VHF radio waves is 50 MHz to 300 MHz. These radio waves used for FM transmission, radar and telecasting television programmes.

(vi) Ultra high frequency (UHF) radio waves : The frequency of UHF radio waves is 300 MHz to 3000 MHz. These radio waves are used for long distance communication. Cellular phone make use UHF radio. Now, TV's also making use of UHF, hyper waves and super bands upto 900 MHZ.

2**. Microwaves** . The wave kength of microwaves is greater than 1.0 mm and less than 30 cm. The frequency range of microwaves is 10^9 Hz to 3.0×10^{11}Hz . They are produced by oscillating electrons in a cavity. The commonly used oscillators to produce microwaves are **Klystron, Magnetron** and**Gunn diodes**.

Uses:

(i) Microwaves are used in a radar communication
(ii) These are used for atomic and molecular research
(iii) These are used for aircraft navigation

(iv) These are used in microwave ovens for cooking and warming foods. Frequency of the microwaves is set around 3GHz which matches the resonant frequency of water molecules which make them to vibrate at larger amplitudes to produce heat. This heat is produced for cooking/warming food.
(v) Microwaves are used for communication by cellular phones.
(vi) Microwaves are used in weather radar.
(vii) Used in gun speed

3**. Infra-red (IR) rays** . The wave length range of infra-red rays is 1 mm to 700 nm and the frequency range is 3.0×10^{11} Hz to 4.3×10^{14}Hz. Infra-red rays are produced by the excitation of atoms and molecules. Hot bodies also radiate infra-red rays. These are called **heat waves** also.
Uses:
(i) These rays can be pass through the haze, fog and mist, so these rays are used in night vision devices during warfare and for taking photographs of earth under foggy conditions from great height. Infrared detectors are used by earth satellites.
(ii) these rays are used to function the green houses because green house gas CO2 and water vapours absorb the infrared rays readily.
(iii) They are used in revealing the secret writings on the ancient walls.
(iv) Infrared lamps are used to treat muscular strains.
(v) The infra-red rays from the sun keep he earth warm.
(vi) Infrared remotes are used to operate electronic devises like TV, VCD, music hi-fi systems etc.

4. **Visible light**. The wavelength rane of visible* light is 400 nm (violet) to 780 nm (red) and the
frequency range is 4.3×10^{14} Hz to 7.5×10^{14} Hz. Visible light is emitted when an electron jumps from higher energy level to lower energy level of an atom.
Uses:
(i) Visible light stimulates the sense of the sight in human beings, so the beautiful world around us is seen in the presence of visible light.
(ii) Visible light is useful in photography.
(iii) It is useful in optical microscopy.
(iv) It is useful in astronomy.
(v) It is a great source of energy for human life.

5**. Ultra-violet (UV) rays:** The range of ultra-violet rays is 400 nm to 0.6 nm and their frequency range is 7.5×10^{14} Hz to 5.0×10^{15} Hz. **The sun is the most important source of ultra violet rays.** Ultra-violet rays are also produced by the welding arc. These rays in large quantities are very harmful to the living tissues. They cause tanning of the skin due to their promotion of melanin in the skin. Prolonged exposure to Uv rays can induce cancer in human beings. Tanning can be protected by using glass panes because glass can absorb UV rays. Ozone layer also protects us from the UV radiations present in the sun rays.
Caution: The sun should not be directly looked at even during total solar eclipse. Ultra-violet rays constantly entering our eyes may cause total blindness.
Uses:

(i) They are used to preserve food stuff and make drinking water free from bacterias as these rays can kill bacteria, germs etc.
(ii) They are used for sterilizing the surgical instruments.
(iii) They are used in detecting the invisible writings, forged documents and finger prints.
(iv) They are used to study the structure of molecules.
(v) UV rays are used in LASIK eye surgery.;

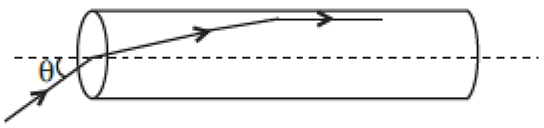
6. **X –rays.** These rays were discovered by Prof. Rontgen in 1895. X-rays can be produced by bombarding a target of high atomic number (Z) with a beam of fast moving electrons. The range of the wavelength of X-rays varies from 10 nm to 10^{-4} nm. The frequency of these rays varies from 5.0×10^{15} Hz to 3.0×10^{18} Hz. X-rays can penetrate through the human flesh but bones or metallic materials block these rays. These can be damaging for living tissues.

Uses:
(i) These are used in medical diagnosis like locating the fracture in the bone, foreign materials like coin or bullet in the body.
(ii) These are used in radio therapy to cure skin diseases, cancer and tumors.
(iii) These are used in engineering for locating the faults, cracks and flaws in the finished metallic materials.
(iv) X-rays are used by detective agencies to detect gold, silver, diamonds and other contraband goods etc. concealed in bags or the body of a person.

7. **Gamma rays.** These rays are produced when an electron jumps from higher orbit to the lower orbit of an atom. Y rays also produced during radioactive decay of nuclei and nuclear reactions. The wavelength of y-rays is the shortest of all the electromagnetic waves. The range of the wavelength of these rays varies from 10^{-10} m to 10^{-14} m. On the other hand, the frequency of y-rays is the highest of all the electromagnetic waves. The range of the frequency of y-rays varies from 3.0×10^{18} Hz to 3.0×10^{22}Hz. The penetration power of these rays is extremely high.
Uses:
(i) These are used for the treatment of cancer.
(ii) These are used to examine the thick materials for structural flaws.
(iii) These are used for food preservation
(iv) These are used to get valuable information about the structure of atomic nuclei.

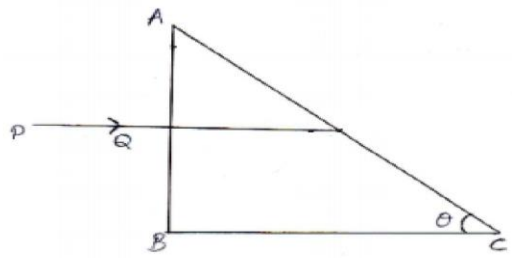
Type	Wavelength range	Production	Detection
Radio	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave	0.1m to 1 mm	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1mm to 700 nm	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared 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 1nm	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells Photographic film
X-rays	1nm 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	-do-

Chapter No 9
Ray Optics and Optical Instruments
Assignment

1.	A transparent solid cylindrical rod has a refractive index of $2/\sqrt{3}$. It is surrounded by air. A light ray is incident at the mid-point of one end of the rod as shown in the figure.  (a) $\sin^{-1}\left(\frac{1}{2}\right)$ (b) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (c) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (d) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$
2	A beam of light consisting of red, green and blue colours is incident on a right angle C prism. The refractive index of the material of the prism for the above red, green and blue wavelengths are 1.39, 1.44 and 1.47 respectively The prism will (a) not separate the three colours at all (b) separate the red colour part from the green and blue colours (c) separate the blue colour part from the red and green colours (d) separate all the three colours from one another.
3.	A beam of white light is incident on glass air interface from glass to air such that green light just suffers total internal reflection. The colors of the light which will come out to air are (A) Violet, Indigo, Blue (B) All colors except green (C) Yellow, Orange, Red (D) White light
4.	The refractive index of a material of a plano concave lens is 5/3, the radius of curvature is 0.3m. The focal length of the lens in air is a. -0.45m b. -0.6m c. -0.75m d. -1m
5.	Will the focal length of a lens for red light be more, same or less than that for blue light?
6.	1) The focal length of a convex lens made of glass is 20 cm. What will be its new focal length when placed in a medium of refractive index 1.25? 2) Violet light is incident on a converging lens of focal length f. state, with reason, how the focal length of the lens will change, if violet light is replaced by red light.

<table>
<tr><td>7</td><td>Draw a labelled ray diagram of an astronomical telescope in the normal adjustment position and find the magnitudes of
a) The length of the telescope
b) The magnification of the telescope
if the focal length of the objective lens is = 15 m and the focal length of an eye lens is 5 cm.</td></tr>
<tr><td>8</td><td>The following data was recorded for values of object distance and the corresponding values of image distance in the experiment on study of real image formation by a convex lens of power 5D. One of these observations is incorrect. Identify this observation and give reason for your choice:
<table>
<tr><td>S.No.</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>Object distance</td><td>25</td><td>30</td><td>35</td><td>45</td><td>50</td><td>55</td></tr>
<tr><td>Image distance</td><td>97</td><td>67</td><td>37</td><td>35</td><td>32</td><td>30</td></tr>
</table></td></tr>
<tr><td>9</td><td>a)The image of a candle is formed by a convex lens on a screen. Draw the ray diagram to show the formation of image. The lower half of the lens is painted black to make it completely opaque. What happens to the position and intensity of image? Explain.
b) The radii of curvature of both the surfaces of a lens are equal. If one of the surfaces is made plane by grinding, how will the focal length and power of the lens change?</td></tr>
<tr><td>10</td><td>A point object O is kept at a distance of 30 cm from a convex lens of power +4D towards its left. It is observed that when a convex mirror is kept on the right side at a distance of 50 cm from the convex lens, the image of the object O formed by the lens-mirror combination coincides with the object itself. Calculate the focal length of the convex mirror</td></tr>
<tr><td>11.</td><td>Draw a graph showing the variation of power of a lens, with the wavelength of the incident light. A converging light of refracting index 1.5 and focal length 15cm in air has the same radii of curvature for both sides. If it is immersed in a liquid of refractive index 1.7, find the focal length of the lens in the liquid.</td></tr>
<tr><td>12.</td><td>An object is placed at a distance of 40cm from a concave mirror of focal length 15cm. if the object is displaced through a distance of 20cm towards the mirror, by how much distance is the image displaced?</td></tr>
<tr><td>13.</td><td>An object is placed at a distance of15cm from a convex lens of focal length10cm. on the other side of lens, a convex mirror is placed such that its distance from the lens, equals the focal length of the lens. The image formed by this combination is observed to coincide with the object itself. Find the focal length of the convex mirror?</td></tr>
<tr><td>14.</td><td>a) When light travels from an optically denser medium to a rarer medium, why does the critical angle of incidence depend on the colour of light ?
b) A concave lens made of material of refractive index n_2 is held in a medium of refractive index n_1.trace the path of parallel beam of light passing through the lens when</td></tr>
</table>

	(a) $n_1 > n_2$ (b) $n_1 < n_2$ (c) $n_1 = n_2$
15.	Draw a labeled ray diagram to show the image formation by astronomical telescope in normal adjustment. Write the expression of its magnifying power. Write two basic features which can distinguish between a telescope and a compound microscope.
16.	Draw an appropriate ray diagram to show the passage of a 'white ray', incident on one of the two refracting faces of a prism. State the relation for the angle of deviation, for a prism of small refracting angle. It is known that the refractive index,μ , of the material of a prism, depends on the wavelength ,λ , of the incident radiation as per the relation $\mu = A + \frac{B}{\lambda^2}$ Where A and B are constants. Plot a graph showing the dependence of μ on λ and identify the pair of variables that can be used here, to get a straight line graph.
17.	Suhasini's mother complains of severe headache. Suhasini asked her to visit an eye specialist for a check up but suhasini's mother refused to visit the doctor saying that her eyes are perfectly alright. After a few days Suhasini saw her mother requesting her granddaughter to thread the needle. Suhasini came to know about the defects in her mothers eye. She immediately decided to do something about it. She took the help of her family members and convinced her mother to go for eye check up. The doctor found that the near point of her eyes increases to 40cm and recommended a glass lens suitable power. (a) What defect does occur in the eye of Suhasini mother? (b) What according to you , are the values displayed by Suhasini and her family to her mother. (c) Calculate the power of corrective lens recommended by Doctor.
18.	A convex lens is placed in contact with a plane mirror. A point object at a distance of 20cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?
19.	Draw a labeled ray diagram showing the formation of a final image by a refracting type telescope at least distance of distinct vision.
20.	The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focused on a certain object. The distance between the objective and the eyepiece is observed to be 14cm. if the least distance of distinct vision is 20cm, calculate the focal length of the objective and the eyepiece.
21.	A mobile phone lies along the principal axis of a concave mirror. Show, with the help of a suitable diagram, the formation of its image. Explain why magnification is not uniform. Suppose the lower half of the concave mirror is covered with an opaque material. What effect will have on the image of the object? Explain.

22.	(a) Explain, with the help of a diagram, how is the phenomenon of total internal reflection used in (i) an optical fibre (ii) a prism that inverts an image without changing its size .
23.	(b) A right angled prism made from a material of refractive index μ is kept in air. A ray PQ is incident normally on the side AB of the prism as shown in figure below Find (in terms of μ) the maximum value of □ upto which this incident ray necessarily undergoes total internal reflection at the face AC of the prism 
24	A concave mirror, of aperture 4cm, has a point object placed on its principal axis at a distance of 10cm from the mirror. The image, formed by the mirror, is not likely to be a sharp image. State the likely reason for the same.
25	An object is placed in front of convex lens made of glass. How does the image distance vary if the refractive index of the medium is increased in such a way that still it remains less than the glass?
26	A) A compound microscope consists of an objective of focal length 1cm and eye piece of focal length 5cm separated by 12.2cm. (a) At what distance from the objective should an object be placed so that the final image is formed at least distance of distinct vision? (b) Calculate the angular magnification in this case. B) How is the resolving power of microscope affected when, (a) The diameter of the objective lens is decreased? b) The focal length of the objective lens is increased?
27	Draw a graph showing the variation of angle of deviation 'δ' with that of angle of incidence 'i' for a monochromatic ray of light passing through a glass prism of refracting angle 'A'. What do you interpret from the graph? Write a relation showing the dependence of angle of deviation on angle of incidence and hence derive the expression for refractive index of the prism.
28	State the essential conditions for the phenomenon of total internal reflection to take place. Draw a ray diagram to show how a right isosceles prism made of crown glass can be used to obtain the inverted image.
29	An angular magnification of 30X is desired using an objective of focal length 1.25 cm and an eye piece of focal length 5 cm. How will you set up the compound microscope for the final image formed at least distance of distinct vision?
30	An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and an eye piece is 36 cm and the final image is formed at infinity. Calculate the focal length of the objective and the focal length of the eye piece?

Practice Questions: Ray Optics and Optical Instrument

SHORT ANSWER QUESTIONS

1. A double convex lens, made from a material of refractive index μ_2, is immersed in a liquid of refractive index μ_1 where $\mu_2 > \mu_1$. What change, if any, would occur in the nature of lens?
2. A converging lens of refractive index 1.5 is kept in a liquid having same refractive index. What would be the focal length of the lens in this liquid?
3 How does the power of a concave mirror and convex lens vary, if the incident red light is replaced by violet light?
4 Use the mirror formula to show that for an object lying between pole and focus of a concave mirror, the image formed is always virtual in nature
5 The aperture of objective lens of an astronomical telescope is doubled. How does it affect intensity of image?
6 How will you explain twinkling of stars?
7 Give reasons for the following observations made from earth
   (a) Sun is visible before the actual sunrise
   (b) Sun looks reddish at sunset.
8. A cassegrain telescope uses two mirrors 20mm apart. If the radius of curvature of large mirror is 220mm and the small mirror is 140mm, where will the final image of an object at infinity be?
9. What type of a lens is an air bubble inside water? Give reason also
10. A beam of light converges at a point on the screen. A plane parallel glass plate is introduced in the path of this converging beam. How will the point convergence be affected? Draw the relevant diagram.
11. You are given following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope?

Lenses	power	Aperture
L_1	3D	8cm
L_2	6D	1cm
L_3	10D	1cm

12. If a plane glass slab is placed on letters of different colors. Which color colors appear more raised up. Why?
13. An object is first seen in red light and the in violet light through a simple microscope. In which case is the magnifying power of simple microscope greater?
14. A person looking at a mesh of crossed wires is able to see the vertical wires more distinctly than the horizontal wires. What is this defect due to? How is such a defect of vision corrected?

LONG ANSWER QUESTIONS.

1. Which two main considerations are kept in mind while designing the objective of an astronomical telescope? Obtain an expression for the angular magnifying power and the length of the tube of an astronomical telescope in its 'normal adjustment' position.
2. A right angled isosceles glass prism is made from glass of refractive index 1.5. Show that a ray of light incident normally on
   (a) One of the equal sides of this prism is deviated through 90^0.
   (b) The hypotenuse of this prism is deviated through 180^0.

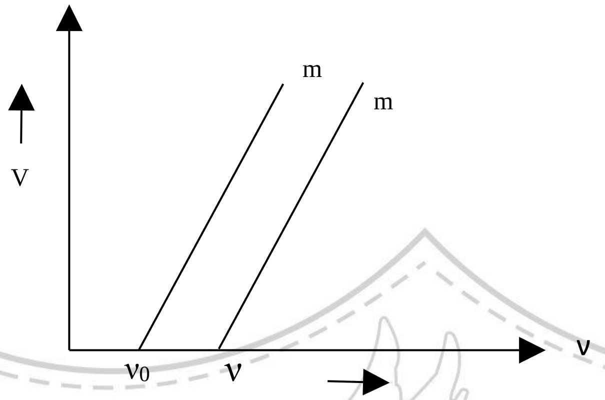
3. With the help of a labeled ray diagram, show the image formation by a compound microscope. Derive an expression for its magnifying power.
4. Write three distinct advantages of a reflecting type telescope over a refracting type telescope.
5. Use mirror formula to show that an object placed between f and 2f of a concave mirror produces a real image beyond 2f.

6. Draw a ray diagram to show the formation of the image of an object placed between F and 2F of a thin concave lens. Deduce the relation between the object distance, the image distance and the focal length of the under this condition
7. By stating the sign conventions and assumption used, derive the relation between distance of object, distance of image and radius of curvature of convex spherical surfaces, when refraction takes place from optically rarer to optically denser medium and the image formed is virtual
8. Plot a graph to show the variation of the angle of deviation as a function of angle of incidence for light rays passing through a prism. Write the relation for the refractive index of the prism in terms of the angle of minimum deviation and the angle of prism.
9. A ray of light goes from medium 1 to medium 2. Velocities of light in two media are c_1 and c_2 respectively. For an angle of incidence θ in medium1, the corresponding angle of refraction in medium 2 is $\theta/2$.
   (i) Which of the two media is optically denser and why?
   (ii) Establish the relationship between θ, c_1 and c_2.

III NUMERICAL EXAMPLES

1. A convex lens of focal length 10cm is placed coaxially 5cm away from a concave lens of focal length 10cm. if an object is placed 30cm in front of the convex lens, find the position of the final image formed by the combined system.
   Infinity
2 A sunshine recorder globe of diameter 30cm is made of glass of refractive index 1.5. a ray enters the globe parallel to the axis. Find the position from the center of the sphere where the ray crosses the axis.
   22.5cm
3. A convergent beam of light passes through a diverging lens of focal length 20cm comes to focus at distance 30cm from the lens. Find the position of the point at which the beam would converge in the absence of the lens.
   12cm
4. An illuminated object and a screen are placed 90cm apart. What is the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object?
   20cm
5. A double convex lens made of glass of refracting index 1.5 has its both surfaces of equal radii of curvature of 20cm each. An object of 5cm height is placed at a distance of 10cm from the lens. Find the position, nature and size of the image.
   -20cm , 10cm

6. The near point of a hypermetropic person is 50cm from the eye. What is the power of the lens required to enable the person to read clearly a book held at 25cm from the eye? 2D



7. An object is kept in front of a concave mirror of focal length 15cm. the image formed is three times the size of the object. Calculate the possible positions of the object?

-20cm,-10cm

8. A compound microscope has a magnification of 30. The focal length of its eye-piece is 5cm. assuming the final image to be formed at least distance of distinct vision(25cm), calculate magnification produced by the objective

-5

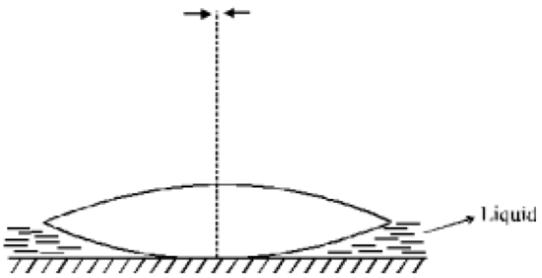
9. The magnifying power of an astronomical telescope in the normal adjustment position is 100. The distance between the objective and the eye-piece is 101cm.calculate the focal length of the objective and the eye-piece

10. The focal lengths of the objective and eye-piece of a compound microscope are 4cm and 6cm respectively. If an object is placed at a distance of 6cm from the objective. What is the magnification produced by the microscope? Distance of distinct vision =25cm

11. A small bulb is placed at the bottom of a tank containing water to depth of 80cm. what is the radius of curvature on the surface of water through which light from the bulb can emerge out. $\mu = 4/3$

12. A convex refracting surface of radius curvature 20cm separates two media of refractive indices 4/3 and 1.6. An object is placed in the first medium $\mu = 4/3$ at a distance of 200cm from the refracting surface. Calculate position of image formed?

13. An equiconvex lens with radii of curvature of magnitude r each, is put over a liquid layer poured on top of a plane mirror. A small needle, with its tip on the principal axis of the lens, is moved along the axis until its inverted real image conicides with the needle itself. The distance of the needle from the lens is measured to be 'a'. On removing the liquid layer and repeating the expriment the distance is found to be 'b'. Given that two values of distances measured represent the focal length values in the two cases, obtain a formula for the refractive index of the liquid



Multiple choice questions

1. When a ray of light enters a glass slab from air
   (a) Its wavelength decreases (b) its wavelength increases
   (c) Its frequency increases (d) neither frequency nor wavelength changes

2. A container is filled with water up to height of 33.25cm. A concave mirror is placed 15cm above the water level and the image of an object placed at the bottom is formed 25cm below the water level. The focal length of the mirror is
   (a)10cm (b) 15cm (c) 20cm (d) 25 cm

3. A ray of light travelling in water is incident on its surface open to air. The angle of incidence(θ) is less than the critical angle. Then there will be
   (a) only a reflected ray and no refracted ray
   (b) only a refracted ray and no reflected ray
   (c) a reflected ray and a refracted ray and angle between them would be less than $180^0-2\theta$.
   (d) a reflected ray and a refracted ray and angle between them would be greater than $180^0-2\theta$.

4. A convex lens A of focal length 20cm and a concave lens of focal length 5cm are kept along the same axis with a distance d between them. If a parallel beam of light falling on A leaves B as parallel beam, then the distance d(in cm) will be
   (a)25 (b) 15 (c) 30 (d) 50

5. Spherical aberration, in a thin lens can be reduced by
   (a) Using a monochromatic light
   (b) Using a doublet combination
   (c) Using a circular annular mask over the lens
   (d) Increasing the size of the lens.

6. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen,
   (a) Half the image will disappear.
   (b) Complete image will be formed
   (c) Intensity of image will decrease
   (d) Intensity of image will increase

7. One cannot see through fog , because
   (a) Fog absorbs the light
   (b) Light suffers total reflection at droplets
   (c) Refractive index of the fog is infinity
   (d) Light is scattered by the droplets.

8. A leaf which contains only green pigments is illuminated by a laser light of wavelength 0.6328μm. it would appear to be
   (a)black (b) brown (c) red (d) green

9. Rainbow is formed due to formed due to combination of
   (a)refraction and scattering (b) refraction and absorption
   (c) dispersion and total internal reflection
   (d) dispersion and focusing

10. A prism is filled with liquid of refractive index of √2. If angle of prism is 60^0, find angle of minimum deviation.
    (a)75^0 (b)60^0 (c)45^0 (d)30^0

Answer
1. a 2.c 3.c 4.b 5.c 6.b 7.d 8.a 9.c 10.d

Study Material

Scattering of light:

When sunlight enters the earth atmosphere, the atoms and molecules of different gases present in the atmosphere absorb the light. Then these atoms and molecules of gases re-emit light in all direction. This process is known as scattering of light.

The intensity of scattering light is inversely proportional to the fourth power of the wavelength of incident light.

Blue colour of the sky: During the daytime, when sunlight passes through the earth's atmosphere the very small molecules of the earth's atmosphere mainly scatter the blue light (short wavelength) towards the earth. It is the scattered blue light which reaches our eyes making the appearance of the sky blue in colour.

The sun appears reddish at sunset or sunrise: During the sunrise and sunset the sun is near the horizon and sunlight travels a long distance through the earth's atmosphere to reach our eyes. Due to this, most of the blue light is scattered away by the small molecules of the earth's atmosphere and only red light (of higher wavelength) reaches us. So the sun appears reddish at sunrise and sunset.

During noon, the sun is overhead and sunlight travels less distance through the earth's atmosphere to reach our eyes. Therefore scattering of almost all colours is very small, hence the sun appears white.

Clouds are generally white : Clouds are made of water droplets of different sizes. These different sized droplets scatter different colours. The tiniest droplet scatter more blue light, bigger one scatter more red light. As all the colours are scattered by the different droplets in clouds so the resultant light is white. Hence clouds appear white.

Tyndall Effect: The scattering of a beam of light by colloidal particles in a solution/suspension is called Tyndall effect.

Atmospheric Refraction: The refraction of light takes place when ray of light goes from one medium to another. The earth's atmosphere has air all around. The air in the atmosphere is in the form of layers. As we go up, the density of the layers decreases. The layers which are very close to the earth's surface have more density than those which are far apart.

When sunlight enters the earth's atmosphere, it continuously goes from rarer to the denser medium and hence reflection of light takes place. The refraction of light taking place in the atmosphere is known as Atmospheric refraction.

Twinkling of Stars: The sunlight, on entering the earth's atmosphere undergoes refraction. Since the light goes from rarer to the denser medium, it bends towards the normal due to which the apparent position of star appears slightly higher than its actual position. The intensity of light coming from the star also changes with the change in the apparent position of the star. This fluctuating effect leads to the twinkling of stars.

Advanced sunrise and delayed sunset: The sun is visible to us 2 minute before sunrise and 2 minutes after sunset due to atmospheric refraction.

When the sun is slightly below the horizon, then the sun's light coming from less dense air to more dense air is refracted downwards as it passes through the atmosphere. Due to this the sun appears to be raised above the horizon when it is actually slightly below the horizon.

Planets don't twinkle : The star appears very small in size while planets are bigger. Star is considered a point source of light and planets are extended source, consisting of a number of point sources of light such that they nullify the twinkling effect. Hence turbulent atmosphere is unable to cause variation in light flux entering the eye from the planet. Thus planet does not give rise to twinkling effect.

Danger signals are red in colour: Red colour light, having longer wavelength, is scattered the least. Thus the signal can be seen from very far off distance clearly.

What is the colour of the sky on the moon? Or Why does the sky appear dark to an astronaut?

The moon (or space) doesn't have an atmosphere. Hence no scattering of light takes place. Therefore the sky looks dark (black).

Primary Rainbow : After rain, a large no of tiny water droplets remain suspended in air. Every droplet acts like a small prism. They reflect and dispense the incident sunlight then reflect it internally and finally refract it again, when it comes out of the raindrop. Due to the dispersion of light and internal reflection, different colours rainbow is formed. A rainbow is always formed in a direction opposite to that of the sun.

Secondary Rainbow: It is formed by the rays which undergo two internal reflection and two refraction before emerging from the water drops. The sequence of colour in sec. rainbow is opposite to that in primary rainbow.

Chapter No.10
Wave Optics

Assignment

1.	In a double slit interference pattern, the first maxima for infrared light would be (a) at the same place as the first maxima for green light (b) closer to the centre than the first maxima for green light (c) farther from the centre than the first maxima for green light (d) infrared light does not produce an interference pattern
2.	Consider the sunlight incident on a slit of width 104 A. The image seen through the slit shall (a) be a fine sharp slit white in colour at the centre. (b) a bright slit white at the centre diffusing to zero intensities at the edges. (c) a bright slit white at the centre diffusing to regions of different colours. (d) only be a diffused slit white in colour.
3.	Consider the diffraction pattern for a small pinhole. As the size of the hole is increased (a) the size decreases. (b) the intensity decreases. (c) the size increases. (d) the intensity decreases.
4.	In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case (a) there shall be alternate interference patterns of red and blue. (b) there shall be an interference pattern for red distinct from that for blue. (c) there shall be no interference fringes. (d) there shall be an interference pattern for red mixing with one for blue.
5.	What happens to the interference pattern if the phase difference between the two sources varies continuously.
6.	For a single slit of width "a", the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of □/a. At the same angle of □ /a, we get a maximum for two narrow slits separated by a distance "a". Explain.
7.	When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a decrease in the energy carried by the light wave? Justify your answer.
8.	Why does light from clear blue portion of sky show a rise and fall of intensity when viewed through a Polaroid which is rotated?
9.	Light of $\lambda = 550nm$, is incident as a parallel beam on a slit of width 0.1mm. Find the angular width and linear with of principal maxima on a screen kept at a distance of 1.1m from the slit. Which of these widths would change if screen is moved to 2.2m?

10.	Two plane monochromatic waves propagating in the same direction with amplitudes A and 2A and differing in phase by π/3 superpose. Calculate the amplitude of the resultant wave.
11.	What is the effect on the interference fringes in a Young's double slit experiment when (i) Separation between two slits is increased. (ii) Monochromatic light is replaced by a white light. (iii)
12.	If the angle between the planes of polarizer and analyser is 60^0, by what factor does the intensity of transmitted light change when passing through analyser? How does the intensity of central maxima changes if the width of the slit is halved in a single slit diffraction experiments?
13	What are coherent sources of light? Explain why do we need coherent source to produce interference of light? Two independent sources of light cannot be coherent. Explain why?
14.	How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a Polaroid gets polarized?
15.	A partially plane polarized beam of light is passed through a Polaroid. Show graphically the variation of transmitted light with angle of rotation of Polaroid.
16.	In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is λ/3
17.	A microscope is focused on a dot at the bottom of a beaker. Some oil is poured into the beaker to a height of y cm and it is found necessary to raise microscope through a vertical distance of x cm to bring the dot into focus. Express refractive index o foil in terms of x and y
18.	How would the angular separation of interference fringes in young's double slit experiment change when the distance of separation between the slits and the screen is doubled?
19.	State the principle which helps us to determine the shape of the wavefront at a later time from its given shape at any time. Apply this principle to (i) Show that a spherical/ plane wavefront continues to propagate forward as a spherical/plane wave front. (ii) Derive Snell's law of refraction by drawing the refracted wave front corresponding to a plane wavefront incident on the boundary separating a rarer medium from a denser medium.
20.	Name the phenomenon which proves transverse wave nature of light. Give two uses of the devices whose functioning is based on this phenomenon.

21	Name the phenomenon which is responsible for the bending of light around sharp corner of an obstacle. Under what conditions does this phenomenon take place? Give one application of this phenomenon in everyday life.
22	What do we understand by 'polarization' of a wave? How does this phenomenon help us to decide whether a given wave is transverse or longitudinal in nature?
23	Two polaroids are placed with their optic axis perpendicular to each other. One of them is rotated through 45°, what is the intensity of light emerging from the second polaroid if I0 is the intensity of unpolarised light.
24	(a) When a wave is propagating from a rarer to a denser medium, which characteristic of the wave does not change and why ? (b) What is the ratio of the velocity of the wave in the two media of refractive indices μ1 and μ2 ?
25	What does a polaroid consist of ? Show, using a simple polaroid, that light waves are transverse in nature. Intensity of light coming out of a polaroid does not change irrespective of the orientation of the pass axis of the polaroid. Explain why.
26	In a double slit experiment, the distance between the slits is 3 mm and the slits are 2 m away from the screen. Two interference patterns can be seen on the screen one due to light with wavelength 480 nm, and the other due to light with wavelength 600 nm. What is the separation on the screen between the fifth order bright fringes of the two interference patterns?

Practice Questions: Wave Optics

VERY SHORT ANSWER QUESTIONS

1. What do you mean by polarization of light?
2. When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.
3. When a tiny circular obstacle is placed in the path of light from a distance source, a bright spot is seen at the center of the shadow of the obstacle. Explain why?
4. Which of the following waves can be polarized :
   (a) X-ray (b) sound waves? Give reasons
5. How does angle of polarization depend on the color of light?
6. The fringe width in diffraction patterns is x. how much is the distance between the central bright and fourth dark fringe?
7. Explain why the intensity of the first secondary maximum is much less than that of the central maximum.
8. The ratio of the intensities at minima to maxima in the interference pattern is 9:25. What will be the ratio of the widths of the two slits in the young's double slits experiment?

SHORT ANSWER QUESTIOS

1. Why is no interference patterns observed when two coherent sources are (i) infinitely close to each other (ii) far apart from each other?
2. Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slit is now completely covered. What is the name of the pattern now obtained on the screen? Draw the intensity patterns obtained in the two cases
3. What is Polaroid? How is plane polarized light obtained with its help?
4. Give differences between interferences and diffraction of light.
5. Show that the central maximum in the single slit diffraction is twice as wide as the secondary maximum and the patterns becomes narrower as the width of the slit is increased
6. What is a sustained interference pattern? State the necessary conditions for obtaining a sustained interference of light.

LONG ANSWER QUESTIONS

1. What is meant by the plane polarization light? What type of waves show the property of polarization? Describe a method for producing a beam of plane polarized light.
2. What is a wave front? What is the geometrical shape of a wave front emerging from a convex lens when a point source is placed at the focus? Using Huygen's principle show that for parallel beam incident on a reflecting surface the angle of reflection is equal to the angle of incidence?
3. Describe diffraction of light due to a single slit. Explain formation of a pattern of fringes obtained on the screen and plot the variation of intensity with angle θ in single slit diffraction
4. Derive snell's law of refraction by drawing the refracted wavefront corresponding to a plane wavefront incident on the boundary separating a rarer medium from a denser medium.

5. Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slit is now completely covered. What is the name of the pattern now obtained on the screen? Draw intensity pattern obtained in the two cases. Also write two differences between the patterns obtained in the above two cases.
6. What do we understand by 'polarization' of a wave? How does this phenomenon help us to decide whether a given wave is transverse or longitudinal in nature? Light from an ordinary source (say a sodium lamp) is passed through a polaroid sheet P_1 .The transmitted light is then made to pass through a second polaroid sheet P_2 which can be rotated so that the angle (θ) between the two polaroid sheets varies from $O^0$to 90^0. Show graphically the variation of the intensity of light, transmitted by $P_1$and P_2, as a fuction of the angle . Take the incident beam intensity as I_0. Why does the light from a clear blue portion of the sky, show a rise and fall of intensity when viewed through a polaroid which is rotated?

NUMERICAL PROBLEMS

1. Two sources of intensity I and 4I are used in an interference experiment. Find the intensity at points where the waves from two sources superimpose with a phase difference (i) zero (ii) $\pi/2$ (iii) π
2. Find the ratio of intensities at two points in a screen in Young's double slit experiment, when waves from the two slits have path difference of (i) 0 and (ii) λ
3. In a Young's double experiment, red light of wavelength $6000A^0$ is used and the nth bright fringe is obtained at a point P on the screen. Keeping the same setting, the source is replaced by green light of $5000A^0$ and now $(n+1)^{th}$ bright fringe is obtained at the point P. calculate the value of n?
   5
4. Calculate the distance that a beam of light of wavelength 500nm can travel without significant broadening, if the diffracting aperture is 3mm wide.
5. An incident beam of light of intensity I_o is made to fall on a Polaroid A. Another Polaroid B is oriented with respect to A, there is no light emerging out of B. A third Polaroid C is now midway between A and B and is so oriented that its axis bisects the angle between A & B. What is the intensity of light now between (i) A and C (ii) C and B?
6. If the two slits in Young's double slit experiment have width ratio 4:1, deduce the ratio of intensity at maxima and minima in the interference patterns. 9:1
7. In a double slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from slits. If the screen is moved by $5x10^{-2}$m towards the slit the change in fringe width is $3x\ 10^{-5}$m. If the distance between slits is $10^{-}3$m, calculate the wavelength of light used? $6000A^0$

Multiple choice questions

1. A young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is
   (a) Hyperbola (b) circle (c) straight line (d) parabola.
2. The maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double slit experiment is
   (a) Infinite (b) five (c) three (d) zero
3. The colors seen in the reflected white light from a thin oil film are due to
   (a) Diffraction (b) interference (c) polarization (d) dispersion
4. If in Young's double slit experiment of light, interference is performed in water, which of the following is correct?
   (a) Fringe with will decrease (b) fringe width will increase
   (c) fringe width will remain unchanged (d) there will be no fringe
5. Light appears to travel in a straight line, because
   (a)its velocity is very large (b) it is not absorbed by surrounding
   (c) its wavelength is very small (d) it is reflected by surrounding.
6. Polarization of light proves
   (a) Corpuscular nature of light (b) quantum nature of light
   (c) transverse wave nature of light (d) longitudinal wave nature of light
7. The angular width of central maximum of diffraction pattern of a single slit does not depend upon
   (a) Distance between slit and screen (b) wavelength of light used
   (c) Width of the slit (d) frequency of light used.
8. A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?
   (a) Bands disappear (b) no change will take place
   (c) bands becomes broader and farther apart (d) diffraction bands becomes narrower and crowded together.
9. Two waves are said to be coherent, if they have
   (a) Same phase and different amplitude (b) different frequency, phase and amplitude
   (c)same frequency , but different amplitude (d) same frequency and same phase
10. Which of the phenomenon is not common to sound and light waves?
    (a) interference (b) diffraction (c) coherence (d) polarization.

Answer

1. a 2.b 3.b 4.a 5.c 6.c 7.a 8.d 9.d 10.d

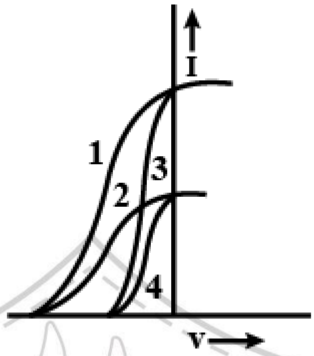
Chapter No.11: Dual Nature of Matter and Radiation

Assignment

1.	In a plot of the kinetic energy of the emitted photo electrons from a metal with respect to the frequency of the incident radiation gives a straight line whose slope (a) depends on the nature of the metal used (b) depends on the intensity of the radiation (c) is the same for all metals and independent of the intensity of the radiation (d) depends both on the intensity of the radiation and the metal used
2	The velocity of the most energetic electrons emitted from a metallic surface is doubled when the frequency (v) of incident radiation is double. What is the work function of this metal? (a) zero (b) hv/3 (c) hv/2 (d) 2hv/3
3.	When light of wavelength λ strikes a photo sensitive surface, then the kinetic energy of ejected electrons is E. If the kinetic energy is to be changed to 2E then the wavelength should be changed to λ'. The correct relation between λ and λ' is (a) $\lambda' = \lambda$ (b) $\lambda' = 2\lambda$ (c) $\lambda/2 < \lambda' < \lambda$ (d) $\lambda' = \lambda/2$
4.	K_1 and K_2 are maximum kinetic energies of photo electrons emitted when light having wavelengths λ_1 and λ_2 respectively incident on a metallic surface. If $\lambda_1 = 3\lambda_2$, then (a) $K_1 < (K_2/3)$ (b) K1 > $(K_2/3)$ (c) $K_1 = 3K_2$ (d) None of these
5.	In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by increasing the potential difference between the anode and filament. Give reason
6.	A proton is accelerated through a potential difference V. Find the percentage increase or decrease in its de-Broglie wavelength if potential difference is increased by 21%.
7	For what kinetic energy of a neutron will the associated de-Broglie wavelength be $5.6\text{x}10^{-10}$m?
8	A nucleus of mass M initially at rest splits into two fragments of masses M/3 and 2m/3. Find the ratio of de-Broglie wavelength of fragments?
9	Using Bohr model, calculate the electric current created by the electron when the H-atom is in the ground state.
10	An alpha particle and a proton are accelerated from rest through the same potential difference V. Find the ratio of de-Broglie wavelengths associated with them.
11	Define electron volt. Express its value in joule.

12	Two metals A and B have work functions 2eV and 4eV respectively. Which of the two metals has a smaller threshold wavelength?
13	State how in a photocell, the work function of the metal influence the kinetic energy of emitted electrons. If the frequency of incident light on a metal surface is doubled, will the kinetic energy of the photoelectrons be doubled? Give reason
14	a)Calculate the ratio of the de-Broglie wavelengths associated with a deuteron moving with velocity 2V and an alpha particle moving with a velocity V b) A proton and an α-particle have the same de Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.
15	By how much would the stopping potential for a given photosensitive surface go up if the frequency of the incident radiation were to be increased from $4\times10^{15}\,Hz$ to 8×10^{15} Hz? Given h $=6.4\times10^{-34}$ J-s
16	(a)Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation. (b)Draw a graph between the frequency of incident radiation υ and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. State clearly how this graph can be used to determine (i) Planck's constant and (ii) work function of the material.
17.	Draw the schematic diagram of the experimental arrangement used by Davison and Germer to establish the wave nature of electrons. Express the de-Broglie wavelength associated with electron in terms the accelerating voltage V. An electron and a proton have the same K.E. Which of the two will have larger wavelength and why?
18	Write Einstein's photoelectric equation and use it to explain the (i) independence of maximum energy of emitted photoelectrons from intensity of the incident light, (ii) existence of threshold frequency for a given photosensitive surface.
19	Name the device that converts changes in intensity of illumination into changes in electric current. Give any three applications of this device. Draw its diagram.
20	Draw the graph showing the variation of photoelectric current with anode potential of a photocell for i) the same frequencies but different intensities $I_3 < I_2 < I_1$ of incident radiation and ii) the same intensity but different frequencies $v_1 < v_2 < v_3$ of incident radiation. If the wavelength of incident light is increased, what happens to the stopping potential, kinetic energy of electrons and photoelectric current?
21	When radiation of wavelength λ is incident on a metallic surface, the stopping potential is 4.8 volts. If the same surface is illuminated with a radiation of double the wavelength, then the stopping potential becomes 1.6 volts. What is the threshold wavelength for the surface?
22	Light of wavelength 2000A^0 falls on a metal surface of work function 4.2eV. What is the kinetic energy (in eV) of (i) the fastest, and (ii) the slowest photoelectrons emitted from the surface?

23 The given graph shows the variation of photoelectric current with applied voltage for two different materials and for two different intensities of the incident radiation. Identify the pair of curves corresponding to different materials but same intensity of incident radiation.



24 An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photo electrons emitted from this surface have the de Broglie wavelength λ_1, prove that $\lambda=(2mc/h)\lambda_1^2$

25 An electron and a proton are accelerated through the same potential. Which one of the two has (i) greater value of de Broglie wavelength associated with it and (ii)less momentum? Justify your answer.

26 The ground state energy of hydrogen atom is -13.6eV. The photon emitted during the transition of electron from n=2 to n=1 state, is incident on a photosensitive material of unknown work function. The photoelectrons are emitted from the materials with a maximum kinetic energy of 8eV. Calculate the threshold wavelength of material used.

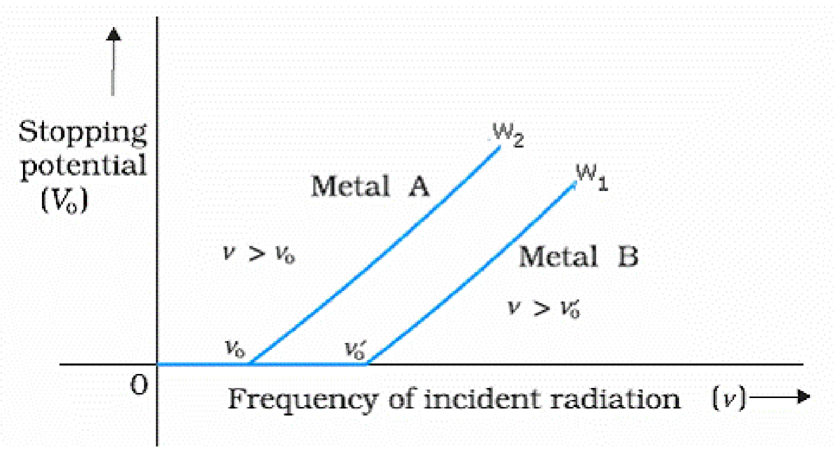
27 The given graphs show the variation of the stopping potential V_0 with the frequency v of the incident radiations for two different photosensitive materials w_1 and w_2.

(i) What are the values of work function for w_1 and w_2

(ii) The values of the stopping potential for w_1 and w_2 for a frequency v_3 (> v_0').

If the stopping potential of the incident radiations are V_1 and V_2 respectively, show that the slope of the line =

$$\frac{V_1 - V_2}{\upsilon_0' - \upsilon_0}$$



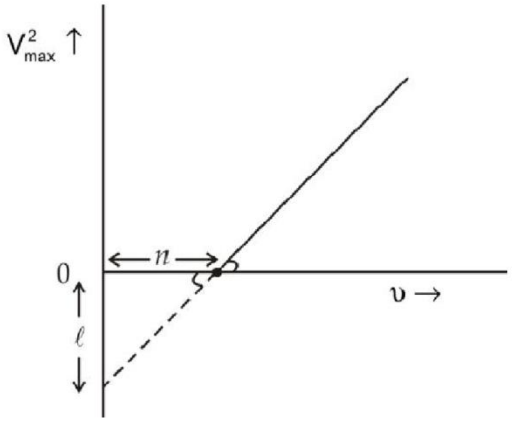
Practice Questions: Dual Nature of Matter and Radiation

VERY SHORT ANSWER QUESTIONS

1. Why are alkali metals most suited as photo-sensitive metals?
2. Work function of aluminum is 4.2eV. If two photons each of energy 2.5eV are incident on its surface, will the emission of electrons take place? Justify your answer
3. Ultraviolet light is incident on two photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$). In which case will the kinetic energy of the emitted electrons be greater? Why?
4. The de Broglie wavelengths, associated with a proton and a neutron, are found to be equal. Which of the two has a higher value for kinetic energy?
5. The stopping potential in an experiment on photoelectric effect is 1.5V. What is the maximum kinetic energy of the photoelectrons?
6. A nucleus of mass M initially at rest, splits into two fragments of masses M'/3 and 2M'/3 (M>M'). Find the ratio of de-Broglie wavelength of the two fragments.
7. The de Broglie wavelength associated with an electron accelerated through a potential difference V is λ. What will be its wavelength when the accelerating potential is increased to 4V?

SHORT ANSWER QUESTIONS

1. A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de Broglie wavelength associated with it, and (ii) less kinetic energy? Justify your answers
2. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photo-electrons emitted from this surface have the de-Broglie wavelength λ_1, prove that $\lambda=(2mc/h)\lambda_1^2$
3. The wavelength λ of a photon and the de-Broglie wavelength of an electron have the same value. Show that the energy of the photon is $(2\lambda mc/h)$ times the kinetic energy of the electron, where m, c and h have their usual meanings.
4. If the frequency of the incident radiation on the cathode of a photocell is doubled, how the following change:
   (i) Kinetic energy of the electrons
   (ii) Photoelectric current
   (iii) Stopping potential. Justify your answer
5. Mention the significance of Davison-Germer experiment. An alpha particle and a proton are accelerated from rest through same potential difference V. Find the ratio of de-Broglie wavelength associated with them $2\sqrt{2}$
6. Define work function for a metal. Every metal has a definite work function. Why do all photoelectrons not come out with same energy if incident radiation is monochromatic?
7. The variation of square of maximum speed of photoelectrons V max with the frequency of incident radiation r is shown in figure given below. Obtain expressions for
   (i) Planck's constant , and
   (ii) The work function of the given photosensitive materials in terms of the parameters, l, n, and the mass of the electron.



NUMERICAL PROBLEMS

1. By how much would the stopping potential for a given photosensitive surface go up if the frequency of the incident radiations were to be increased from $4x10^{15}$Hz to $8x10^{15}$Hz?
2. Calculate the longest wavelength of radiation which will eject an electron from the surface having work function 1.9eV.
3. Work function of an emitter is 2.14eV. A stopping of 600mV brings the emission of photo electrons to zero. Find wavelength of the incident light and cut off frequency of the emitter also.
   $5.16X10^{14}$Hz
4. A transmitter of 10kV is emitting radio waves of wavelength 500m. How many photons per second are emitted by the transmitter?
   $2.5X10^{31}$
5. Calculate the maximum kinetic energy of electrons emitted from a photosensitive surface of work function 3.2eV , for the incident radiation of wavelength 300nm

Multiple choice questions

1. The time taken by a photoelectron to come out after the photon strikes is approximately
   (a) 10^{-4}s (b) 10^{-10}s (c) 10^{-16}s (d) 10^{-1}s
   (b)
2. A photocell is illuminated by a small bright source placed 1m away. when the same source of light is placed 0.5m away, the number of electrons emitted by photo cathode would
   (a)decrease by a factor of 4 (b) increase by a factor of 4
   (c) decrease by a factor of 2 (d) increase by a factor of 2

3. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal versus the frequency of incident radiation gives a straight line, whose slope
   (a)depends on the nature of the metal used
   (b) depends on the intensity of the radiation
   (c) depends both on the intensity of the radiation and the metal used
   (d) is same for all metals and independent of the intensity of the radiation.

4. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is
(a)E/c (b) 2E/c (c) Ec (d) E/c^2

5. A photocell employs photoelectric effect to convert
(a)change in the frequency of light into a change in the electric current
(b) change in the frequency of light into a change in electric voltage
(c) change in the intensity of illumination into a change in photoelectric into a change in
photoelectric current.
(d)change in the intensity of illumination into a change in the work function of the photo
cathode.

6. A source of 25W emits monochromatic light of wavelength 6600A^0. If efficiency for photo electric emission is 3%,then the photoelectric current would be
(a) 0.4A (b) 4A (c) 0.4μA (d) 0.4mA
(b)

7. The work function for an emitter is 4.2eV. For what wavelength of incident light, the stopping potential would be zero?
(a) 2000A^0 (b) 2555A^0 (c) 2955A^0 (d) 3000A^0

8. When light of wavelength 300nm falls on a photoelectric emitter, photoelectrons are emitted. For another emitter, light of wavelength 600nm is sufficient for liberating photoelectrons. The ratio of the work function of the two emitter is
(a) 2:1 (b) 1:2 (c) 4:1 (d) 1:4
(b)

9. When green light is incident on a certain metal surface, electrons are emitted, but no electrons are emitted by yellow light. If red light is incident on the same metal surface, then
(a) More energetic electros will be emitted
(b) Less energetic electrons will be emitted
(c) Emission of electrons will depend on the intensity of light
(d) No electrons will be emitted.
(e)

10. A particle A has charge +q and a particle B has a charge +4q with each of them having same mass m. when allowed to fall from rest through the same potential difference, the of their speed will become
(a) 2:1 (b) 1:2 (c) 1:4 (d) 4:1

Answer
1.b 2.b 3.d 4.b 5.c 6.a 7.c 8.a 9.d 10.b

STUDY MATERIAL
Dual Nature of Matter &Radiation

A metal has free electrons, but these electrons cannot come out of the metal surface. It is because, as an electron makes an attempt to come out of the metal surface, the metal surface acquires positive charge and the electron is pulled back into the metal. Thus, free elections are held inside the metal surface by the positive ions, it contains. In order that an electron may come out of the metal surface, it must possess sufficient energy to overcome the attractive pull of the positive ions.

The minimum amount of energy required to eject an electron out of a metal surface is called work function of the metal. It is denoted by ω .

By supplying energy atleast equal to work functionelectron emission can caused from a metal surface by thefollowing processes:

1. Thermionic emission. It can be caused by supplying the minimum required energy by heating the metal surface to a suitable temperature.
2. Field emission. It can be caused by applying an electric field to the metal surface. If the electric field is sufficiently strong (= 10^8V/m), the electrons get pulled out of the metal surface.
3. Photoelectric emission. It can be caused by supplying the minimum required energy by illuminating the metal surface with light of suitable frequency.

• Dual nature of Radiation

The various phenomena concerning radiation can be divided into three parts:

1**. *The phenomena such as interference, diffraction, polarization, etc in which interaction radiation takes places with radiation itself. Such phenomena can be explained on the basis of electromagnetic (wave) nature of radiation only.***
2. The phenomena such as photoelectric effect, Compton Effect, etc in which interaction radiation takes place with matter. Such phenomena can be explained on the basis quantum (particle) nature of radiation.
3. The phenomena such as rectilinear propagation, reflection, refraction, etc in which interaction of radiation takes place neither with itself, nor with matter. Such phenomena can be explained on the basis of either of the two natures of the radiation.

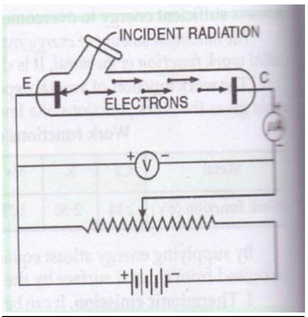
It may be pointed out that in a particular experiment, radiation has a particular nature i.e. either it possesses wave nature or particle nature.

PHOTOELECTRIC EFFECT

Hallwach discovered that an insulated zinc plate connected to a gold leaf electroscope and charged negatively lost its charge, when a beam of ultra-violet light was directed on the plate. In order to explain this observation, Hallwach suggested that the metal surface loses negative charge due to ejection of electrons from its surface by the ultra-violet light. The effect was termed as photoelectric effect.

The phenomenon of ejection of electrons from a metal surface, when light of sufficiently high frequency falls upon it, is known as the photoelectric effect. The electrons so emitted were called photoelectrons. J. J. Thomson showed that the photoelectrons were not different from the ordinary electrons.

EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT



In 1900, Lenard studied the photoelectric effect experimentally the experimental arrangement used to study the photoelectric effect.
The apparatus consists of an evacuated glass tube fitted with two electrodes. The electrode E is called the emitter and the other electrode C is called the collector or anode. A varying potential difference can be applied across the two electrodes. The polarity of the electrodes E and C can be reversed. Thus, the collector C can be maintained at a positive or negative potential w.r.t. the emitter E. The intensity and frequency of the light incident on the emitter can also be varied .
When a suitable radiation is incident on the emitter, electrons are ejected from its surface. If the collector is at a positive potential w.r.t. the emitter, the electrons are attracted by it. It leads to the flow of current, called photocurrent in the circuit, which is measured by a micro ammeter (□A). The photocurrent can be increased or decreased by varying the potential of the collector W.r.t. the emitter.

On the other hand, when the collector is maintained at a negative potential w.r.t. the emitter, the electrons are repelled by it. The electrons, which have sufficient kinetic energy, reach the collector despite its negative polarity. The potential difference between the two electrodes acts as the retarding potential. As the collector made more and more negative, fewer and fewer electrons will reach the collector and the photoelectric current recorded by the micro ammeter will decrease. In case the retarding potential equals Vo, called the stopping potential, no electron will reach the collector and the current will become zero. In such a case, the work done by the stopping potential is equal to the maximum kinetic energy of the electrons i.e.

$$e V_o = \frac{1}{2} m v^2_{max}$$

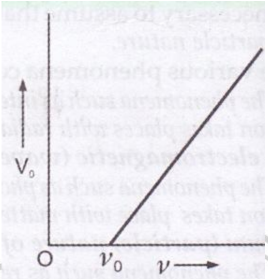
As e, the charge on electron, is constant,

$$V_o \propto \frac{1}{2} m v^2_{max}$$

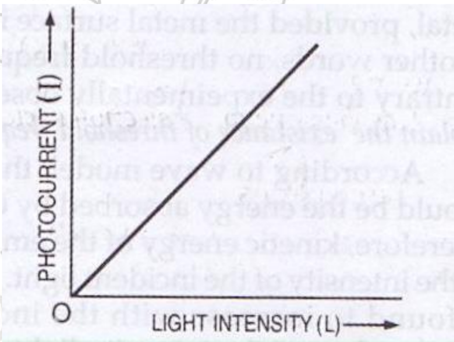
Thus, the stopping potential gives the estimate of the maximum kinetic energy, with which the photoelectrons may be emitted.

Laws of photoelectric emission.

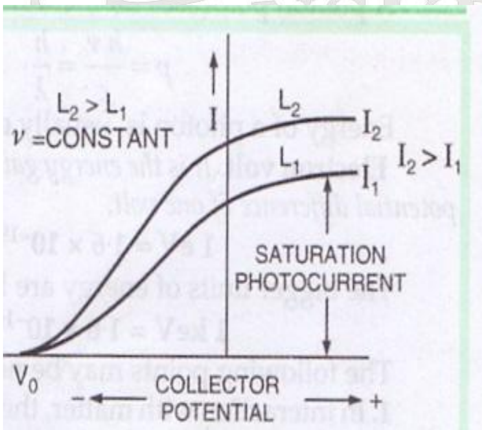
1. The emission of photoelectrons takes place only when the frequency of the incident radiation is above a certain critical value, characteristic of that metal. The critical value of frequency is known as the threshold frequency for the metal used to make the emitter.



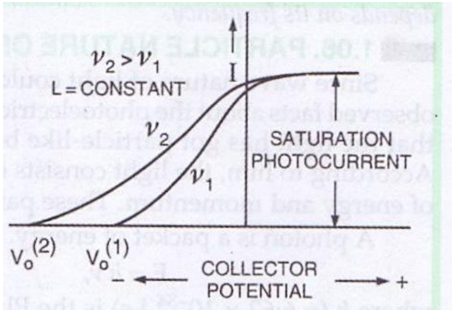
2. The emission of photoelectrons starts as soon as light falls on metal surface. It has been found that the time lag between the incidence of photon and the emission of electron is less than 10^{-9} s.



3. The number of photoelectrons emitted (photoelectric current) from a metal surface depends only on the intensity of the incident light and is independent of its frequency.



4. The maximum kinetic energy with which photoelectrons are emitted from a metal surface depends only upon the frequency of the incident light and is independent of its intensity.



<u>FAILURE OF CLASSICAL WAVE THEORY</u>

Attempts were made to explain the laws of photoelectric effect on the basis of wave nature of radiation. However, it failed to explain the various features of the photoelectric effect as discussed below :

According to wave model, when light is incident on a metal surface, it spreads evenly all over the metal surface. The energy of the incident light is shared by all the free electrons present at the surface of the metal. As a result, an electron receives energy, which is too small to eject it out of the metal surface. However, with the passage of time, energy goes on accumulating with an electron, till it becomes just sufficient to eject it out. The calculations" show that it may take days or even months for an electron to gather the required energy. However, photoelectric effect is found be instantaneous. Thus, wave nature of radiation cannot explain the instantaneous emission of photoelectrons.

According to wave model, no matter what the frequency of the incident light is, even less energetic light should be able to cause photoelectric emission in any metal, provided the metal surface is kept exposed to the light for a sufficient time. In other words, no threshold frequency exists for a metal surface. However, it is contrary to the experimentally observed fact. Thus, wave nature of radiation can not explain the existence of threshold frequency for a metal surface.

According to wave model, the greater the intensity of incident light, greater should be the energy absorbed by each electron present at the surface of the metal. Therefore, kinetic energy of the emitted electrons should increase with the increase in the intensity of the incident light. However, kinetic energy of the emitted electrons is found to increase with the increase of frequency of the incident light and independent of the intensity light. Thus, wave nature of radiation cannot explain the fact that kinetic energy of the emitted electrons is independent of the intensity light and depends on its frequency.

<u>Particle nature of light- photon.</u>

Since wave nature of light could not offer any satisfactory explanation of photoelectric effect, Einstein suggested that the light has got particles like behavior during its interaction with matter.

According to him, the light consists of particles associated with a definite amount of energy & momentum. These particles are called photons.

A photon is a packet of energy. It possess energy given by E= h□

Where h= 6.62 x 10^{-34}JS is the planck's constant
C=□□
: E= h□=hc/□
Electron Volt- It is the energy gained by an e^- when it is accelerated through a pot diff. of one volt 1eV=1.6 x 10^{-19}J.

<u>The particle nature of radiation:</u>

1. In interaction with matter, the radiation behaves as particles called photons.
2. The rest mass of photon is zero.
3. The photons are electrically neutral.
4. The photons are not deflected by E&B fields.
5. The photons travels with the speed of light.
6. A photon has energy E= h□& momentum p= h□/c= h/□.
7. The increase in intensity of the radiation imply an increase in the no. of photons crossing a given area per sec.

<u>EINSTEIN'S PHOTOELECTRIC EQUATION</u>

To explain photoelectric effect, Einstein postulated that the energy carried by a photon of radiation of frequency v is h v. According to him, the emission of a electron was the result of the interaction of a single photon with an electron, ih the photon is completely absorbed by the electron.

The minimum amount of energy required to eject an electron out of the metal surface is called the work function of the metal. It is denoted by w.

Thus, when a photon of energy h v is absorbed by an electron, an amount of at least equal to w (provided h v> w) is used up in liberating the electron free and the difference h v - w becomes available to the electron as its maximum kinetic energy
Thus,

$$1/2 \ m v^2_{max} = hv-w$$

$$1/2 \ m v^2_{max} + hv = w$$

Where $w = hv_o$
The work function of the metal is a characteristic of the metal and does not depend upon the nature of the incident radiation. It is sometimes also the threshold energy of the metal.

$$1/2 \ m v^2_{max} = hv - hv_o$$

The above relation is called the Einstein's photoelectric equation.

1. For photoelectric emission to take place, the kinetic energy of the emitted electrons must be positive. From the equation, it follows that the photoelectrons will possess positive kinetic energy only if h v > hvo or if v >vo It proves that for photoelectric emission to take place, the frequency of the incident radiation must be greater than threshold frequency for the metal. If the frequency of the incident radiation is the threshold frequency for the metal, no photoelectric emission will take no matter how intense the incident radiation may be or how long it falls on metal surface.

2. From the equation, it follows that the value of maximum kinetic energy of the emitted photoelectrons depends linearly on the frequency. It proves that the maximum kinetic energy of the emitted photoelectrons increases, as the frequency of the incident radiation is increased. Since the Einstein's equation does not involve a factor representing intensity of the incident radiation, it proves that the maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident radiation.

3. According to Einstein, the photoelectric effect arises, when a single photon is absorbed by a single electron i.e. it is a one photon-one electron phenomenon.

Therefore, number of photoelectrons ejected will be large, when intense radiation is incident. It is because; intensity of radiation is proportional to number of photons per unit area per unit time. Therefore, an intense radiation will contain a large number of photons and likewise, the number of photoelectrons emitted will also be large. It proves that the number of photoelectrons emitted depends on the intensity of incident radiation. Further, there is no effect of frequency of the incident radiation on the number of photoelectrons emitted. It is because; one photon is capable of ejecting only one electron, provided v > vo'

4. According to Einstein, the basic process involved in photoelectric emission is absorption of a photon of light by an electron. Therefore, as the photon is absorbed, the emission of electron takes place instantaneously. It may be noted that irrespective of the intensity of the incident radiation, photoelectric emission is instantaneous.

VERIFICATION OF EINSTEIN PHOTOELECTRIC EQUATION

In an attempt to disprove the Einstein's photoelectric equation, RA. Millikan performed a series of experiments. However, in 1912, instead of disproving, his experiments rather proved the correctness of Einstein's photoelectric equation. From the Einstein's photoelectric equation, we have

$1/2\ m\ v^2{}_{max} = h\ v - h\ vo$

If e is charge on electron and Vo is the stopping potential, then

$1/2\ m\ v^2{}_{max} = e\ Vo$

From the above two equations, we get

eVo = hv - hvo

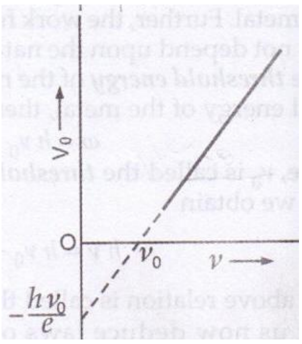
Vo = hv/e - hvo/e

= hv/e - w/e

y = mx + c

m = tan θ =h/e

h = e X slope



Millikan plotted a graph between the frequency v (along X-axis) and the stopping potential Vo (along Y-axis) over a wide range of frequencies. The graph was a straight line. It has a slope h/e and makes an intercept – hvo/e on Y-axis
By measuring the slope of the graph and using the known value of e, Millikan determined the value of h.
Millikan also determined the value of the work function of the metal used in the experiment. By definition, when light of threshold frequency (vo) is incident, photoelectrons just come out and no stopping potential is required. Therefore,
when v =vo Vo= 0
i.e. the intercept of the straight line graph on v-axis gives the threshold frequency vo, which when multiplied with h, gives the work function of the alkali metal.
The values of Planck's constant and work function of the metal determined by Millikan were in close agreement with values obtained from other experiments. It verified the correctness of Einstein's photoelectric equation.

WAVE NATURE OF MATTER

DE-BROGLIE WAVES (MATTER NATURE)

Radiation behaves both as wave and particle. In 1924, Loius de-Broglie put forward a bold hypothesis that matter should also possess dual nature.
The following observations led him to the duality hypothesis for matter: .
1. The whole energy in this universe is in the form of matter and electromagnetic radiation.
2. The nature loves symmetry. As the radiation has got dual nature, matter should also possess dual nature.
Thus, according to de-Broglie, a wave is associated with every moving particle.
These waves are called de-Broglie waves or matter waves.
According to the quantum theory of radiation, energy of a photon is given by
E = h v
Further, the energy of a relativistic particle is given by
$E = mc^2$
E=pc
From the equations pc=hv
- p= hv/c
=h/λ
Therefore, the wavelength of the photon is given by λ =h/p =h/mv
This is called de-Broglie relation. It connects the momentum, which is characteristic of the particle, with the wavelength, which is characteristic of the wave.
From the equation the following conclusions can be drawn:
(i) Lighter the particle, greater is its de-Broglie wavelength.
(ii) The faster the particle moves, the smaller is its de-Brogue wavelength

(iii) The de-Broglie wavelength of a particle is independent of the charge or nature of the particle.
(iv) The matter waves are not electromagnetic in nature. The electromagnetic waves are produced only in the accelerated charged particles.

DE-BROGLIE WAVELENGTH OF ELECTRON

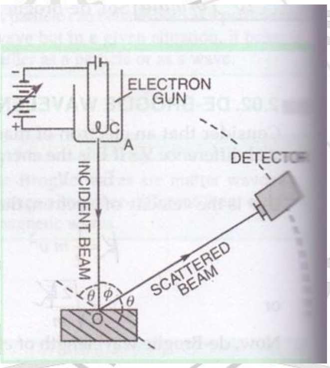
Consider that an electron of mass m and charge e is accelerated through a Potential difference V. If E is the energy acquired by the particle, then
$E=eV$
If v is the velocity of electron, then
$E = 1/2.\ m v^2$
$v = (2E/m)^{1/2}$
Now, de-Broglie wavelength of electron is given by
$\lambda = h/mv = h/m\ (2E/m)^{1/2} = h/m\ (2mE)^{1/2}$

Substituting the value of E (= e V), we get

$\lambda = h/\ m\ (2eV/m)^{1/2}$
$= h/\ \sqrt{2meV} = 12.27/\ \sqrt{V}\ \ X\ 10^{-10}$ m

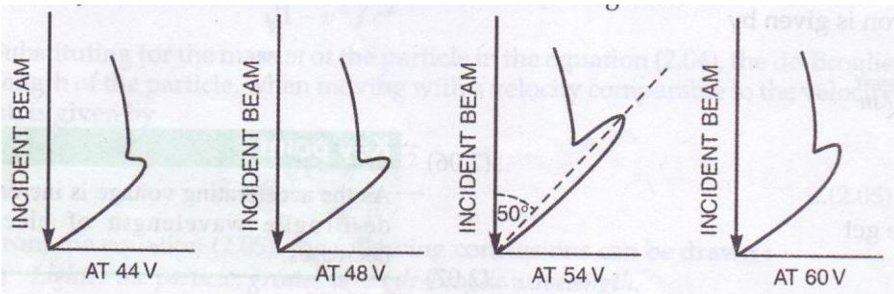
EXPERIMENTAL DEMONSTRATION OF WAVE NATURE OF ELECTRON

The wave nature of the material particles as predicted by de-Broglie was confirmed by Davisson and Germer (1927) in United States and by G.P. Thomson (1928) in Scotland. To demonstrate the wave nature of electrons, Davisson and Germer experiment is as discussed below:



Davisson and Germer experiment. Experimental arrangement used by Davisson and Germer is as shown. Electrons from hot tungsten cathode (C) are accelerated by a potential difference V between the cathode and anode (A).
A narrow hole in the anode renders the electrons into a fine beam of electrons and allows it to strike the nickel crystal. The electrons are scattered in all directions by the atoms in the crystal. The intensity of the electron beam scattered in a given direction is found by the use of a detector. By rotating the detector about an axis through the point 0, the intensity of the scattered beam can be measured for different values of □, the angle between incident and the scattered direction of electron beam.
The graph is plotted between angle □and the intensity of scattered electron beam. Such graphs are plotted at different accelerating voltages. In each graph, the intensity of electron beam in a given direction is proportional to the distance of the curve from the

point 0 (the point of scattering) in that direction



From these experimental curves, following inferences can be drawn:

(i) Intensity of scattered electrons depends upon the angle of scattering ϕ.
(ii) Always a 'bump' or a kink occurs in the curve at ϕ= 50°, the angle which the scattered beam makes with the incident beam.
iii) The size of the bump goes on increasing as the accelerating voltage is increased.
(iv) The size of the bump becomes maximum, when accelerating voltage is 54 volt.
(v) The size of the bump starts decreasing with further increase in accelerating voltage.
However, according to classical physics, there should be very little variation the intensity of electron beam with the angle of scattering and the accelerating voltage.

Explanation. The maximum intensity obtained in particular direction ϕ = 50°is due to constructive interference of electrons scattered from different layers of the regularly spaced atoms of the crystal at an accelerating voltage of 54 V

$$\theta = \frac{1}{2}(180^\circ - \phi)$$

For $\phi = 50^\circ,\ \theta = \frac{1}{2}(180^\circ - 50^\circ) = \frac{1}{2} \times 130^\circ = 65^\circ$

According to Bragg's law, for first order diffraction maximum ($n = 1$), we have

$2\,d \sin\theta = 1 \times \lambda$ or $\lambda = 2\,d \sin\theta$

For nickel crystal, the distance between atomic planes, $d = 0{\cdot}91$ Å

Therefore, $\lambda = 2 \times 0{\cdot}91 \times \sin 65^\circ = 1{\cdot}66$ Å

Now, the wave nature of electron and hence the de-Broglie hypothesis will be confirmed, if the de-Broglie wavelength of the electrons, when accelerated through 54 volt comes out to be just 1·66 Å.

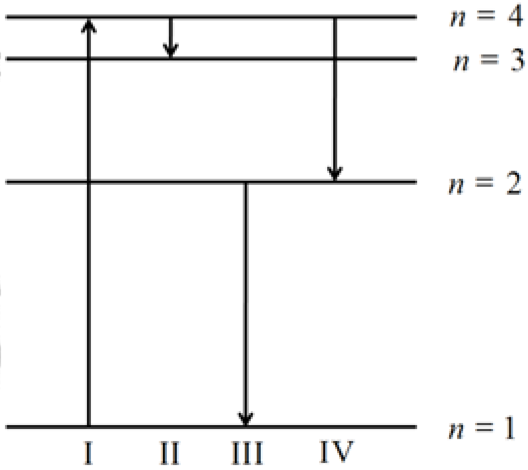
Putting V = 54 volt in the equation (2.08), we get

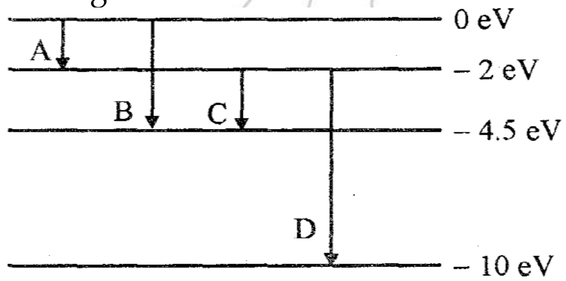
$$\lambda = \frac{12{\cdot}27}{\sqrt{54}} = 1{\cdot}65 \text{ Å}$$

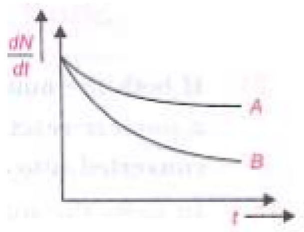
As the two results are in remarkable agreement, the experiment establishes the wave nature of an electron in particular and of a particle in general.

Chapter No 12& 13: Atoms and Nuclei

Assignment

1.	The ionization energy of an electron in a hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of wavelengths Maximum wave- length of emitted radiation corresponds to the transition between (a) n = 4 to n = 3 states (b) n = 3 to n = 2 states (c) n = 3 to n = 31 states (d) n = 2 to n = 1 states
2	The energy level for an electron in a certain atom is shown in the figure given below. Which of the transitions shown in the figure represents the emission of a photon with maximum  energy? (a) I (b) II (c) III (d) IV
3.	The transition from the state n = 4 to n = 3 in a hydrogen like atom results in ultra = violet radiation. Infrared radiation will be obtained in the transition from. (a) 3 – 2 (b) 2 – 1 (c) 4 – 2 (d) 5 – 4
4.	The total energy of an electron in the ground state of a hydrogen atom is – 13.6 e V. What is the K.E. of this electron in the first excited state? (a) 13.6 eV (b) 6.8 eV (c) 1.7 eV (d) 3.4 eV
5.	The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. Give reasons
6.	Name the series of hydrogen spectrum which lies in the visible region of electromagnetic spectrum?

7	In the nuclear decay relation ${}_1^1H \rightarrow {}_0n^1 + {}_PX^Q$: Identify X
8	Four nuclei of an element fuse together to form a heavier nucleus. If the process is accompanied by release of energy, which of the two-the parent or the daughter nucleus would have a higher binding energy/nucleus?
9	Calculate the ratio of energies of photons produced due to transition of electron of hydrogen atom from its (a) second permitted energy level to the first level, and (b) highest permitted energy level to the second permitted level
10	The energy levels of a hypothetical atom are shown below. Which of these transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions correspond to emission of radiation of 1) maximum wavelength 2) minimum wavelength? 
11	Two radioactive nuclei X and Y initially contain an equal number of atoms. Their half-life is 1hour and 2hour respectively. Calculate the ratio of their rate of disintegration after 2hours.
12	What are thermal neutrons? Why are they so effective as bombarding particles?
13	State Bohr's postulate for the permitted orbits for the electron in a hydrogen atom. Use this postulate to prove that the circumference of the nth permitted orbit for the electron can contain exactly n wavelength of de-Broglie wavelength associated with electron in that orbit.
14	The nucleus Ne 23 decays by β-emission. Write down the β-decay equation and determine the maximum kinetic energy of the electrons emitted from the following data m(10Ne23) = 22.994466u m(11Na23) = 22.989770u (Given 1u = 931.5Mev/c^2)
15	a) Draw the energy level diagram of showing the emission of beta particles followed by gamma rays by a ${}_{27}Co^{60}$ nucleus. b) Why is it very difficult to detect neutrino?
16	In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of Z= 80 , when an α particle of 8 MeV energy impinges on it before it

	comes momentarily to rest and reverses its direction. How will the distance of closest approach be affected when the kinetic energy of the α particle is doubled?
17	A radioactive nucleus undergoes a series of decay according to the scheme. $A \xrightarrow{\infty} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\infty} A_3 \xrightarrow{\gamma} A_4$ If mass number and atomic number of A_4 are 172 and 69 respectively. What are these numbers for A?
18	Calculate the longest and shortest wavelength in the Balmer series of hydrogen spectrum. Given R= 1.0987 x 10^7/m.
19	Which of the following radiations are α β and γ rays. a. Similar to X rays b. Easily absorbed by the matter c. Travel with greatest speed. d. Similar in nature to cathode rays?
20	(Draw the plot of binding energy per nucleon (BE/A) as a function of mass number A. Write two important conclusions that can be drawn regarding the nature of nuclear force. a) Mark the region where the nuclei are most stable. (b)Use the graph to explain the release of energy in both the processes of nuclear fusion and fission.
21	Find the Q- value and the kinetic energy of the emitted a-particle in the α- decay of $_{88}Ra^{226}$ Given m($_{88}Ra^{226}$)= 226.02540u, m($_{86}Rn^{222}$)= 222.01750u, m($_{86}Rn^{220}$) =220.01137 u, m($_2He^4$)= 4.00260 u. Also write the equation .
22	The decay constant for the radioactive nuclide Cu^{64} is 1.516 x 10^{-5} s^{-1}. Find the activity of a sample containing 1μg of Cu^{64}. Take atomic weight of copper = 63.5g/mole.
23	Which nucleus has greater mean life, A or B? Why? 
24	Write the basic nuclear process of neutron undergoing β- decay. Write symbolically the β - decay process of $_{15}P^{32}$.
25	A photon falls on a hydrogen atom which is initially in the ground state and excite it to the n= 4state. Calculate the wavelength of the photon

26	Draw a plot of binding energy per nucleon as a function of mass number for a large number of nuclei, $2 < A < 240$. How do you explain the constancy of binding energy per nucleon in the range $30 < A < 170$ using the property that nuclear force is short - ranged?
27	How will the distance of closest approach change when (i) the K.E of the projectile is doubled (ii) velocity of the projectile is halved?

Practice Questions: Atoms & Nuclei

Very Short Answer Questions

1. Write two important inferences drawn from Rutherford's alpha particle scattering experiment.
2. The total electrical energy of an electron in the first excited state of hydrogen atoms is about -3.4eV. What is the potential energy of the electron in this state?
3. The element like tritium and plutonium are not found in observable quantities in nature. Why?
4. A radioactive substance decays to 1/32th of its initial activity in 25days. Calculate its half life?
5. Plutonium decays with a half life of24000 years. If plutonium is stored for 72000years, what fraction of its remains?
6. When ${}_3Li^7$ is bombarded with a certain particle, two alpha particles are produced. Identify the bombarding particle
7. Why is heavy water used as a moderator in a thermal nuclear reaction?
8. Name the series of hydrogen spectrum which lies in the visible region of electromagnetic spectrum?
9. Define impact parameter. What is its value when a particle scattered through an angle of 180^0.
10. A beam of monochromatic photon of energy 9eV is incident on a hydrogen gas containing all atoms in ground state. It is found that the beam is fully transmitted without absorption. Why?

11 Binding energy of $2He^4$ and $3Li^7$ are 27.37 Mev and 39.3Mev respectively. Which of the two nuclei is more stable?

12 Why do α particle have high ionizing power?

13 The mean life of a radioactive sample is T_m . What is the time in which 50% of this sample would get decayed?

14 The mass number of He is 4 and that of Sulphur is 32 .By what factor is the radius of the Sulphur nucleus larger than that of helium?

15 The sequence is represented as $D \xrightarrow{\alpha} D_1 \xrightarrow{\beta} D_2 D \xrightarrow{\alpha} D_1 \xrightarrow{\beta} D_2$ if the mass numbers and atomic numbers of D_2 are 176 and 71 respectively, what is the mass number and atomic number of D.

Short and Long Answer Questions

1. Prove that the instantaneous rate of change of the activity of a radioactive substance is inversely proportional to the square of its half life.
2. Define the term 'Activity' of a radioactive substance. State its SI unit. Two different radioactive elements with half lives T_1 and T_2 have N_1 and N_2 atoms respectively present at a given instant. Determine the ratio of their activities at this instant.
3. Plot the distribution of kinetic energy of beta particles and state why the energy spectrum is continuous.
4. Define critical size and critical mass of a fissionable material. What happens when the size becomes supercritical and subcritical?
5. Explain the role played by the moderator in a nuclear reactor.

6. A nucleus makes a transition from one permitted energy level to another level to lower energy. Name the region of the electromagnetic spectrum to which the emitted photon belongs. What is the order of its energy is electron volts? Write four characteristics of nuclear force.

7 Draw a graph showing the variation of potential energy between the pair of nucleons as the function of their separation. Indicate the regions in which the nuclear force is attractive and repulsive.

8 Show that Bohr's second postulate "The electron revolves around the nucleus only in certain fixed orbits without radiating energy" can be explained on the basis of de – Broglie hypothesis of wave nature of electron.

9 Derive an expression for the potential and kinetic energy of an electron in any orbit of a hydrogen atom. How does the potential energy change with increasing n?

10 A registered medical practitioner sends his patient repeatedly for X ray examinations. The patient tells the doctor that repeated exposure to X rays is harmful but the doctor tells him not to worry as he knows better. Do you are a student of physics or a person of values need to talk to the doctor or not? Explain.

11. In a given sample, two radioactive nuclei A and B, are initially present in the ratio 4:1 . The half lives of A and B are 25 years and 50 years respectively. Find the time after which the amounts of A and B become equal

Numerical Problems

1. In a head on collision between an alpha particle and a gold nucleus, the alpha particle is deflected by 180^0 when it was at a distance of 39.5fermi from the nucleus. Calculate energy of alpha particle in MeV.

   5.75eV
2. A radioactive material is reduced to 1/16 of its original amount in 4 days. How much material should one begin with so that $4X10^{-3}$kg of the material is left after 6days? 0.256kg.
3. In a given sample, two radioactive nuclei A and B, are initially present in the ratio 4:1 . The half lives of A and B are 25 years and 50 years respectively. Find the time after which the amounts of A and B become equal. (100 yrs)
4. A heavy nucleus X of mass number A=240 and binding energy per nucleon 7.6MeV is split into two nearly equal fragments Y and Z of mass numbers A_1=110 and A_2=130. The binding energy of each one of these nuclei is 8.5MeV per nucleon. Calculate the total binding energy of each of the nuclei X,Y and Z and hence the energy released per fission in MeV. 216MeV
5. The nucleus Ne^{23} decays by β-emission. Write down the β-decay equation and determine the maximum kinetic energy of the electron emitted from the following data: m($_{10}Ne^{23}$) =22.994466amu, m($_{11}Na^{23}$) = 22.989770amu
6. A 12.5eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelength s will be emitted?

Competition Kit :

1. What is the ratio of nuclear radii of $_1H^1$ and $_{13}Al^{27}$?
   a) 1:2 (b) 2:1 (c) 1:3 (d) 3:1
2. When $_3Li^7$ nuclei bombarded by protons, and the resultant nuclei are $_4Be^8$,the emitted particles will be:
   (a) α-particle (b) β- particle
   (c) γ-photon (d) neutron

3. The binding energy per nucleon for deuteron and helium are 1.1Mev and 7.0Mev respectively. The energy released when two deuterons fuse to form a helium nucleus is
   (a) 3.6 Mev (b) 2.2 Mev (c) 23.6 Mev (d) 28.0 Mev

4. An atom bomb works on the principle of
   (a)Nuclear fusion (b) nuclear fission (c) α-decay (d) β- decay

5. If 75% of the radioactive reaction is completed in two hours, what would be the half life of the substance?
   (a) 1hour (b) 1.5 hour (c) 2 hour (d) 3 hour
   (b)
6. Which of the following spectral series in hydrogen atom give spectral line of 4860A^0?
   (a) Lyman (b) Balmer (c) Paschen (d) Brackett
7. In gamma ray emission from a nucleus
   (a) Only the neutron number changes
   (b) Only the proton number changes
   (c) Both the neutron number and proton number change
   (d) There is no change in the proton number and the neutron number.
8. I. Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion
   II. For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z.
   (a) Statement I is true, statement II is false
   (b) Statement I is false, statement II is true
   (c) Statement I is true, statement II is true and statement II is correct explanation for statement I
   (d) Statement I is true, statement II is true and statement II is not a correct explanation for statement I
9. Which of the following transitions in hydrogen atom emit photon of highest frequency?
   1. n = 2 to n =1 (b) n = 1 to n =2 (c) n =2 to n = 6 (d) n =6 to n= 2

10. The largest wavelength in the ultraviolet region of hydrogen spectrum is 122nm. The smallest wavelength in the infrared region of the hydrogen spectrum is
    2. 802nm (b) 823nm (c) 1882 nm (d) 1648nm

1. c 2.c 3.c 4.b 5.a 6.b 7.d 8.a 9.a 10. b

Study Material

Davisson and Germer Experiment

Davission and Germer experiment: This electron diffraction experiment has verified and confirmed the wave-nature of electrons.

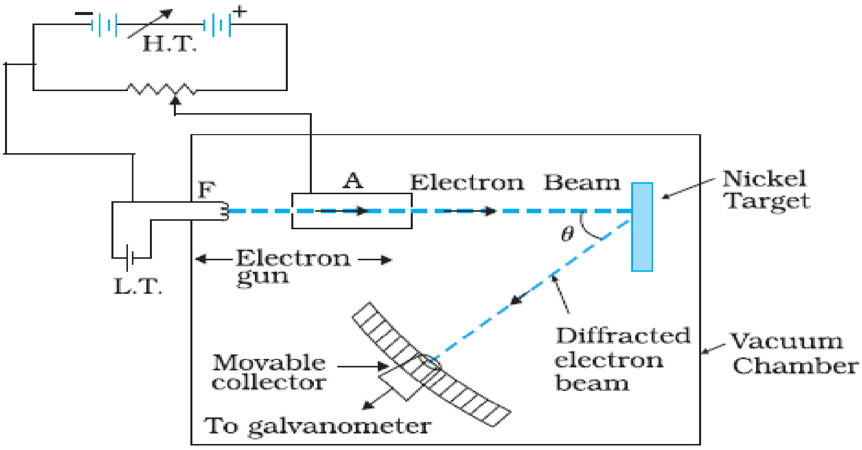


FIGURE 11.7 Davisson-Germer electron diffraction arrangement.

403

The wave nature of electrons was experimentally verified by this Davisson and Germer. Electrons emitted by the hot filament of an electron gun are accelerated by applying a suitable potential difference V between the cathode and anode. The fine collimated beam of electrons is made to fall on the surface of a ni crystal. The intensity of the electron beam scattered in a given direction is measured by the electron detector. The detector can be moved on a circular scale and is connected to a galvanometer to record current. The deflection in the galvanometer is proportional to the intensity of the electron beam entering the detector. The experiment was performed by varying the accelerating voltage from 44V to 68V. It was noticed that a strong peak appeared in the intensity (I) of the scattered electron for an accelerating voltage of 54 V at a scattering angle of 50°. The appearance of the peak in a particular direction is due to the constructive interference of electrons scattered from different layers of the regularly spaced atoms of the crystals.

From the electron diffraction measurements, the wavelength of matter waves was found to be 0.165 nm.

The de Broglie wavelength λassociated with electrons, for V = 54 V is given by

$\lambda = h/p = 1.227/\sqrt{V} = 1.227/\sqrt{54}$ nm = 0.167 nm

Thus, there is an excellent agreement between the theoretical value and the experimentally obtained value of de Broglie wavelength. Davisson- Germer experiment thus strikingly confirms the wave nature of electrons and the de Broglie relation.

Rutherford's model of an atom:

An atom consists of a small and massive central core in which the entire positive charge and almost the whole mass of the atom are concentrated. This core is called the

Rutherford's model of an atom:

1. An atom consists of a small and massive central core in which the entire positive charge and almost the whole mass of the atom are concentrated. This core is called the nucleus.
   The nucleus occupies a very small space as compared to the size of the atom.
   The atom is surrounded by a suitable number of electrons so that their total negative charge is equal to the total positive charge on the nucleus.
   The electrons revolve around the nucleus in various orbits.

2. Impact parameter: It is defined as the perpendicular distance of the velocity vector of the α-particle from the centre of the nucleus, when it is far away from the atom. The shape of trajectory of the scattered α-particle depends on the impact parameter and the nature of the potential field.

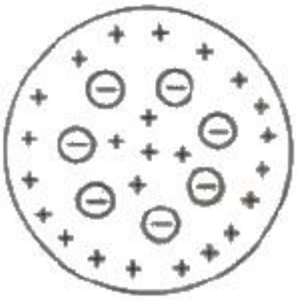
3. Bohr's atomic model:
   An atom consists of a small massive central core called nucleus.
   The electrons are permitted to circulate only in such orbits in which the angular momentum of an electron is an integral multiple of $h/2\pi$.
   While revolving in the permissible orbits, an electron does not radiate energy. These non-radiating orbits are called stationary orbits.
   An atom can emit or absorb radiation in the form of discrete energy photons only when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit.
4. Excitation energy: It is defined as the energy required by an electron of an atom to jump from its ground state to any of its exited states.
5. Ionization energy: It is defined as the energy required to remove an electron from an atom.
6. Excitation potential: It is that accelerating potential which gives to a bombarding electron sufficient energy to excite the target atom by raising one of its electrons from an inner to an outer orbit.
7. Ionization potential: It is that accelerating potential which gives to a bombarding electron sufficient energy to ionize the target atom by knocking one of its electrons completely out of the atom.
8. Nucleons: Protons and neutrons which are present in the nuclei of the atoms are collectively known as nucleons.
9. Isotopes: The atoms of an element, which have the same atomic number but different mass numbers are called isotopes.
10. Isobars: The atoms of different elements having the same mass number are called isobars.
11. Isotones: The nuclides having the same number of neutrons are called isotones.
12. Isomers: These are the nuclei with same atomic number and same mass number but in different energy states.

13. Nuclear force: These are the strong attractive forces which hold protons and neutrons together in a tiny nucleus. These are short ranges forces.
14. Mass defect: The difference between the rest mass of nucleus and the sum of the rest masses of its constituent nucleons is called its mass defect.
15. Binding energy: It may be defined as the energy required to break up a nucleus into its constituent protons and neutrons and to separate them to such a large distance that they may not interact with each other.
16. Packing fraction: The packing fraction of a nucleus is its mass defect per nucleon.
17. When a radioactive nucleus emits an α-particle, its atomic number decreases by 2 and mass number decreases by 4
18. When a radioactive nucleus emits an β-particle, its atomic number increases by 1but mass number remains same
19. The emission of γ-rays does not change the mass number or the atomic number of the radioactive nucleus.
20. Radioactive decay law: The number of atoms of a radioactive sample disintegrating per second at any instant is directly proportional to the number of undecayed radioactive nuclei present at that instant.
21. Decay constant: It may be defined as the reciprocal of the time interval in which the number of active nuclei in a given radioactive sample reduces to 1/e times its initial value.
22. Becquerel: It is the SI unit activity and is defined as the decay rate of one disintegration per second.
23. Nuclear fission: It is the process in which a heavy nucleus when exited gets split up into two smaller nuclei of nearly comparable masses.
24. Thermal neutrons: These are the slow moving neutrons of energy 0.025eV , corresponding to velocities of 2200m/s.
25. Moderator: Any substance which is used to slow down fastmoving neutrons to thermal energies is called moderator. The commonly used moderators are water, heavy water and graphite.
26. Nuclear fusion: it is the process of fusion of two smaller nuclei into a heavier nucleus with the release of large amount of energy. These reactions require the extreme conditions of temperature and pressure so that the reacting nuclei can overcome their electrostatic repulsion. For these reasons, these reactions are called thermonuclear reactions.

ATOMS

Dalton's Atomic Theory
All elements are consists of very small invisible particles, called atoms. Atoms of same element are exactly same and atoms of different element are different.

Thomson's Atom Model
A theoretical explanation for the structure of atom is called an atomic model. According to J.J. Thomson's model , an atom is a sphere of positive charges of uniform density of about 10-10 diameter in which negative charges are embedded like plums in the pudding. Thomson's model of atom is also called ' plum pudding model ' . The total positive charge inside the atom is equal to the total negative charge carried by electrons, so that every atom is electrically neutral.



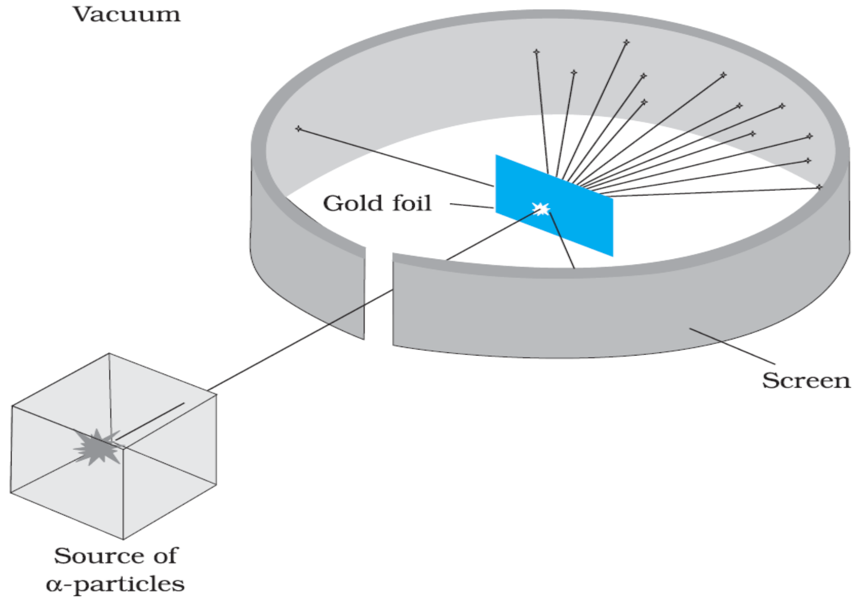
Failure of Thomson's atom model

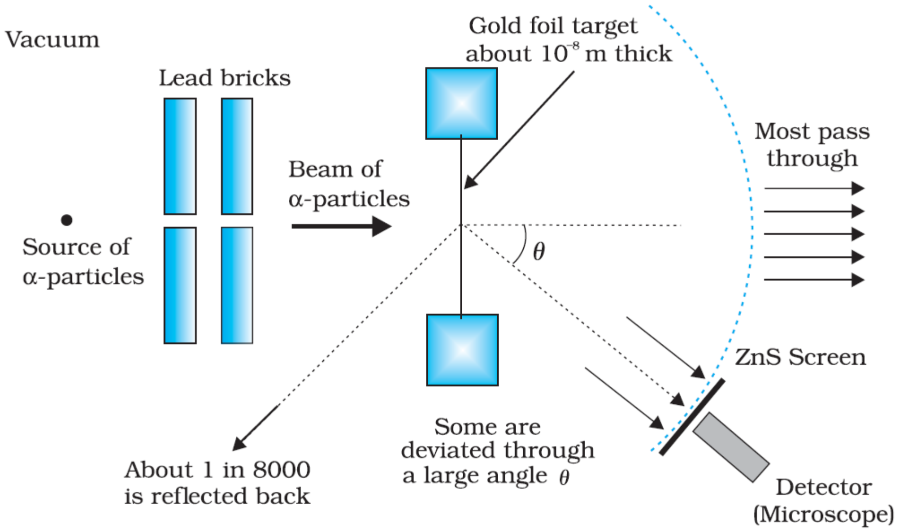
1. It could not explain the origin of the spectral lines in the form of series as in the case of Hydrogen atom.
2. It could not account for the scattering of αparticles through large angles as in the case of Rutherford's α-scattering experiment.

<u>Rutherford's model of an atom:</u>

1. An atom consists of a small and massive central core in which the entire positive charge and almost the whole mass of the atom are concentrated. This core is called the Nucleus.
2. The nucleus occupies a very small space as compared to the size of the atom.
3. The atom is surrounded by a suitable number of electrons so that their total negative charge is equal to the total positive charge on the nucleus.
4. The electrons revolve around the nucleus in various orbits.

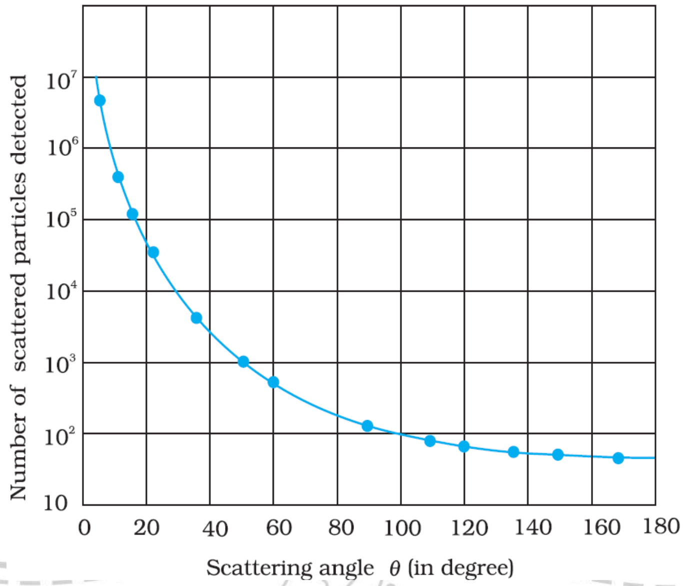
Rutherford's alpha- scattering experiment:
Rutherford and his two associates Geiger and Marsden studied the scattering of α particles from a thin gold foil in order to investigate the structure of the atom.
Experimental arrangement- The α particles from $_{83}Bi^{214}$ contained in a lead cavity are collimated into a narrow beam with the help of a lead plate having a narrow slit. The narrow beam of α particles then falls on a thin gold foil (2.1×10^{-7}m thick). The α particles scattered in different directions were detected with the help of an α detector. The whole apparatus was arranged inside a vacuum chamber to prevent the scattering of α particles from air molecules.





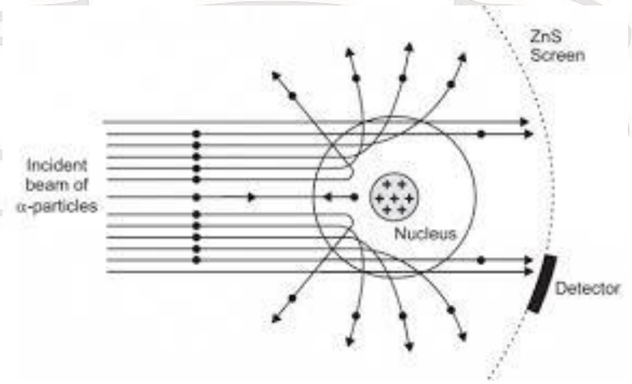
Observations

1) Most of the α particles were found to pass through the gold foil without any appreciable deflection.
2) In passing through the gold foil, the different α particles underwent different amounts of deflection. A large no. of α particles suffered fairly large deflections.
3) A very few α particles (1 in 8000) retraced their paths.



Conclusion

1. As most of the α particles pass through the gold foil undeflected, so it indicates that most of the space in an atom is empty.
2. Since heavy α particles could be deflected through 180°, the whole of the positive charge or the entire mass of the atom is confined to an extremely small central core called nucleus.
3. As the atom is electrically neutral, the total positive charge on the nucleus is equal to the total negative charge of the electrons in the atom.
4. Electrons inside the atom are not stationary for if they were at rest, they would be pulled into the positive nucleus due to the strong electrostatic force of attraction between the nucleus and the electrons. It is assumed that the electrons are revolving around the nucleus in circular orbits. The necessary centripetal force is provided to them by the electrostatic force of attraction between the electrons and the nucleus.



Distance of Closest Approach

It is the distance of charged particle from the centre of the nucleus, at which the whole of the initial kinetic energy of the (far off) charged particle gets converted into the electric potential energy of the system.

Initial charge on an α particle, $q_1 = +2e$

Charge on the scattering nucleu , $q_2 = +Ze$

Initial kinetic energy of the α particle, $K_\alpha = mv^2 / 2$

Electrostatic P.E of α particle = $U = k\, q_1 q_2 / r_o = kZe(2e)/r_o$

By conservation of energy

$K_\alpha = U$

$K_\alpha = mv^2 / 2 = k2Ze^2/r_o$

$r_o = (1 / 4\pi\, \varepsilon_o)\, 2Ze^2 / K_\alpha$

Where, K_α = kinetic energy of the α particle.

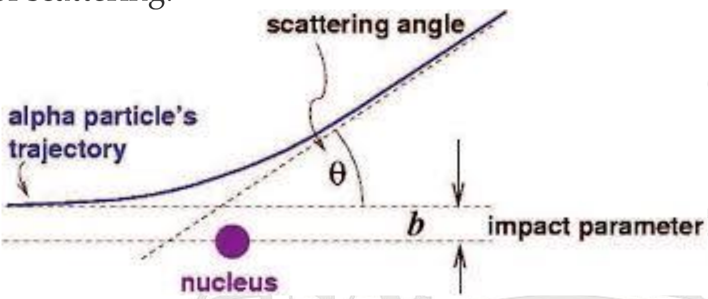
Impact Parameter

The perpendicular distance of the velocity vector of a-particle from the central line of the nucleus, when the particle is far away from the nucleus is called impact parameter.

$$b = \frac{1}{4\pi\,\varepsilon_0} \cdot \frac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{E_k}$$

Impact parameter

where, Z = atomic number of the nucleus, E_k = kinetic energy of the α-particle and θ = angle of scattering.



Drawbacks of Rutherford's Atomic Model :

1. When the electrons revolve around the nucleus, they are continuously accelerated towards the centre of the nucleus. According to Lorentz, an accelerated charged particle should radiate energy continuously. Therefore in the atom, a revolving electron should continuously emit energy and hence radius of its path decreases and ultimately it should fall into the nucleus. Thus, Rutherford's atomic model cannot explain the stability of the atom. (diag)
2. In Rutherford's atomic model, an electron can revolve in orbits of all possible radii. So it should emit a continuous spectrum. But an atom like Hydrogen always emits a discrete line spectrum.

Rutherford Atom Model

The Rutherford nuclear model of the atom which involves classical concepts, pictures the atom as an electrically neutral sphere consisting of a very small, massive and positively charged nucleus at the centre surrounded by the revolving electrons in their respective dynamically stable orbits. The electrostatic force of attraction, Fe between the revolving electrons and the nucleus provides the requisite centripetal force (Fc) to keep them in their orbits. Thus, for a dynamically stable orbit in a hydrogen atom

Fe = Fc

$mv^2 / r = k Ze .e/r^2$

$mv^2 = k Z e^2/r$

$K.E = mv^2 /2 = k Z e^2/2r$

$P.E = k q_1 q_2 /r = kZe(-e)/r = - kZe^2 /r$

Total Energy = K.E + P.E

$E_n = k Z e^2/2r + (- kZe^2 /r) = - kZe^2 /2r = - Ze^2/ 8\pi \varepsilon_o r$

Bohr's Model for the Hydrogen Atom:

Basic postulates:-

a) Nuclear concept: An atom consists of a small massive centre called nucleus around which planetary electrons revolve. The centripetal force required for their rotation is provided by the electrostatic attraction between the electrons and the nucleus.

b) Quantum condition: Of all the possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in such orbits in which the angular momentum of an electron is an integral multiple of $h/_{2Л}$, h being Planck's constant. where n is called principal quantum number.

c) Stationary orbits: While revolving in the permissible orbits, an electron does not radiate energy. These non-radiating orbits are called stationary orbits.

d) Frequency condition: An atom can emit or absorb radiation in the form of discrete energy photons only when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit. If E_1 and E_2 are the energies associated with these permitted orbits then the frequency of the emitted/absorbed radiation is,

$$hv = E_2 - E_1$$

BOHR'S THEORY A HYDROGEN ATOM

According to Bohr's theory a hydrogen atom consists of a nucleus with positive charge Ze, and a single electron of charge –e, which revolves around it in a circular orbit of radius r. Here Z is the atomic number and for hydrogen Z=1. The electrostatic force of attraction between the nucleus and the electron is

$F = K\,Ze.e/r^2 = K\,Ze^2/r^2$

To keep the electron in its orbit, the centripetal force on the electron must be equal to the electrostatic attraction. Therefore

$mv^2 / r = k\,Ze^2/r^2$

$mv^2 = k\,Z\,e^2/r$ ……………………………(1)

$r = k\,Ze^2/ mv^2$ ……………………………(2)

Where m is the mass of the electron and v, its speed in an orbit of radius r.

Bohr's quantisation condition for angular momentum is

$L = mvr = nh/2\pi$

$r = nh/2\pi mv$ ………………………(3)

From equation (2) and (3) we get

$k\,Ze^2/ mv^2 = nh/2\pi mv$

$v = 2\pi\,k\,Ze^2/nh$ ……………………………………(4)

Substituting this value of v in equation (3), we get

$r = nh/2\pi m \;\times\; nh/2\pi k\,Ze^2$

$r = n^2h^2/4\pi^2 mk\,Ze^2$

If n = 1 (for hydrogen atom)

r = 0.53 Å

Clearly the radii of the permitted orbits are proportional to n^2 and increase in the ratio of 1:4:9:16….The parameter n is called the principle quantum number.

The radius of the innermost orbit of the hydrogen atom, called Bohr's radius can be determined by putting Z=1 and n=1 in the equation (5) and it is denoted by r_0.

Speed of Electron.

From equation (4), the orbital speed of electron is

$V = 2\pi k\,Ze^2/nh$

For hydrogen, Z=1, therefore,

$v = 2\pi k\,^2/nh = \{2\pi k\,^2/ch\}\, c/n$

Or $v = \alpha.\, c/n$.

The quantity α=2 Лk $^{2/}$ch, is a diamensionless constant is called ***fine structure constant.***
Its value is

α = 2Л x 9x10^9 x (1.6 x 10^{-19})^2/3 x 10^8 x 6.63 x 10^{-34} = 1/137

v= 1/137 x c/n

for the first orbit(n=1), v = c /137

Thus the speed of the electron in the innermost orbit is 1/137 of the speed of light in vacuum, while the speed of light in the outer varies inversely with n.

Energy of the electron.
It includes the electron's kinetic energy and the electrostatic potential energy of the two changes.
Kinetic energy of the electron in nth orbit is

K.E. = 1/2mv^2= k Ze ^{2}/2r [using equation(1)]

Potential energy of the electron in nth orbit is

P.E. = k q_1q_2/r= k Ze.(-e)/r= k Ze ^{2}/r

Hence total energy of the electron in nth orbit is

E_n= K.E+ P.E.

k Ze ^{2}/2r- k Ze ^{2}/r = - k Ze ^{2}/2r

= -k Ze ^{2}/2 x 4Л^2 mk Ze ^{2}/n^2h^2 using equation (5)

E_n = 2 Л^2 mk^2 Z^2e ^{4}/ n^2h^2 = -13.6/n^2

The negative value of the total energy indicates that the electron is bound to the nucleus by means of electrostatic attraction and some work is required to be done to pull it away from the nucleus.

According to Bohr's frequency condition, whenever an electron makes a transition from higher energy level n_2 to a lower energy level n_1 , the difference of energy appears in the form of photon

h υ = En_2 - En_1

$$= \frac{2\,Л^2 \mathrm{m}k^2\, e^4}{h^2}\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

$$υ = c/λ = \frac{2\,Л^2 \mathrm{m}k^2\, e^4}{h^2}\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = \frac{2\pi^2 mK^2 e^4 Z^2}{ch^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$R = \frac{2\pi^2 mK^2 e^4 Z^2}{ch^3}$$

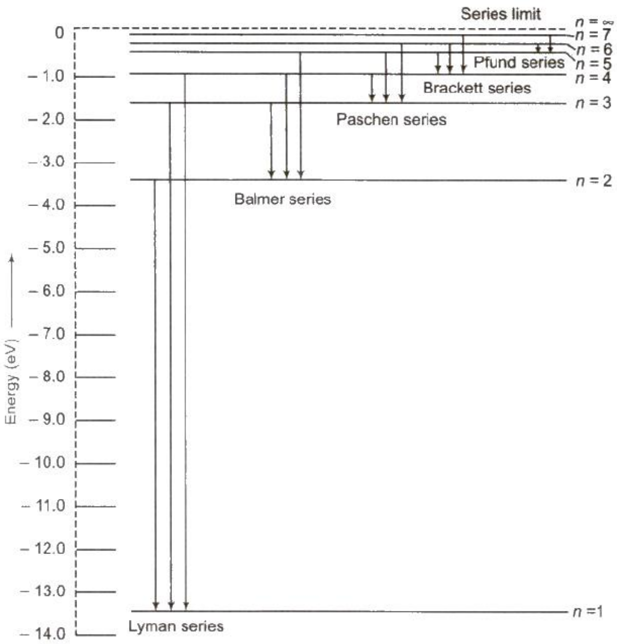
$$= 1.097 \times 10^7 \text{ m}^{-1}$$

Limitations of Bohr's Theory

1. It explains the spectra of only Hydrogen-like atom i. e. Single electron atoms and fails in the case of atoms with two or more electrons.
2. It does not tell about the relative intensities of spectral lines.
3. It does not explain the further splitting of spectral lines in a magnetic field (Zeeman effect) or in an electric field (Stark effect).
4. It considers an electron only as a particle, but electrons exhibit wave nature also.
5. In the spectrum of Hydrogen, certain spectral lines are not single lines but a group of closed lines with slightly different frequencies. Bohr's theory could not explain the fine structure of spectral lines.

Hydrogen Spectrum Series

Each element emits a spectrum of radiation, which is characteristic of the element itself. The spectrum consists of a set of isolated parallel lines and is called the **line spectrum.**



Hydrogen spectrum contains five series

(i) **Lyman Series** When electron jumps from n_2 = 2, 3,4, …orbit to n_1 = 1 orbit, then a line of Lyman series is obtained.

$$1/\lambda = R \left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$$

This series lies in ultra **violet region.**

(ii) **Balmer Series** When electron jumps from n_2 = 3, 4, 5,… orbit to n_1 = 2 orbit, then a line of Balmer series is obtained.

$$1/\lambda = R \left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

This series lies in **visual region.**

(iii) **Paschen Series** When electron jumps from n_2 = 4, 5, 6,… orbit to n_1 = 3 orbit, then a line of Paschen series is obtained.
This series lies in **infrared region**

(iv) **Brackett Series** When electron jumps from n_2 = 5,6, 7…. orbit to n_1 = 4 orbit, then a line of Brackett series is obtained.
This series lies in **infrared region.**

(v) **Pfund Series** When electron jumps from n_2 = 6,7,8, … orbit to n_1 = 5 orbit, then a line of Pfund series is obtained.
This series lies in **infrared region.**

NUCLEI

Nucleus: The entire positive charge and nearly the entire mass of atom is concentrated in a very small space called the nucleus of an atom. The nucleus consists of protons and neutrons. They are called nucleons.

- **Atomic Number:** The number of protons in the nucleus is called the atomic number. It is denoted by Z.
- **Mass number:** The total number of protons and neutrons present in a nucleus is called the mass number of the element. It is denoted by A.
- **No. of Protons, Electrons, Nucleons, and Neutrons in an Atom:**

1. Number of protons in an atom = Z
2. Number of electrons in an atom = Z
3. Number of nucleons in an atom = A
4. Number of neutrons in an atom = N = A – Z.

- **Nuclear Mass:** The total mass of the protons and neutrons present in a nucleus is called the nuclear mass.
- **Nuclide:** A nuclide is a specific nucleus of an atom characterized by its atomic number Z and mass number A. It is represented as, $_{Z}X^{A}$

Where X = chemical symbol of the element, Z = atomic number a and A = mass number

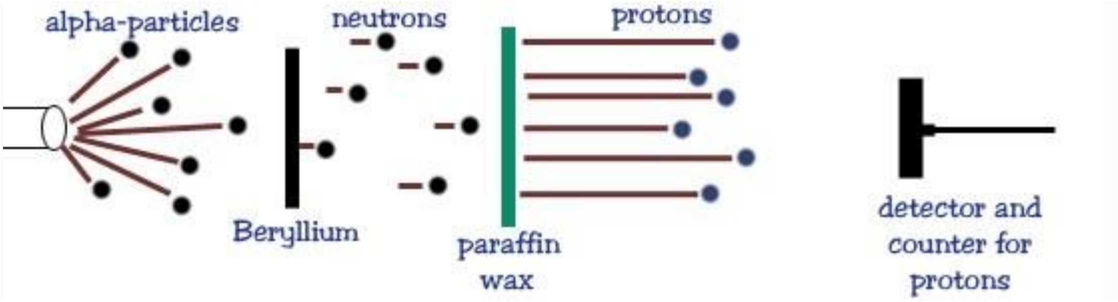
- **Isotopes:**

1. The atoms of an element which have the same atomic number, but different mass number are called isotopes. e.g., $_1H^1$, $_1H^2$, $_1H^3$ are isotopes of hydrogen.
2. Isotopes have similar chemical properties but different physical properties.

- **Isobars:** The atoms having the same mass number, but different atomic number are called isobars. e.g., $_1H^3$, $_2He^3$ and $_{10}Na^{22}$, 10Ne22 are isobars.
- **Isotones:** The nuclides having the same number of neutrons are called isotones. e.g., $_1H^3$, $_2He^4$ and $_6C^{14}$, $_8O^{16}$
- **Isomers:** These are nuclei with same atomic number and same mass number but in different energy states.
- **Electron Volt:** It is defined as the energy acquired by an electron when it is accelerated through a potential difference of 1 volt and is denoted by eV.
- **Atomic Mass Unit:**

1. It is 1/12th of the actual mass of a carbon atom of isotope $_6C^{12}$. It is denoted by amu or just by u.
2. 1 amu =1.660565×10^{-27} kg
3. The energy equivalence of 1 amu is = 931 MeV

- **Discovery of Neutrons:**



1. Neutrons were discovered by Chadwick in 1932.
2. When beryllium nuclei are bombarded by alpha-particles, highly penetrating radiations are emitted, which consists of neutral particles, each having mass nearly that of a proton. These particles were called neutrons.$^4_2He + ^9_4Be \rightarrow ^1_0n + ^{12}_1C$
3. A free neutron decays spontaneously, with a half- life of about 900 s, into a proton, electron and an antineutrino.$^1_0n \rightarrow ^1_1H + ^0_{-1}e + \bar{v}$

Properties of a neutron

1. It has no charge.
2. Being neutral, it is neither attracted, nor repelled by the nucleus of an atom. Therefore, it can penetrate deep into the atom of a target.
3. It has low ionising power.
4. Inside the nucleus, a neutron is stable but outside a nucleus, it is unstable and decays (eqn)
5. It induces radioactivity in many elements.
6. The half life period of a free neutron is about 15 min.
7. Thermal neutrons are more suitable for causing nuclear reactions.

- **Size of the Nucleus:**

  The volume of the nucleus is proportional to mass number A

  $4ЛR^3/3 \ \alpha \ A$

  $R \ \alpha \ A^{1/3}$

  $R = R_o A^{1/3}$

  Where, $R_0 = 1.2 \text{ x } 10^{-15} m$

- **Density of the Nucleus:** Nuclear density is independent of mass number and therefore same for all nuclei.
  ρ = mass of nucleus / volume of nucleus
  $\Rightarrow \rho = 3m / 4\pi R_0^3$ where, m = average mass of a nucleon.
  Density of nuclear matter is approximately $2.3 \times 10^{17} kgm^{-3}$
  which is very large as compared to ordinary matter, say water which is 10^3 kg m^{-3}.

- **Mass-Energy equivalence:** Einstein proved that it is necessary to treat mass as another form of energy. He gave the mass-energy equivalence relation as,
  $E = mc^2$ Where m is the mass and c is the velocity of light in vacuum.

- **Mass Defect:** The difference between the rest mass of a nucleus and the sum of the masses of its constituent nucleons is called its mass defect. It is given by-

$$\Delta m = [Zm_p + (A - Z)m_n] - m$$

- **Binding Energy:**

1. It may be defined as the energy required to break a nucleus into its constituent protons and neutrons and to separate them to such a large distance that they may not interact with each other.
2. It may also be defined as the surplus energy which the nucleus gives up by virtue of their attractions which they become bound together to form a nucleus.
3. The binding energy of a nucleus ${}_ZX^A$ is-

$$\text{Binding Energy} = \left[Zm_p + (A-Z)m_n - m_n\right]c^2 \; or \; \text{Binding Energy} = \left[Zm_H + (A-Z)m_n - m({}_zX^A)\right]c^2$$

Here, c is the velocity of light in ms^{-1}

$m\left({}_ZX^A\right)$ is the mass of the atom,

m_H is mass of the hydrogen atom,

m_N is mass of the nucleus

m_p is mass of the proton

m_n is mass of the neutron

- **Binding Energy per Nucleon:** It is average energy required to extract one nucleon from the nucleus.

It is obtained by dividing the binding energy of a nucleus by its mass number.

$$\bar{B} = \frac{B.E}{A} = \frac{[Zm_p + (A - Z)m_n - m]c^2}{A}$$

Packing Fraction (P)

Packing fraction of a nucleus is its mass defect per nucleon

p = Δ m/ A

The larger the value of packing friction. greater is the stability of the nucleus.

[The nuclei containing even number of protons and even number of neutrons are most stable. The nuclei containing odd number of protons and odd number of neutrons are most instable.]

Binding Energy Curve and its Features

Binding energy per nucleon as the average energy per nucleon needed to separate a nucleus into its individual nucleons.

Binding energy curve is a plot of the binding energy per nucleon versus the mass number for large nuclei.

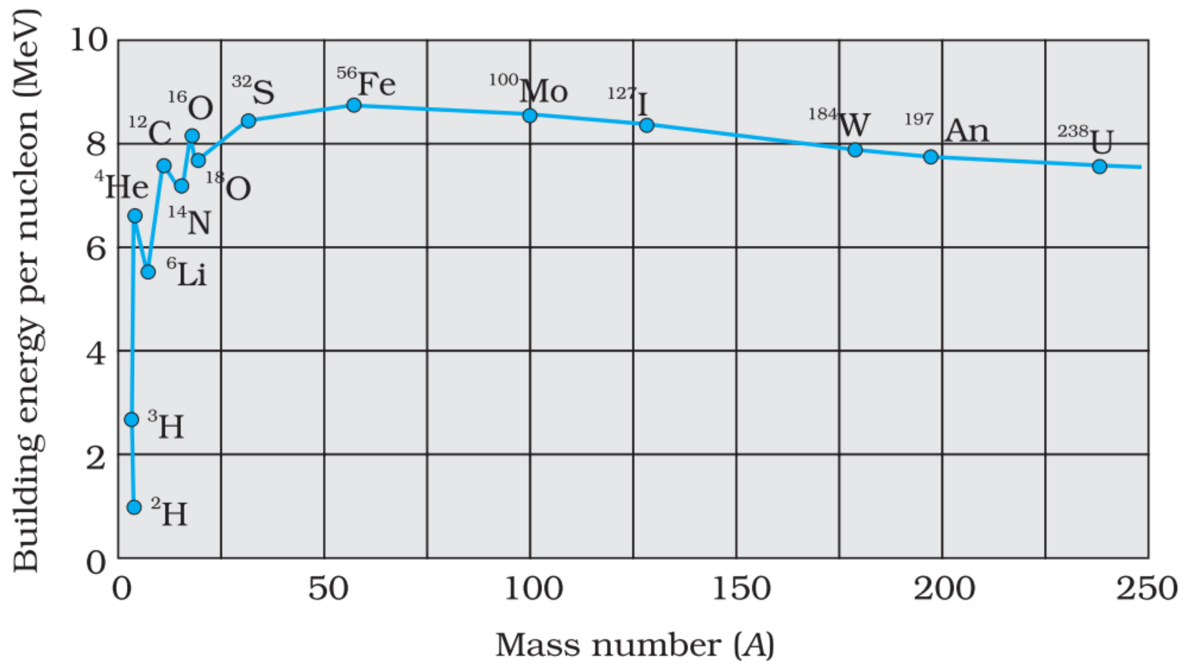


FIGURE The binding energy per nucleon as a function of mass number.

The main features of his curve are give below:

(*i*) The binding energy per nucleon (E_{bn}) is practically constant, i.e. practically independent of the atomic number for nuclei of middle mass number (30 < A < 170). The curve has a maximum of about 8.75 MeV for A = 56 and has a value of 7.6 MeV for A = 238.

(*ii*) Binding energy per nucleon is lower for both light nuclei (A<30) and heavy nuclei (A>170).

From above two observations we can draw the conclusions given below:

(*a*) The force is attractive and sufficiently strong to produce a binding energy of a few MeV per nucleon.

(*b*) The constancy of the binding energy in the range 30 <*A*< 170 is a consequence of the fact that the nuclear force is short-ranged.

(*c*)A very heavy nucleus, say A = 240, has lower binding energy per nucleon compared to that of a nucleus with A = 120. Thus if a nucleus A = 240 breaks into two A = 120 nuclei, nucleons get more tightly bound. This implies energy would be released in the process.

(*d*) Consider two very light nuclei (A ≤ 10) joining to form a heavier nucleus. The binding energy per nucleon of the fused heavier nuclei is more than the binding energy per nucleon of the lighter nuclei. This means that the final system is more tightly bound than the initial system. Again energy would be released in such a process of fusion. This is the energy source of the sun.

Nuclear Forces:

1. These are the strong in attractive forces which hold protons and neutrons together in a tiny nucleus.

2. These are short range forces which operate over very short distance of about 2 – 3 fm of separation between any two nucleons.
3. The nuclear force does not depend on the charge of the nucleon.
4. It is non-central. non-conservative force. •
5. It is neither gravitational nor electrostatic force.
6. It is 100 times that of electrostatic force and 1038 times that of gravitational force.

According to the Yukawa, the nuclear force acts between the nucleon due to continuous exchange of meson particles.

Previously, we have studied that for average mass nuclei the binding energy per nucleon is approximately 8 MeV, which is much larger than the binding energy in atoms.

Therefore, to bind a nucleus together there must be a strong attractive force of a totally different kind.

This force is nuclear force (strongest force in nature). It is strong enough to overcome the repulsion between the (positively charged) protons and to bind both protons and neutrons into the tiny nuclear volume.

Some important features of the nuclear binding force are given below:

(*i*) The nuclear force is much stronger than the Coulomb force acting between charges or the gravitational forces between masses. The nuclear binding force has to dominate over the Coulomb repulsive force between protons inside the nucleus. This happens only because the nuclear force is much stronger than the coulomb force. The gravitational force is much weaker than even Coulomb force.
(*ii*) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few femtometres. This leads to saturation of forces in a medium or a large-sized nucleus, which is the reason for the constancy of the binding energy per nucleon. A rough plot of the potential energy between two nucleons as a function of distance is shown in the figure given below. The potential energy is a minimum at a distance r of about 0.8 fm. This means that the force is attractive for distances larger than 0.8 fm and repulsive if they are separated by distances less than 0.8 fm. Which saves the nucleus from collapsing.

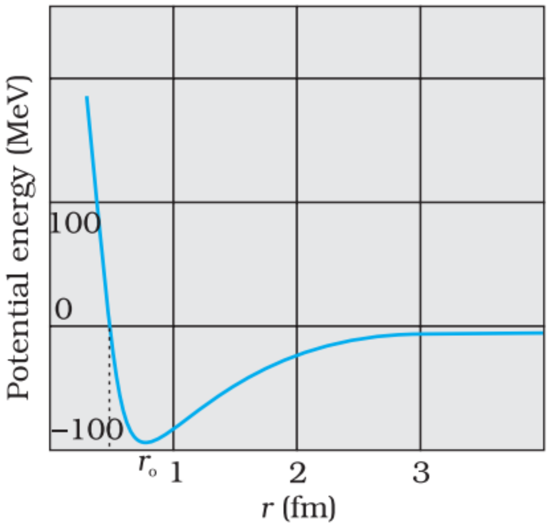


FIGURE Potential energy of a pair of nucleons as a function of their separation. For a separation greater than r_0, the force is attractive and for separations less than r_0, the force is strongly repulsive.

- **Nuclear Density:** The density of a nucleus is independent of the size of the nucleus and is given by-

$$\rho_v = \frac{\text{Nuclear mass}}{\text{Nuclear volume}}$$

- **Radioactivity:**

1. It is the phenomenon of spontaneous disintegration of the nucleus of an atom with the emission of one or more radiations like α-particles, β-particles or γ-rays.
2. The substances which spontaneously emit penetrating radiation are called radioactive substances.

Radiations Emitted by a Radioactive Element

Three types of radiations emitted by radioactive elements (i) α-rays (ii) β-rays (iii) γ – rays α-rays consists of α-particles, which are doubly ionised helium ion. β-rays are consisting of fast moving electrons. γ – rays are electromagnetic rays.

- **Radioactivity Displacement Law:** It states that-

1. When a radioactive nucleus emits an α-particle, atomic number decreases by 2 and mass number decreases by 4.
2. When a radioactive nucleus emits β-particle, its atomic number increases by 1 but mass number remains same.
3. The emission of a γ-particle does not change the mass number or the atomic number of the radioactive nucleus. The γ-particle emission by a radioactive nucleus lowers its energy state.

- **Alpha Decay:** It is the process of emission of an α-particle from a radioactive nucleus. It may be represented as,

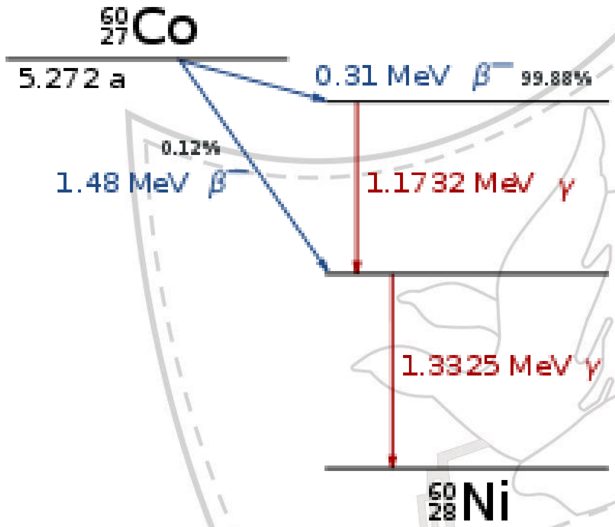
$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He + Q$$

- **Beta Decay:** It is the process of emission of an electron from a radioactive nucleus. It may be represented as,

$$^{A}_{Z}X \rightarrow \, ^{A}_{Z+1}Y + \, ^{0}_{-1}e + \bar{v}$$

- **Gamma Decay:** It is the process of emission of a γ-ray photon during the radioactive disintegration of a nucleus. It can be represented as,

$$\underset{\text{(Excited State)}}{^{A}_{Z}X} \rightarrow \underset{\text{(Ground State)}}{^{A}_{Z}X + \gamma}$$



Laws of Radioactive Decay

1. Radioactivity is a spontaneous phenomenon and one cannot predict when a particular atom in a given radioactive sample will undergo disintegration.
2. When a radioactive atom disintegrates, either an α particle or a β particle is emitted.
3. The emission of an α particle by a radioactive atom results in a daughter atom, whose atomic no. Is 2 units less and mass no. Is 4 units less than that of the parent atom.
4. The emission of a β particle by a radioactive atom results in a daughter atom, whose atomic no. is 1 units more and mass no. is the same as that of the parent atom.
5. The number of atoms disintegrating per second of a radioactive sample at any time is directly proportional to the number of atoms present at that time.(**Radioactive Decay Law**)

RADIOACTIVE DECAY LAW

The number of nuclei disintegrating per second of a radioactive sample at any instant is directly proportional to the number of undecayed nuclei present in the simple at that instant.
Let
N_0= the number of radioactive per second of a radioactive nuclei present initially at time t=0 in a sample of radioactive substance.
N= the number of radioactive nuclei present in the sample at any instant t and
dN= the number of radioactive nuclei which are disintegrate in the small time interval dt.
According to radioactive law, the rate of decay at any instant is proportional to the number of undecayed nuclei i.e
+dN/dt α N
+dN/dt = λ N

Where λ is a proportionally constant called the decay or disintegration constant. Here the negative sign shows that the number of undecayed nuclei N decreases with time. The equation (1) can be written as

dN/N= -λdt
Integrating, $\int \frac{dN}{N} = -\lambda \int dt$
Log_e N= - λt+C
Where C is a constant of integration.
At t=0 , N= N_0, therefore from equation (2), we get
Log_e N= C.
Then the equation (2) becomes

Log_e N= - λt+ Log_e N_0
Log_e N/ N_0= - λt
N/ N_0= $e^{-\lambda t}$
N= N_0 $e^{-\lambda t}$.

MEAN LIFE
Radioactive atoms disintegrate spontaneously and it is not possible to predict which atom is going to disintegrate next. So, in order to deal this type of difficulty calculation mean life or average life of radioactive substance is introduced.
The atom which disintegrates at first is said to have zero (0) life and the atom which disintegrate last is said to have infinite life.
So the life of radioactive atoms ranges from 0-infinity mean life gives the sum of the life of all the atoms to the total no. of atoms present initially.
Mathematically, it can be expressed as:
Mean life (τ) = sum of life of all atom / total no of atoms present
Mathematical calculation shows that mean life of radioactive substance is reciprocal of decay constant,
Mean life = 1/ decay constant
Derivation of mean life:
Let us consider, N_0 be the total number of radioactive atoms present initially. After time t , total no. of atoms present (undecayed) be N . IN further dt time dN be the no. of atoms

disintegrated. So, the life of dN atoms ranges lies between t + dt and dt. Since, dt is very small time, the most appropriate life of dN atom is t . So the total life of N atom = t. dN

$$sum\ of\ ages\ of\ all\ atoms = \int_0^{N_o} tdN ----------(i)$$

$$N = N_o e^{-\lambda t}$$

$$dN = N_o(-\lambda)e^{-\lambda t}dt --------(ii)$$

Now substituting the value of dN and changing the limit in equation i from ii we get

$$\int_{\infty}^{0} t\, N_o(-\lambda)e^{-\lambda t}dt$$

$$-\int_0^{\infty} t\, N_o(-\lambda)e^{-\lambda t}dt$$

$$N_o\lambda \int_0^{\infty} te^{-\lambda t}dt$$

$$= sum\ of\ life\ of\ all\ atoms$$

$$\text{Mean life } (\tau) = \frac{N_o\lambda \int_0^{\infty} te^{-\lambda t}dt}{N_o}$$

$$\tau = \lambda \int_0^{\infty} te^{-\lambda t}dt$$

$$\tau = \lambda \times \frac{1}{\lambda^2}$$

$$\tau = \frac{1}{\lambda}$$

This expression gives the relation between mean life and decay constant. Hence, mean life is reciprocal of decay constant.

HALF LIFE

The time interval in which one-half of the radioactive nuclei originally present in radioactive sample disintegrate is called half-life of the radioactive substance. The half-life of a particular radioactive isotope is a characteristic constant of that isotope. It is denoted by $T_{1/2}$.

Relation between half-life and decay constant. Let
N_0= Number of radioactive nuclei present in the radioactive sample initially (at t=0).
N= Number of radioactive nuclei left at any instant t.
At t= $T_{1/2}$, N= $N_0/2$
Now N= $N_0\ e^{-\lambda t}$, where λ is the radioactive decay constant.
$N_0/2 = N_0\ e^{-\lambda T_{1/2}}$ or $1/2 = e^{-\lambda T_{1/2}}$

Or $e^{\lambda T_{1/2}} = 2$.
Taking natural logarithm, we get
$\lambda T_{1/2} \, Log_e \, e = Log_e \, 2$.
$T_{1/2} = Log_e \, 2/\lambda = 2.303 \log 2/\lambda$.
$= \quad 2.303 \times 0.3010/\lambda \; (\log_e e = 1)$
$T_{1/2} = 0.693/\lambda$.
Thus the half-life of a radioactive substance is inversely proportional to its decay constant and is independent of the number N_0, the number of radioactive nuclei present initially in the sample.

ACTIVITY OF RADIOACTIVE SUSTANCE

It is defined as The number of nuclei disintegrating per second of a radioactive sample at any instant.
If a radioactive sample contains N radioactive nuclei at any instant t, then activity R at the same time is $R = - dN/dt$
Also
$- dN/dt = \lambda N$
$R = - \lambda N$
As $N = N_0 \, e^{-\lambda t}$
So $R = \lambda N_0 \, e^{-\lambda t}$
$R = R_0 \, e^{-\lambda t}$

Curie:

1.It is the SI unit of decay.

2.One curie is the decay rate of 3.7×10^{10} disintegrations per second.

Properties of α , β and γ rays
α rays
1. An α particle is a doubly ionised Helium atom or is simply the HeIium nucleus.
2. The velocity of α particles ranges from 1.4×10^7 m/s to 2.1×10^7 m/s(depends on the source).
3. They have a large mass and small penetrating power.
4. High ionising power
5. Produce fluorescence in ZnS etc.
6. Are deflected by electric and magnetic fields.
7. Are scattered while passing through thin metal foils.
8. Produce heating effect when absorbed.
9. Can be stooped by an Al sheet 0.02 mm thick.
10. Affect a photographic plate slightly.

β rays
1. β particles have a charge of -1.6×10^{-19} C and a mass of 9.1×10^{-31} kg.
2. Their velocity ranges from 33% to 99 % of the speed of light in vacuum.

3. They have a small mass and higher penetrating power (pass easily through a few mm of Al).
4. Their ionising power is 1/100 of α particles.
5. Produce fluorescence in ZnS.
6. Affect a photographic plate.
7. Are deflected by electric and magnetic fields.

γ rays

1. They are electromagnetic radiation of extremely short wavelength (shorter than β rays) with energy of the order of MeV.
2. They are not charged and are not deflected by electric and magnetic fields.
3. The rest mass of a γ ray photon is zero.
4. They travel with the speed of light in vacuum.
5. They have small ionising power.
6. Affect a photographic plate more strongly than β rays.
7. Can knock out electrons from a metal surface.

SPEED OF ALPHA PARTICALS

An alpha particle is a helium nucleus ${}^{4}_{2}He$. Whenever a nucleus goes through alpha decay, it transforms into a different nucleus by emitting an alpha particle. For example, when ${}^{238}_{92}U$ undergoes alpha-decay, it transforms into ${}^{234}_{90}Th$.

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He \ldots (1)$$

Now, ${}^{4}_{2}He$ contains two protons and two neutrons. Hence, after emission, the mass number of the emitting nucleus reduces by four and the atomic number reduces by two. Therefore, the transformation of ${}^{A}_{Z}X$ nucleus to ${}^{A-4}_{Z-2}X$ nucleus is expressed as follows,

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}He \ldots (2)$$

where ${}^{A}_{Z}X$ is the parent nucleus and ${}^{A-4}_{Z-2}X$ is the daughter nucleus. It is important to note that the alpha decay of ${}^{238}_{92}U$ can occur without an external source of energy. This is because of the total mass of the decay products (${}^{234}_{90}Th$ and ${}^{4}_{2}He$) < the mass of the original ${}^{238}_{92}U$

Or, the total mass-energy of the decay products is less than that of the original nuclide. This brings us to the concept of '*Q value of the process*' or '*Disintegration energy*' which is the difference between the initial and final mass-energy of the decay products. For an alpha decay, the Q value is expressed as,

$$Q = (m_x - m_y - m_{He})\, c^2 \ldots (3)$$

This energy is shared between the daughter nucleus, $_{Z-2}X^{A-4}$ and the alpha particle, $^{4}_{2}He$ in the form of kinetic energy. Also, alpha decay obeys the radioactive laws.

Speed of the emitted α particals can be calculated by law of conservation of energy and momentum. Suppose the parent nucleus A/z x be at rest before decay. Let v_{He} and v_y be the velocities of the α-particle and daughter nucleus. Applying the law of conservation of momentum we get

$m_{y}.\ v_y = m_{He}\ v_{He}$ .... (1)

As the energy Q released in the decay process appearing in the form of kinetic energy of α-particle and daughter nucleus, so we get

$\frac{1}{2} m_{He}\ v^2_{He} + \frac{1}{2} m_y v^2_y = Q$

Substituting the value of v_y from eq. (1) we get

$\frac{1}{2} m_{He}\ v^2_{He} + \frac{1}{2} m_y m^2_{He} v^2_{He} / m^2_Y = Q$

$\frac{1}{2} m_{He}\ m_{Y+} v^2_{He} + \frac{1}{2} m^2_{He} v^2_{He} = m_Y Q$

$\frac{1}{2} (m_{Y+} m_{He})\ m_{He}\ v^2_{He=} m_Y Q$

Or $K_{He} = ½\ m_{He}\ v^2_{He} = \frac{m_Y}{m_Y + m_{He}} Q$

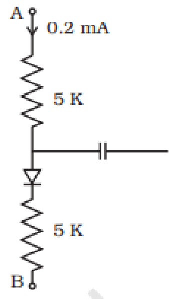
Now $m_Y = (A-4)$ amu and $m_{He} = 4$ amu, therefore,

$K_{He} = ½\ m_{He}\ v^2_{He} = (A-4)/A\ .\ Q$

$v_{He=} \sqrt{2}\ K_{He}/\ m_{He} = \sqrt{2}(A-4)Q/A\ m_{He}$

Chapter No. 14: Semiconductor

Assignment:

1	The conductivity of a semiconductor increases with increase in temperature because a) number density of free current carriers increases. (b) relaxation time increases (c) both number density of carriers and relaxation time increase (d) number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.
2	Hole is (a) an anti-particle of electron (b) a vacancy created when an electron leaves a covalent bond (c) absence of free electrons (d) an artifically created particle.
3	When an electric field is applied across a semiconductor (a) electrons move from lower energy level to higher energy level in the conduction band. (b) electrons move from higher energy level to lower energy level in the conduction band. (c) holes in the valence band move from higher energy level to lower energy level. (d) holes in the valence band move from lower energy level to higher energy level.
4	In the circuit shown in Fig. , if the diode forward voltage drop is 0.3 V, the voltage difference between A and B is (a) 1.3 V (b) 2.3 V (c) 0 (d) 0.5 V 
5	In a p-n junction, width of depletion region is 300nm and electric field of $7x10^5 V/m$ exists in it. (i) Find the height of potential barrier?

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(ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the n-side to the p-side?

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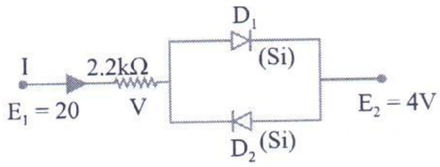
Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt)



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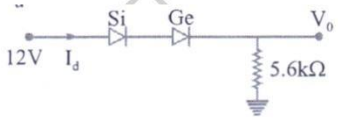
Determine V_0 and I_d for the network.



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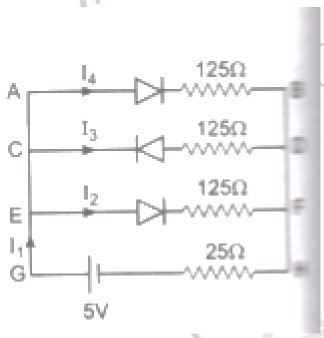
If each diode in figure has a forward bias resistance of 25 Ω and infinite resistance in reverse bias, what will be the values of current I_1, I_2, I_3 and I_4?



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What is an ideal diode? Give the value of the threshold voltage for a (i)Silicon diode (ii) germanium diode? Draw the output wave form across the load resistor R, if the input waveform is as shown in the figure.

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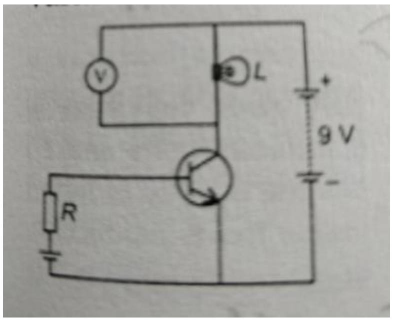
(a)If the frequency of the input signal is f. What will be the frequency of the pulsating output signal in case of : (i) half wave rectifier ? (ii) full wave rectifier ?
(b) In the given circuit diagram, a voltmeter 'V' is connected across a lamp 'L'. How would (i) the brightness of the lamp and (ii) voltmeter reading 'V' be affected, if the value of resistance 'R' is decreased? Justify your answer.



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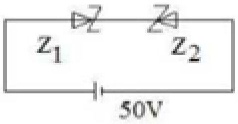
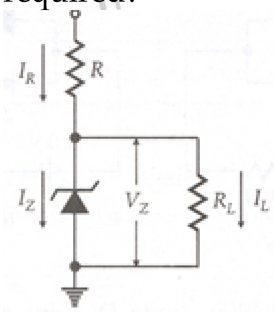
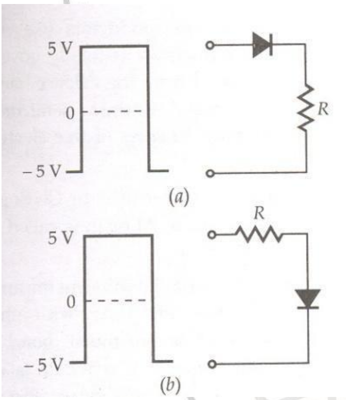
11.	Zener diode Z 1 has saturation current of 20A and reverse breakdown voltage of 100V where as the corresponding value of Z 2 are 40µA and 40. Find the current  through the circuit? How does a higher dopant density in Zener diode affect the (i) width of depletion layer (ii) Junction field?
12	A semiconductor has equal electron and hole concentration of 6 ×10 8 m-3. On doping with a certain impurity electron concentration increases to 3 ×10 12 m-3. Identify the type of semiconductor after doping?
13	In Fig. what is the voltage needed to maintain 15 V across the load resistance RL of 2 K, assuming that the series resistance R is 200Ω and the zener requires a minimum current of 10 mA to work satisfactorily? What is the zener rating required? 
14.	With a circuit diagram, explain how a Zener diode can be used as voltage regulator.
15.	Distinguish between (a) n-type and p-type semiconductors on the basis of their energy band diagrams (b) instrinsic and extrinsic semiconductors on the basis of their energy band
16.	Explain the formation of a p-n junction with the help of a diagram.
17.	Give reasons for the following : (1) GaAs is preferred over Si for making solar cells. (2) A photodiode, when used as a detector of optical signals, is operated under reverse bias. (3) The band gap of the semiconductor used for fabrication of visible LEDs must at least be 1.8 eV (4)The n-p-n transistor is preferred over p-n-p transistor.

	(5)A pn photodiode is fabricated from a semiconductor with a band gap of 2.8eV.Can it detect a wavelength of 600 nm. (6) How is a sample of an n-type semiconductor electrically neutral though it has an excess of negative charge carriers? (7) Why is the base region of transistor made very thin and lightly doped?
18.	Define the terms depletion layer and barrier potential for a p-n junction diode. How does an increase in the doping concentration affect the width of depletion region and junction electric field?

Practice Questions: Semiconductor

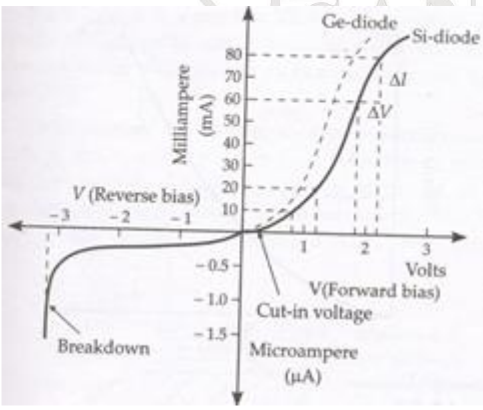
Very Short and Short Answer Questions

1. Carbon and silicon are known to have similar lattice structures. However, the four bonding electrons of carbon are present in second orbit while those of silicon are present in its third orbit. How does this difference result in a difference in their electrical conductivities?
2. What do you mean by an ideal semiconductor junction diode?
3. Distinguish between an intrinsic semiconductor and p-type semiconductor.
4. A photodiode is fabricated from a semiconductor with a band gap of 2.8eV. can it detect wavelength of 6000nm? Justify.
5. (a)State the factor, which controls (i) wavelength of light and (ii) intensity of light, emitted by a LED.
   (b). State the reason, why GaAs is most commonly used in making a solar cell.
   (c) The current in the forward bias is known to be more (mA) than the current in the reverse bias (μA) . What is the reason, then, to operate the photodiode in reverse bias?
6. In the following circuits, if the input waveform is as shown in figure, what will be the output waveform, (i) across R in Fig. (a) And across the diode in Fig. (b)? Assume that the diode is ideal.



7. Why does the conductivity of a semiconductor increase with rise of temperature?
8. If the input frequency is 50Hz. What is the output frequency in half wave rectifier and full wave rectifier?

9. The V-1 characteristic of a silicon diode is given in Fig. Calculate the diode resistance in : (a) forward bias at V = + 2V and V = 1 V, and (b) reverse bias V = - 1V and -2 V.



Long Answer Questions

1. On the basis of energy band diagram, distinguish between metals , insulators and semiconductors
2. What do the terms depletion region and barrier potential mean for a P-N junction?
3. With the help of a suitable diagram, explain the formation of depletion region in a p-n junction. How does its width change when the junction is (i) forward biased, and (ii) reverse biased?
4. With the help of circuit diagrams, distinguish between forward biasing and reverse biasing of a p-n junction diode. Draw V-I characteristics of p-n junction diode in forward bias and reverse bias.

Numerical

1. A 10V Zener diode along with a series resistance is connected across a 40V supply. Calculate the minimum value of the resistance required, if the maximum current is 50mA?
2. Pure Si at 300K has equal electron and hole concentration of $1.5 \times 10^{16}/m^3$. Doping by induction increases concentration of holes to $4.5 \times 10^{22}/m^3$. Calculate concentration of holes in doped silicon?

Multiple choice questions

1. The electrical conductivity of a semiconductor increases when an electromagnetic radiation of wavelength shorter than 1125nm is incident on it. The energy gap of the semiconductor is
   (a) 0.5eV (b) 0.7eV (c) 0.9eV (d) 1.1eV
2. Boron is added as an impurity to silicon, the resultant material is
   (a) N-type semiconductor (b) p-type semiconductor
   (c) an insulator (d) pn junction
3. When a p-n diode is reverse biased, then
   (a) No current flows (b) the depletion region is increased
   (c) the depletion region is reduced (d) the of the potential barrier is Reduced
4. An n-type semiconductor is
   (a) Neutral (b) positively charged (c) negatively charged (d) none of these
5. The output of OR gate is 1
   (a) If either input is zero (b) only if both inputs are 1
   (c) if both inputs are zero (d) if either or both inputs are 1.
6. If a full wave rectifier circuit is operating at 50Hz mains, the fundamental frequency of ripple will be
   (a) 50Hz (b) 70.7Hz (c) 100Hz (d) 25Hz
7. In a transistor, the collector current is always less than the emitter current because
   (a) Collector being reverse biased, attracts less electrons
   (b) Collector side is forward biased and the emitter side is reverse biased

(c) A few electrons are lost in the base and only remaining ones reach the collector
(d) Collector side is reverse biased and emitter side is forward biased.

8. If the ratio of the concentration of electrons to that of holes in a semiconductor is 7/5 and the ratio of currents is 7/4, then what is the ratio of their drift velocities?
(a) 5/4 (b) 5/8 (c) 4/5 (d) 4 /7

9. In the middle of the depletion layer of a reverse biased p-n junction the
(a) Potential is zero (b) electric field is zero
(c) potential is maximum (d) electric field is maximum

10. A p-n photodiode is fabricated from a semiconductor with band gap of 2.8eV.which of the following wavelengths it can detect?
(a) 950nm (b) 820nm (c) 580nm (d) 442nm

Answer

1. d 2. b 3.b 4.a 5.d 6.c 7c 8.a 9.d 10.d

Study Material

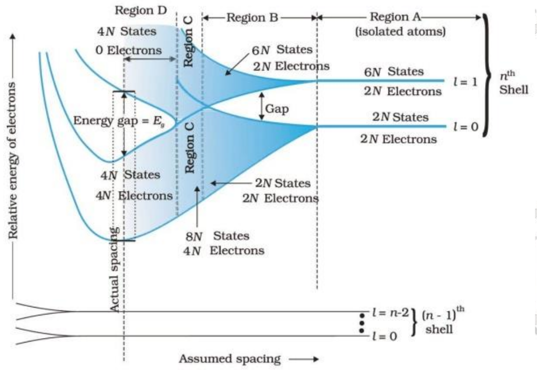
Semiconductor devices and digital Circuit

Classification of solids on the basis of their conductivity: On the basis of relative values of electrical conductivity (σ) and resistivity (ρ) the solids can be classified into 3 categories:

1. Metals - are those solids which have high σ low ρ. e.g. Al, Cu, Ag, An, etc.
   σ – In-between 10^2 to 10^8 Sm^{-1}
   ρ – In-between 10^{-2} to 10^{-8} Ωm
2. Insulators - are those solids which have high ρ and low σ. e.g. rubber, plastic, putty etc.
   σ – less than 10^{-8} Sm^{-1}
   ρ – more than 10^8 Ωm
3. Semi conductors - are those solids which have ρ and σ in between metals and insulators.
   σ – in-between 10^{-5} to 1 Sm^{-1}
   ρ – in-between 10^5 to 1 Ωm

Energy band - In a single atom, electrons have well defined energy levels. But in a crystal, the atoms do not have well defined energy levels because each atom is surrounded by neighboring atoms. Due to this, energy levels of the electrons in the atoms get modified. The modification is not appreciable in case of the electrons in the inner shells as they are bound to the nucleus but is considerable in case of electrons in the outermost shell because they are shared by more than one atom in the crystal.

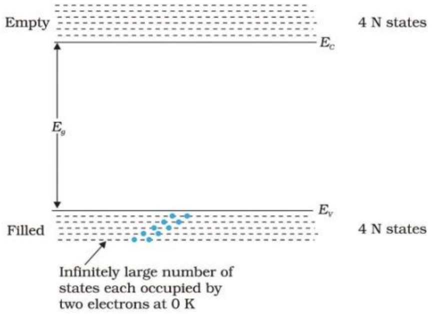
e.g. Consider a silicon crystal made of N atoms. Electronic configuration of an atom is $1s^2 2s^2 2p^6 3s^2 3p^2$. No. of e^-s in the outermost orbit is 4 (2, s e^-s and 2, p e^-s). Therefore, the total no. of valence e^-s in the crystal is 4N. The maximum no. of electrons in the outer orbit of Si atom can be 8. It means for the 4 N valence electrons there are 8N available energy states. These energy levels arrange themselves on the basis of interatomic distance.



1. When r = d >> a
   At this interatomic separation, electrons in the outermost shell of one atom do not interact with others. Thus, no modification is seen.
2. When r = c >> a but c <<d
   As the interatomic separation decreases, the valence electrons of the neighbouring atoms begin to interact. The energy gap between 3s and 3p levels decreases. As N is very large, i.e. 10^{23} atoms/cm^3, enormously large no. of energy levels are spaced in very small energy range. Such sets of closely spaced energy levels form a band called energy band.
3. When r = b> a
   As the separation 'r' decreases further, the energy gap between 3s & 3p levels completely disappears and the upper & lower energy bands merge with each other. Hence we have a set of continuously distributed 4N energy levels.

4. When r = a

At this equilibrium, the band of 4N filled energy levels gets separated from the band of 4N



empty energy levels by an energy gap.

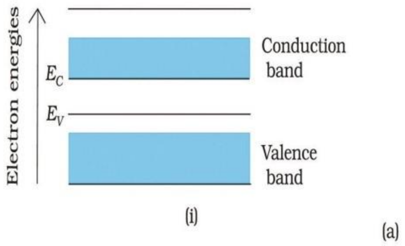
- The energy formed by a series of energy levels containing valence electron is called valence band.
- The highest energy level, which an electron can occupy in the valence band at ok, is called Fermi level.
- The lowest unfilled energy band formed just above the valence band is called conduction band.

<u>Classification of solids on the basis of their Energy Band Diagrams</u>

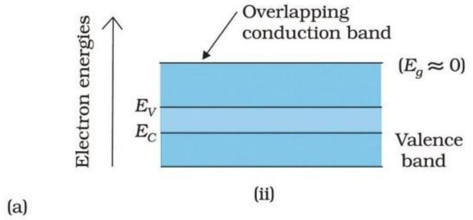
Depending upon the energy gap between the valence band and conduction band, the solids behave as conductors, insulators and semi conductors.

a) **Metals -** 2 possibilities:-

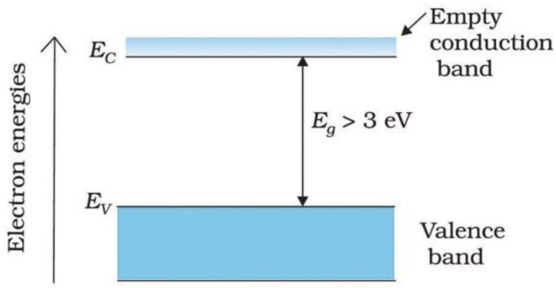
1)The valence band may be completely filled and conduction band partially filled with an extremely small energy gap between them. e.g. Na



2)The valence band is completely filled and the conduction band is empty but the two overlap each other. e.g. Zn. Thus, on applying even a small electric field, the metals conduct electricity.

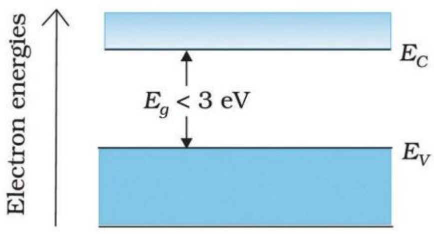


b) **Insulators** - The forbidden energy gap is quite large i.e. of the order 6eV (in case of diamond) which means that minimum of 6ev energy is required to make the electrons jump from the V.B. to the C.B. When electric field is applied, the electrons are not able to acquire such a large amount of energy and C.B. continuous to be empty. No electron flow occurs i.e. no flow of current. Thus, they behave as insulators.



(b)

c) **Semiconductors** - The forbidden energy gap is much smaller than that for the insulators. e.g. for Si is 1.1eV. The electrons can acquire this much energy even at the room temperature due to thermal agitation. Hence, there is a flow of current. So, the conductivity of Si is in between that of conductors and insulators. Si is, thus, called a semiconductor.



(c)

<u>Electrical conductivity of semiconductors</u>

Consider a block of semi-conductor of length l, area of cross section A and having number density of electrons & holes as n_e& n_h respectively.

$I = I_e + I_h$

$I_e = en_eAV_e$ [electron current]

Also the hole current, $I_h = en_hAV_h$

$I = en_eAV_e + en_hAV_h$

$= eA(n_eV_e + n_hV_h)$

If ρ is the resistively of the material of the semiconductor then $R = \rho l/A$

As $V = IR = I\rho l/A$

Therefore, $V = e\,(n_eV_e + n_hV_h)\rho l$

If E is the electric field set up across the semiconductor

$E = V/l = \rho e(n_eV_e + n_hV_h)$

$\sigma = \rho^{-1} = e(n_eV_e + n_hV_h)/E$

On applying electric field, the drift velocity acquired by the electrons or holes per unit strength of $\vec{E}$ is called mobility of electrons or holes.

i.e. $\mu_e = V_e/E$ &$\mu_h = V_h/E$

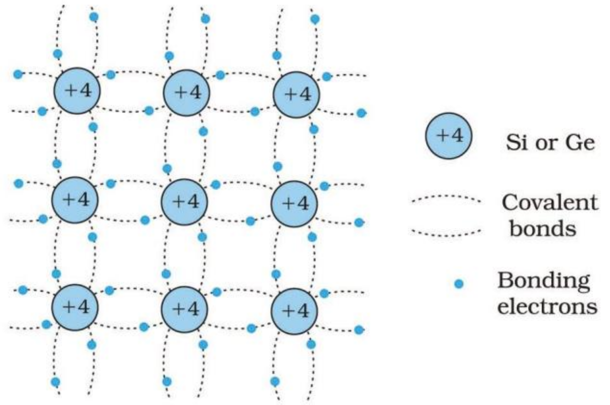
$\rho^{-1} = e(n_e\mu_e + n_h\mu_h)$

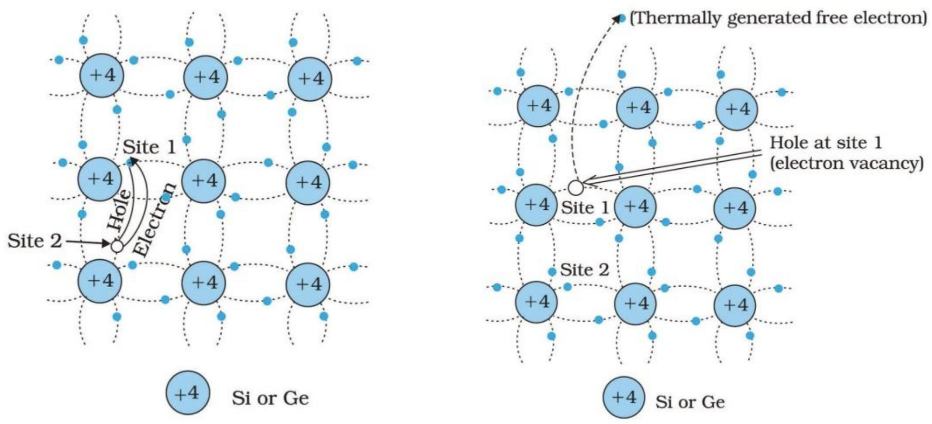
<u>Intrinsic semi conductors</u>

- Lattice structure called diamond-like structure
- Each atom has 4 valence electrons
- At low temp., convalent bonds are intact
- As temperature increases some electrons become <u>free</u> for conduction → Some atoms are ionized creating a <u>vacancy</u> in the bond called a <u>hole</u>.

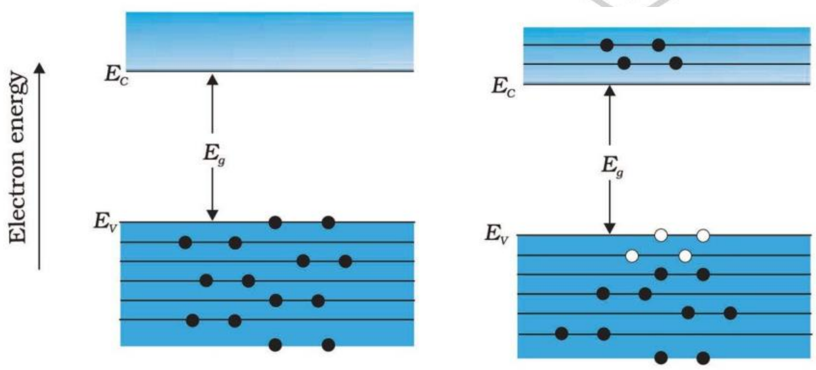
- The hole behaves as an apparent free particle with effective +ve charge
- In intense semi-conductors, $n_e = n_h = n_i$, where n_i – intrinsic carrier concentration
- Semiconductors possess the unique property → electrons and holes both move.
- The free electrons move independent of the hole
- Under the action of an applied electric field, $I = I_e + I_h$, where I is the "total current", I_e is the "electron current" and I_h is the "hole current".
- Simultaneous generation of holes & e^-s, recombination occurs due to electrons colliding to a hole.
- At equilibrium, rate of generation = rate of recombination of charge carriers.

<u>2-D Si or Ge at low-temp</u>





(b) (a)

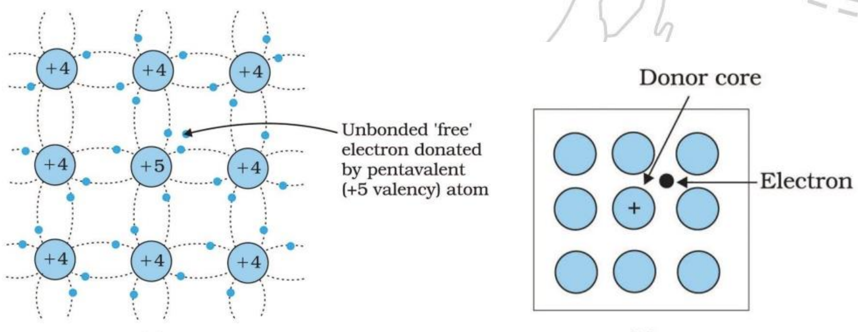


(a) (b)

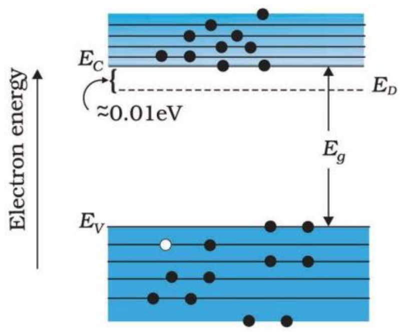
Extrinsic Semiconductors

- At the room temp., conductivity of intrinsic semiconductor is very low
- On adding a small amount (few ppm) of impurity (dopant), conductivity increases manifold . Such doped semiconductor are called extrinsic semiconductors.
- **Doping**- The process of adding impurities to a pure semiconductor crystal (Si or Ge) , so as to improve its conductivity is called doping.
- Size of dopant ≈ size of semiconductor atoms o avoid distortion of lattice
- Pentavalent dopants → Arsenic (As), Antimony (Sb), Phosphorus(P)
- Trivalent dopants → Indium (In), Boron (B), Aluminium (A)

n-type Semiconductor - Pentavalent (+5 valency) dopant (As,P,Sb)



(a) (b)



(a) $T > 0K$
one thermally generated electron-hole pair + 9 electrons from donor atoms

When a pentavalent impurity atom substitute the trivalent atom, it uses four of its five valence electrons in forming four covalent bonds with neighbouring Si atom while 5th electron weakly bound to parent atom and therefore has low ionization energy to separate electrons from its atom in contrast to forbidden gap. Even at room temp., this electron is free to move in lattice. The no. of free electrons made available for conduction by dopant atoms depends strongly upon doping level & is independent of any rise in temperature. But no. of free electrons (with equal no. of holes) generated by Si atoms increases weakly with temperature.

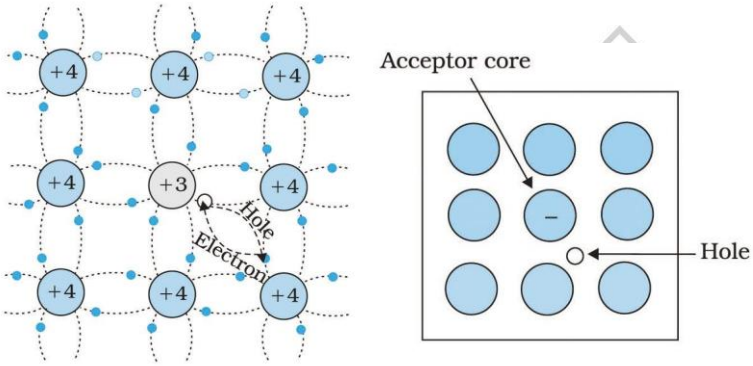
These semiconductor have free electrons contributed by donors and generated by the thermal process (majority carriers) while the holes are only due to thermal agititation (minority carriers). As most of the currents is carried by negatively charged electrons so the semiconductor doped with donor impurities are known as end type semi conductor.

- In n-type, $n_e >> n_h$, e^-s are the majority carriers, holes are the minority carriers.

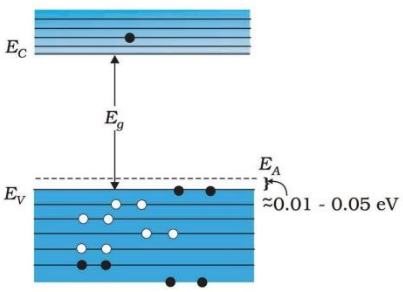
- At room temp, most of donor atoms get ionized but very few Si atoms get ionized.

<u>p-type Semiconductor</u> - Trivalent (+3 valency) dopant (In, B, Al, Ga)
The trivalent impurity atom uses its three valence electrons in forming covalent bonds with three neighbouring Si and one covalent bond with a neighbouring Si atom is left incomplete due to the deficiency of one electron , creating a vacancy or hole in that bond , which is available for conduction .
Hence the trivalent impurity is called an acceptor beause it creates a hole which can accept an electron from the neighbouring atom.

- In p-type, $n_h >> n_e$, e^-s are the minority carriers, holes are the majority carriers.



(a) (b)



(b) $T > 0K$

Distinguish between intrinsic and extrinsic semiconductors

Intrinsic Semi Conductor	Extrinsic Semiconductor
These are pure semiconducting tetravalent crystals.	These are semi-conducting tetravalent crystals doped with impurity atoms of group III or V
Their electrical conductivity is low.	Their electrical conductivity is high.
There is no permitted energy state between valance and conduction bands	There is permitted state of the impurity atom between valance and conduction bands
The number of free electrons in the conduction band is equal to the number of holes in valance band.	The electrons are majority charge carriers in n-type semiconductors while holes are majority charge carries in p-type semi conductors .
Their electrical conductivity depends on temperature	Their electrical conductivity depends on temperature as well as on dopant concentration.

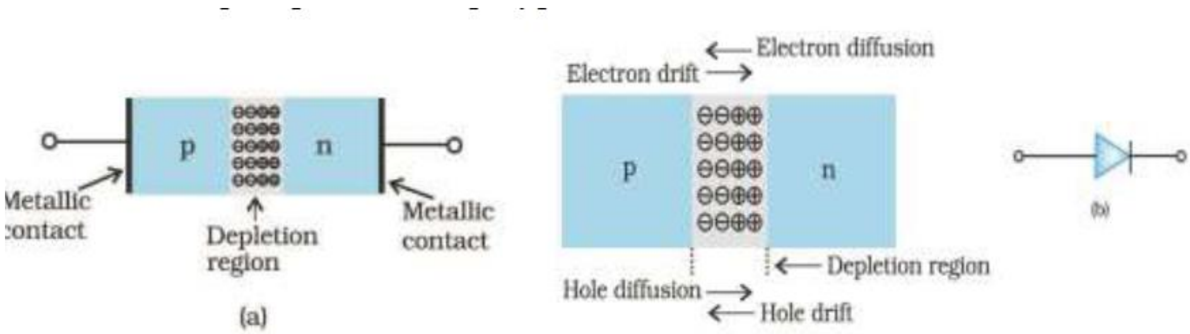
Distinguish between n-type and p-type semiconductors.

n-type semiconductor	p-type semiconductor
These are extrinsic semiconductors obtained by doping impurity atoms of group V to Ge or Si crystal.	These are extrinsic semiconductors obtained by doping impurity atoms of group III to Ge or Si crystal.
The impurity atoms added provide free electrons and are called donors.	The impurity atoms added create vacancies of electrons (or holes) and are called acceptors.
The donor impurity level lies just below the conduction band.	The acceptor impurity level lies just above the valence band.
The electrons are majority charge carriers while holes are minority charge carriers.	The holes are majority charge carriers while electrons are minority charge carriers.
The free electron density is much greater than hole density i.e $n_e >> n_h$	The free electron density is much greater than free electron density i.e $n_h >> n_e$.

<u>P-N Junction</u>

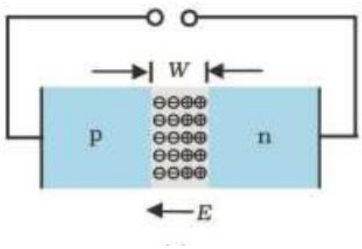
<u>Formation of p-n junction</u>

When a p type semiconductor is placed in contact with n type semiconductor, the assembly so obtained is called p- n junction. The surface of contact of p and n type crystals is called junction. To make a p- n junction, the n type and p type Si crystals are cut into thin slices called wafers. If on a wafer of n type Si, an Al film is placed and heated to a very high temp. (580 C), Al diffuses into Si. In this way, a p- type semiconductor is formed on an n- type semiconductor. Such a formation of p- region on n- region is called p- n junction. (or diffusion of phosphorus into p- type semiconductor).



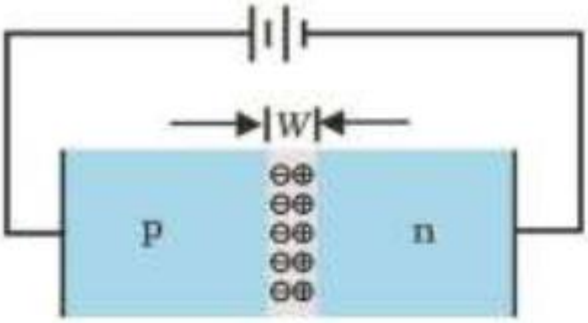
Depletion region and barrier electric field in p- n junction.

Two processes occur during the formation of a p- n junction diffusion and drift: In n-type semiconductor, electrons are majority carriers while in the p- type semiconductor, holes are the majority carriers. Due to difference in concentration of charge carriers in the two regions of p- n junction, the electrons from n region diffuse through the junction into p- region and holes from p- region diffuse into n- region. The motion of charge carriers gives rise to diffusion current across the junction. When an electron diffuses from n- region to p- region of p- n junction, it leaves behind an immobile ionized donor atom in n region having +ve charge. As diffusion of electrons continues from n region to p region, more +vely charged donor atoms are created in n- region resulting in a layer of +ve charge (i.e. +ve space charge region) near the junction in n- region. Similarly -ve space charge region in p region. The space- charge regions on both the sides of p- n junction which has immobile ions and is devoid of any charge carrier from a region called depletion layer. Due to +ve space charge region on n- side of junction & -ve space charge region on p- side of junction, an electric field is set up across the junction, as if fictitious battery is connected with its +ve terminal to n- region and –ve terminal to p- region. The Electric field sets up a potential barrier at junction which opposes the further diffusion of majority carriers. Due to electric field, an electron from p- side moves to n- side and a hole from n- side moves to p- side of the junction. The motion of charge carriers due to electric field is called drift. As a result, drift current starts in the direction opposite to the diffusion current. In the beginning, the diffusion current is large but drift current is small. As the diffusion process continues, the space charge regions across the junction extend. Due to which the strength of electric field across the junction increases and thereby drift current increases. The process continues till the diffusion current becomes equal to drift current. At this stage, p- n junction acquires equilibrium i.e. there is no current across the p- n junction & potential barrier is maximum. At room temp VB $\approx$ 0.3 for G $\approx$ 0.7 for Si Width of depletion layer $\approx$ 10-6 therefore electric field across the junction = E = V/d = 0.7/10-6 = 7x 105 V/m (very high).

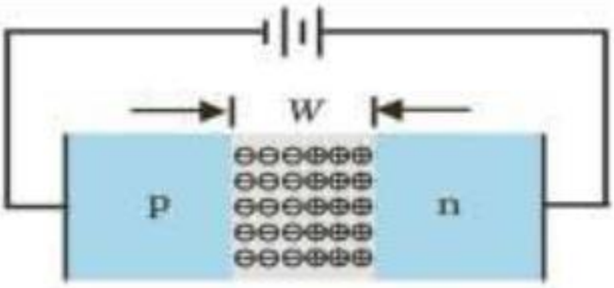


Biasing of the P-N Junction

Forward Biasing – A p-n junction is said to be forward biased if the +ve terminal of thebattery is connected to p-side and the –ve terminal is connected to the n-side of the p-n junction. Working In forward biasing, forward voltage opposes the potential barrier VB. Therefore, the height of the potential barrier is reduced and the width of the depletion layer decreases.



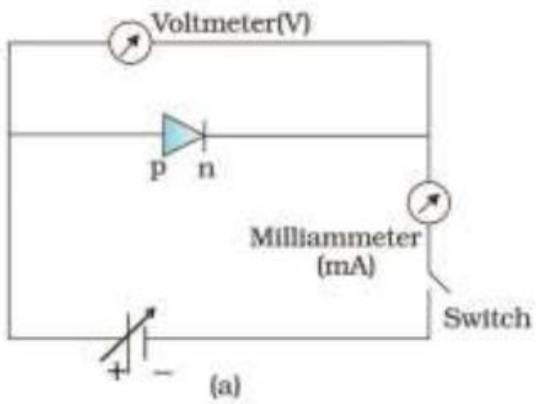
The majority carriers, electrons in the n-region & holes in the p-region are repelled by the battery towards the junction, due to which diffusion of majority carriers takes place across the junction. On crossing the junction, the no. of the free electrons and holes will combine with each other. For each electron-hole combination, a covalent bond in p-region near +ve terminal of the battery is broken and the liberated electron enters the +ve terminal of the battery. At the other hand, the electrons from the –ve terminal of the battery enter the n-region to replace the electrons lost due to the combination with the holes at the junction. Thus electric current flows due to migration of majority carriers, which is called forward current. Small rise in forward voltage shows the large rise in forward current; hence resistance of p-n junction is low. Reverse Biasing - A p-n junction is said to be reverse biased if the -ve terminal of thebattery is connected to p-side and the +ve terminal is connected to the n-side of the p-n junction.



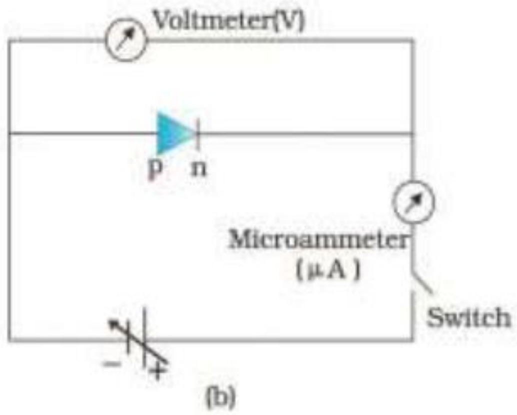
Working

In reverse biasing, there is no conduction across the junction due to majority carriers. However, a few minority carriers are accelerated by high reverse bias voltage. They constitute a current that flows in the opposite direction. This is called reverse current or leakage current. Since the large increase in reverse voltage shows small increment in reverse current, hence the resistance of p-n junction is high to the flow of current.

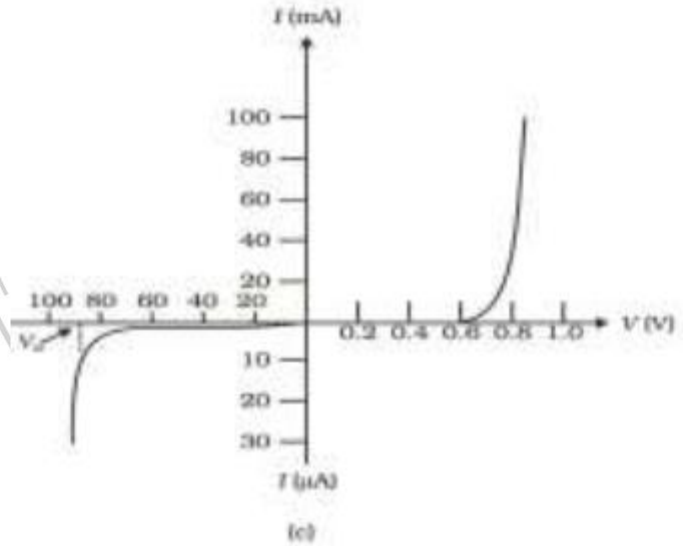
Characteristic Curves



Forward biasing



Reverse biasing

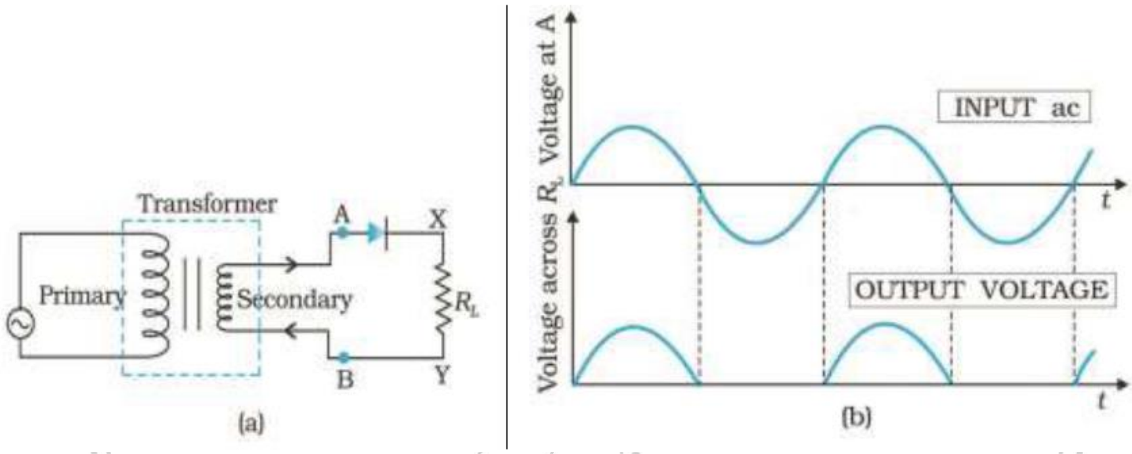


p-n junction diode as a rectifier

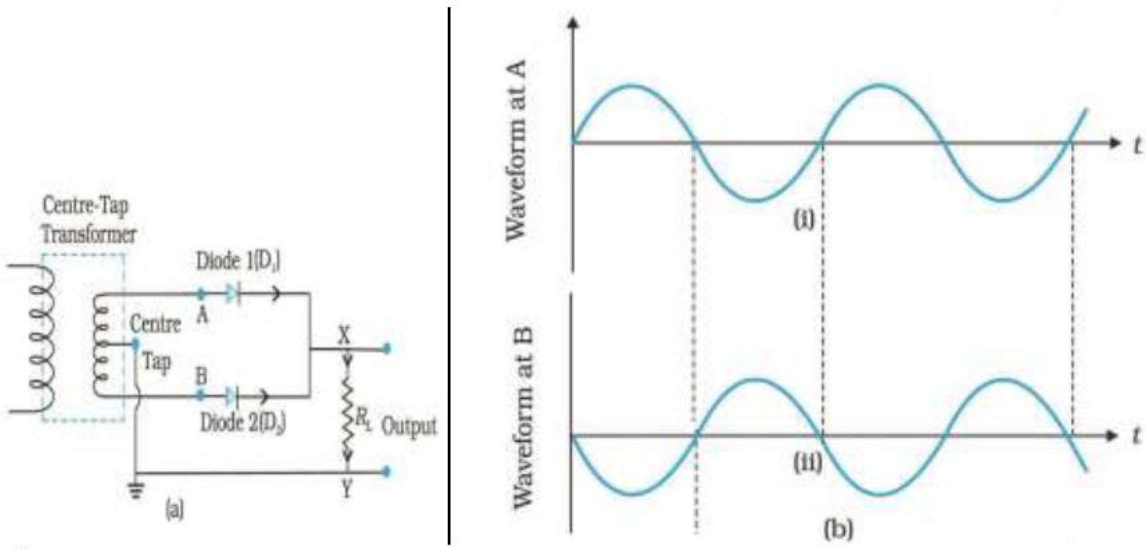
Rectifier is a device which converts A.C. to D.C. voltage. A p-n junction can be used as a rectifier in 2 ways:- 1) Half wave rectifier 2) Full wave rectifier

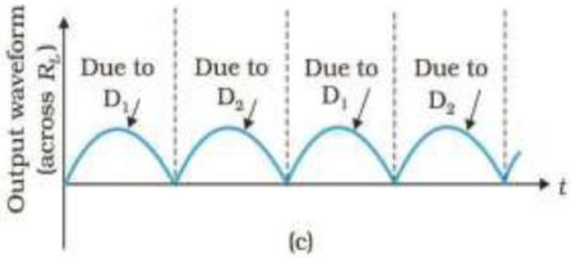
Principle: Its working is based on the fact that it offers low resistance when it is forward biased and high resistance when it is reversed biased. Half wave rectifier - It converts only one half of a.c. into d.c. When the +ve half of a.c.
input flows through the primary coil, an induced emf is set up in the secondary coil due to mutual induction. The direction of the induced emf is such that the upper end of the secondary coil becomes +ve and lower end becomes –ve. So the junction diode is forward biased during the +ve half cycle. Thus the junction diode conducts and output is obtained across RL. During –ve cycle of input a.c., the junction diode is Reverse Bias. hence does

not conduct and no output is obtained across RL. Hence the output signal is discontinuous pulsating d.c. Half wave rectifier produces lots of wastage of energy to overcome it. Full wave rectifier is used. Output d.c. voltage = Mean load current x Load Resistance VDC = IDC x RL = I0RL/π



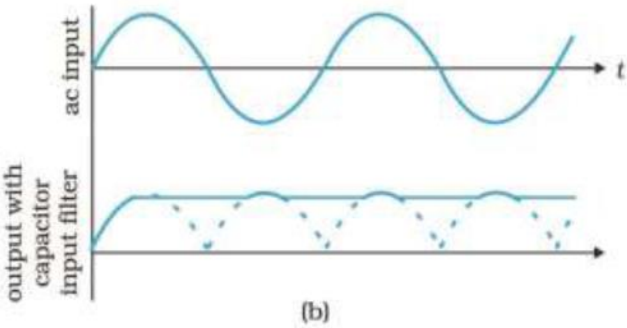
<u>Full wave rectifier</u> - It rectifies both halves of a.c. input cycle. When +ve half cycle of input a.c. signal flows through the primary coil, induced emf is set up in the secondary coil due to mutual induction. The direction of induced emf is such that the upper end of secondary coil becomes +ve while the lower end becomes –ve. Thus diode D1 is forward biased and Diode D2 is reverse biased. The output voltage which varies in accordance with the input half cycle is obtained across central tapped RL. During –ve half cycle of a.c. input signal, Diode D1 is reverse biased and D2 is forward biased. Therefore, the current due to D2 flows through the circuit





(c)

The pulsating output can be smoothened by using a filter circuit.



(b)

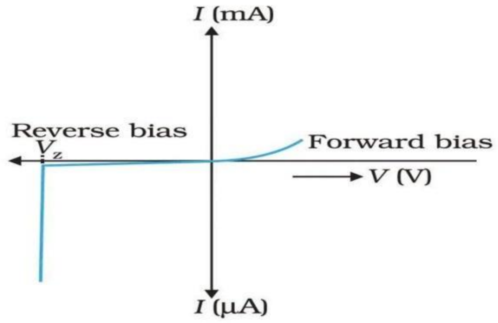
$V_{DC} = 2I_0R_L/\pi$

V_{DC} of full wave rectifier = $2V_{DC}$ of half wave rectifier.

Different types of p-n junction diode

1. **Zener diode**- It was invented by C. Zener. It is specially design p-n junction diode which can operate in reverse breakdown voltage region continuously without being damaged. Both n and p regions of Zener diode are heavily doped. Due to this, depletion region formed is very thin ($<10^{-6}$ m) and the electric field of the junction is extremely high ($5X\ 10^6$ V/m) even for a small reverse bias voltage of about 5 V. Zener diode is available having Zener voltage of 2.4V to 200V. Their power rating (i.e. maximum power dissipation) = Zener breakdown voltage X maximum Zener current vary from 150 mW to 50W)
   Let us understand how reverse current suddenly increases at the breakdown voltage. We know that reverse current is due to the flow of electrons (minority carriers) from
   $p \rightarrow n$ and holes from $n \rightarrow p$. As the reverse bias voltage is increased, the electric field at the junction becomes significant. When the reverse bias voltage $V = V_z$, then the electric field strength is high enough to pull valence electrons from the host atoms on the p-side which are accelerated to n-side. These electrons account for high current observed at the breakdown. The emission of electrons from the host atoms due to the high electric field is known as internal field emission or field ionisation. The electric field required for field ionisation is of the order of 10^6 V/m.

(a)



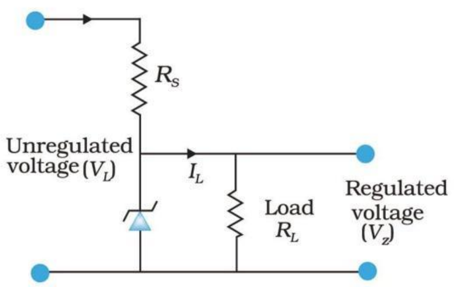
(b)

Essential features for proper working

1. Zener diode must be reverse biased
2. The Zener diodes must have voltage > Zener breakdown voltage (V_z)
3. Current in the circuit < maxi Zener current (I_z) limited by power rating of the given Zener diode.

Zener diode as a voltage stabilizer

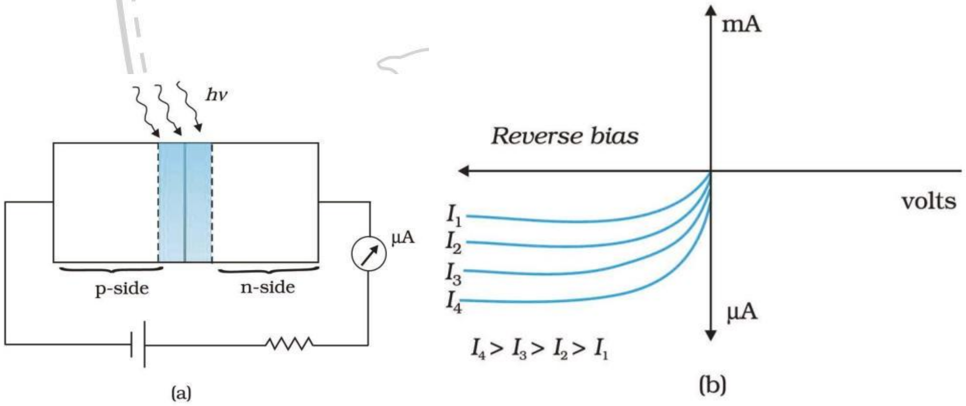
The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance Rs such that the Zener diode is reverse biased. If the input voltage increases, the current through Rs and Zener diode also increases. This increases the voltage drop across Rs without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes. Similarly, if the input voltage decreases, the current through Rs and Zener diode also decreases. The voltage drop across Rs decreases without any change in the voltage across the Zener diode. Thus any increase/ decrease in the input voltage results in, increase/ decrease of the voltage drop across Rs without any change in voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator. We have to select the Zener diode according to the required output voltage and accordingly the series resistance Rs.



Optoelectronic junction device - The junction diode in which current carriers are generated by protons through photo excitation.

Photo diode - A special junction diode made up of photo sensitive semi conducting material. It operates in reverse bias.

Working: . It is operated under reverse bias. When the photodiode is illuminated with light (photons) with energy (hv) greater than the energy gap (E g) of the semiconductor, then electron-hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity of incident light (photocurrent is proportional to incident light intensity).



A photo diode is preferably operated in reverse biased condition

Consider an n-type semiconductor. Its majority carrier density is much more larger than the minority hole density $n_e >> n_h$. When illuminated with light, both types of carrier increase equally in no.

$n_e' = n_e + \Delta n_e$

$n_h' = n_h + \Delta n_h$

Now, $n_e >> n_p$, $\Delta n_e = \Delta n_h$

Thus, $\Delta n_e/n_e << \Delta n_h/n_h$, i.e., fractional increase in majority carrier is much less than fractional increase in minority carriers. Therefore, fractional change in minority carrier due to photo-effect is more easily measurable than fractional change in majority carriers. Hence, photodiodes are preferably used in reverse bias condition for measuring light intensity.

L.E.D. - An especially heavily doped, forward biased p-n junction which spontaneously converts the biasing electrical energy into optical energy like visible light, I.R. etc.

When the p-n junction is forward biased its potential barrier reduces and its depletion region becomes so thin that holes and electrons are free to cross the barrier. Electrons injected into the p-region encounter holes and recombine. Similarly holes injected into the n-region encounter electrons and recombine. For each electron-hole combination, electric potential energy is converted into electromagnetic energy and a photon of light with a frequency characteristic of the semi conductor material is emitted. The colour of light emitted depends upon the type of material used in making semi conductor diode

1. Ga As (Gallium Arsenide) - I.R. radiation
2. GaP (Gallium Phosphide)- red or green light
3. Ga Asp (Gallium-arsenide –phosphide) – red or yellow light
4. Si or Ge - Infra red (or heat) radiation

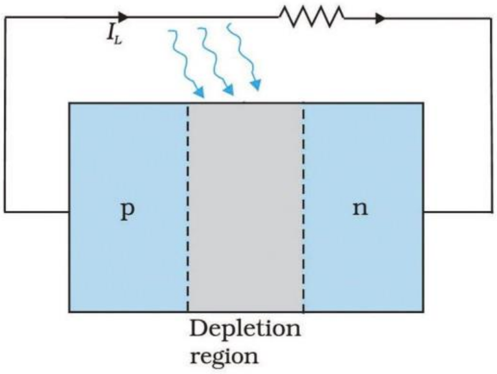
The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV (spectral range of visible light is from about 0.4 μm to 0.7 μm, i.e., from about 3 eV to 1.8 eV). The compound semiconductor Gallium Arsenide – Phosphide (GaAs1–xPx) is used for making LEDs of different colours. $GaAs_{0.6}P_{0.4}$ (E g ~ 1.9 eV) is used for red LED. GaAs (E g ~ 1.4 eV) is used for making infrared LED. These LEDs find extensive use in remote controls, burglar alarm systems, optical communication, etc. Extensive research is being done for developing white LEDs which can replace incandescent lamps.

LEDs have the following advantages over conventional incandescent low power lamps:

(i) Low operational voltage and less power. (ii) Fast action and no warm-up time required. (iii) The bandwidth of emitted light is 100 Å to 500 Å or in other words it is nearly (but not exactly) monochromatic. (iv) Long life and ruggedness. (v) Fast on-off switching capability.

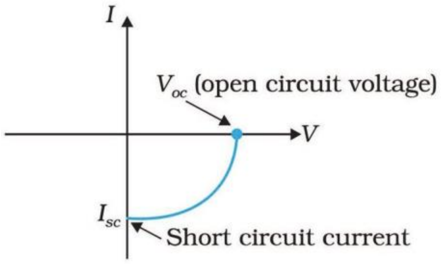
Solar cells - It is a junction diode which converts solar energy into electricity and is based on photovoltaic effect i.e. generation of voltage due to bombardment of light photon.

A p-Si wafer of about 300 μm is taken over which a thin layer (~0.3 μm) of n-Si is grown on one-side by diffusion process. The other side of p-Si is coated with a metal (back contact). On the top of n-Si layer, metal finger electrode (or metallic grid) is deposited. This acts as a front contact. The metallic grid occupies only a very small fraction of the cell area (E g) close to the junction; (ii) separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side; (iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise

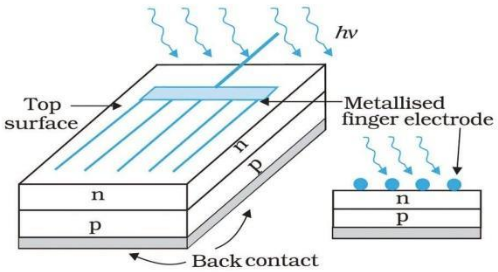


(a)

to photovoltage.



(b)



(a) (b)

The I – V characteristics of solar cell is drawn in the fourth quadrant of the coordinate axes. This is because a solar cell does not draw current but supplies the same to the load. Semiconductors with band gap close to 1.5 eV are ideal materials for solar cell fabrication. Solar cells are made with semiconductors like Si (E g = 1.1 eV), GaAs (Eg = 1.43 eV), CdTe (E g = 1.45 eV), CuInSe2 (E g = 1.04 eV), etc. The important criteria for the selection of a material for solar cell fabrication are (i) band gap (~1.0 to 1.8 eV), (ii) high optical absorption (~104 cm–1), (iii) electrical conductivity, (iv) availability of the raw material, and (v) cost.

Sample Question Paper

Class XII -Physics

(Applicable for March 2016 Examination)

Time Allowed: 3 Hours *Maximum Marks: 70*

General Instructions

1. *All questions are compulsory. There are 26 questions in all.*
2. *This question paper has five sections: Section A, Section B, Section C, Section D and Section E.*
3. *Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.*
4. *There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.*
5. *You may use the following values of physical constants wherever necessary.*

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}

$\boldsymbol{\varepsilon}_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$ N m^2 C^{-2}

$m_e = 9.1 \times 10^{-31}$ kg

mass of neutron = 1.675×10^{-27} kg

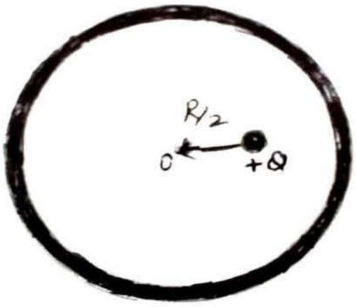
mass of proton = 1.673×10^{-27} kg

Avogadro's number = 6.023×10^{23} per gram mole

Boltzmann constant = 1.38×10^{-23} JK^{-1}

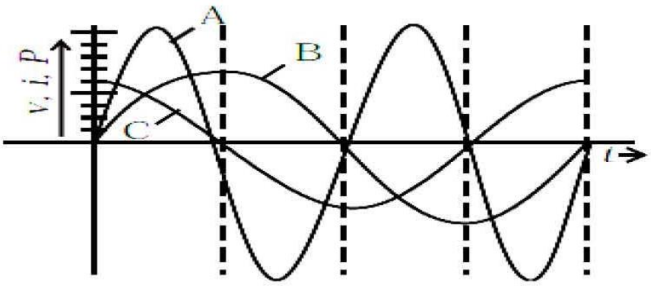
Section A

1. Figure shows a point charge +Q, located at a distance R/2 from the centre of a spherical metal shell. Draw the electric field lines for the given system. (1)



2. Give an example of a material each for which temperature coefficient of resistivity is (i) positive, (ii) negative. (1)

3. A device 'X' is connected to an a.c. source $V = V_o \sin \omega t$. The variation of voltage, current and power in one complete cycle is shown in the following figure. (1)
(i) Which curve shows power consumption over a full cycle?
(ii) Identify the device 'X'.

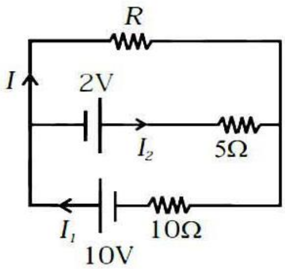


4. An object is placed in front of convex lens made of glass. How does the image distance vary if the refractive index of the medium is increased in such a way that still it remains less than the glass? (1)

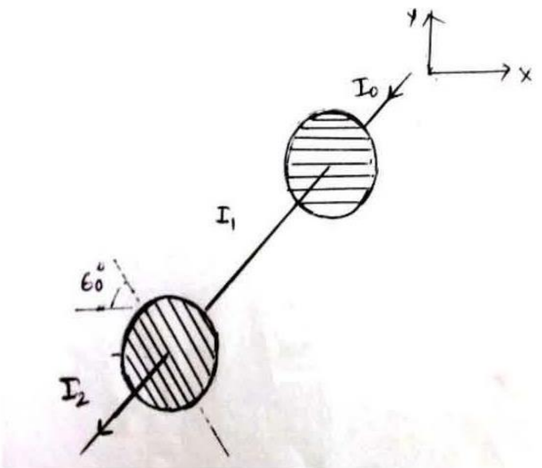
5. Name the network within an institution, made by connecting all or some of their computers. (1)

Section B

6. Two cells of E.M.F. 10 V and 2 V and internal resistances 10 Ω and 5 Ω respectively, are connected in parallel as shown. Find the effective voltage across R. (2)



7. Figure shows a system of two polarizing sheets in the path of initially unpolarized light. The polarizing direction of first sheet is parallel to x-axis and that of second sheet is 60° clockwise from x-axis. Calculate what fraction of intensity of light emerges from the system. (2)



OR

State Huygen's principle. Using it, construct a ray diagram for a plane wave front getting incident on a denser medium. (2)

8. A monochromatic light source of power 5mW emits $8X10^{15}$ photons per second. This light ejects photoelectrons from a metal surface. The stopping potential for this set up is 2V. Calculate the work function of the metal. (2)

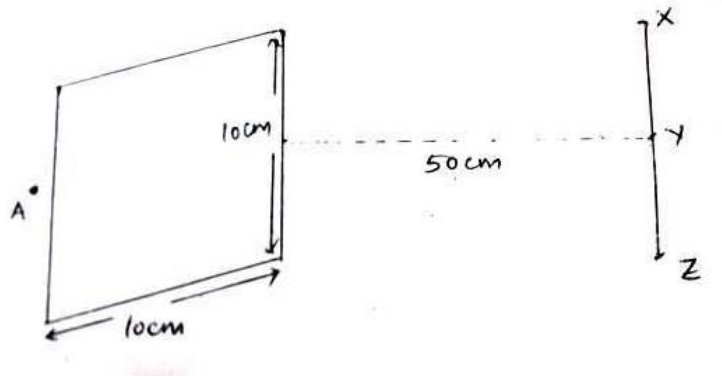
9. The following table shows some measurements of the decay rate of a radionuclide sample. Find the disintegration constant. (2)

Time (min)	lnR (Bq)
36	5.08
100	3.29
164	1.52
218	1.00

10. Distinguish between any two types of propagation of Electromagnetic waves with respect to (i) frequency range over which they are applicable (ii) communication systems in which they are used. (2)

Section C

11. Given a uniformly charged plane/ sheet of surface charge density $\sigma = 2X10^{17}$ C/m^2. (3)
    (i) Find the electric field intensity at a point A, 5mm away from the sheet on the left side.
    (ii) Given a straight line with three points X, Y & Z placed 50 cm away from the charged sheet on the right side. At which of these points, the field due to the sheet remain the same as that of point A and why?



12. The potential difference across a resistor 'r' carrying current 'I' is Ir. (3)
   (i) Now if the potential difference across 'r' is measured using a voltmeter of resistance 'R_v', show that the reading of voltmeter is less than the true value.
   (ii) Find the percentage error in measuring the potential difference by a voltmeter.
   (iii) At what value of R_v, does the voltmeter measures the true potential difference?

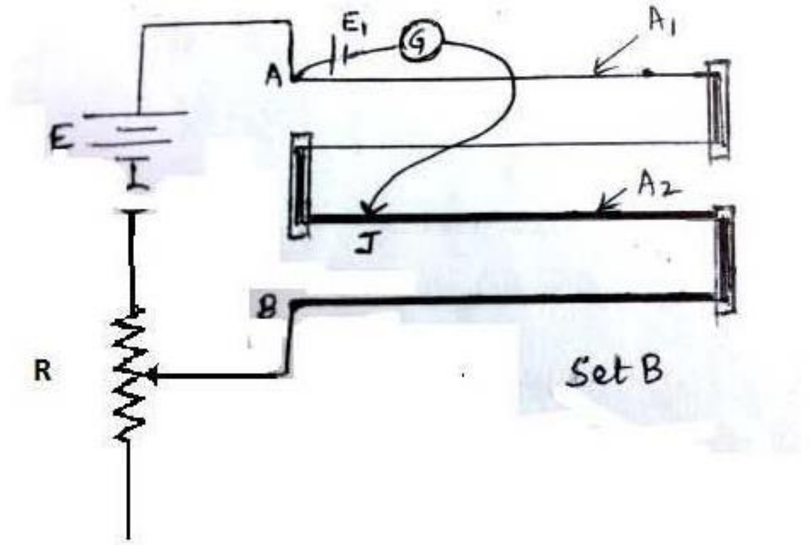
OR

You are given two sets of potentiometer circuit to measure the emf E1 of a cell.

Set A: consists of a potentiometer wire of a material of resistivity ρ_1, area of cross-section A_1 and length l.

Set B: consists of a potentiometer of two composite wires of equal lengths l/2 each, of resistivity ρ_1, ρ_2 and area of cross-section A_1, A_2 respectively.

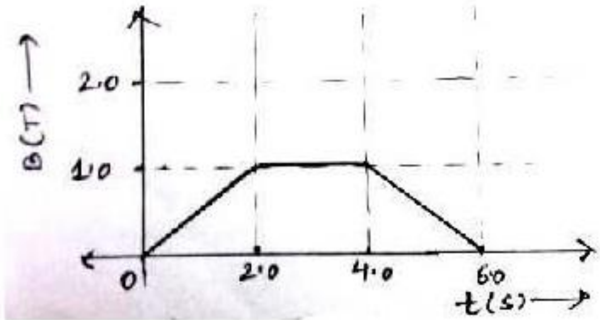
(i) Find the relation between resistivity of the two wires with respect to their area of cross section, if the current flowing in the two sets is same.
(ii) Compare the balancing length obtained in the two sets. (3)



13. (i) Name the machine which uses crossed electric and magnetic fields to accelerate the ions to high energies. With the help of a diagram, explain the resonance condition. (2)

(ii) What will happen to the motion of charged particle if the frequency of the alternating voltage is doubled? (1)

14. The magnetic field through a single loop of wire, 12cm in radius and 8.5Ω resistance, changes with time as shown in the figure. The magnetic field is perpendicular to the plane of the loop. Plot induced current as a function of time. (3)



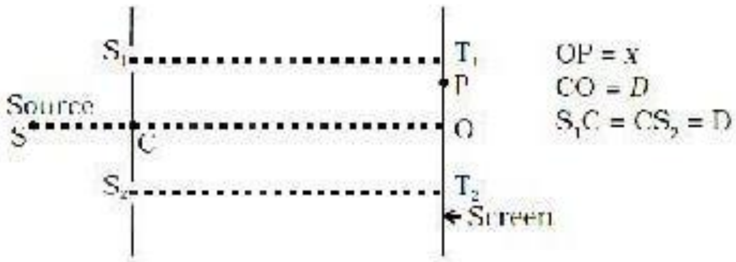
15. Identify the type of waves which are produced by the following way and write one application for each: (3)

(i) Radioactive decay of the nucleus,

(ii) Rapid acceleration and decelerations of electrons in aerials,

(iii) Bombarding a metal target by high energy electrons.

16. Consider a two slit interference arrangement (shown in figure) such that the distance of the screen from the slits is half the distance between the slits. Obtain the value of D in terms of λ such that the first minima on the screen fall at a distance D from the centre O. (3)

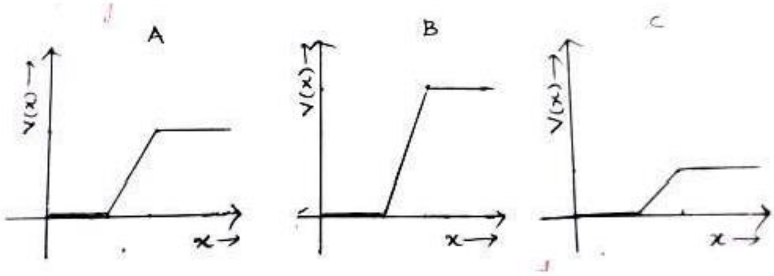


17. A compound microscope consists of an objective of focal length 1cm and eye piece of focal length 5cm separated by 12.2cm. (a) At what distance from the objective should an object be placed so that the final image is formed at least distance of distinct vision? (b) Calculate the angular magnification in this case. (3)

18. Compare the photoelectric effect on the basis of photon theory and wave theory of light and hence explain why the wave theory failed to explain it. (3)

19. Derive the expression for the magnetic field at the site of a point nucleus in a Hydrogen atom due to the circular motion of the electron. Assume that the atom is in its ground state and give the answer in terms of fundamental constants. (3)

20. The graph of potential barrier versus width of depletion region for an unbiased diode is shown in A. In comparison to A, graphs B and C are obtained after biasing the diode in different ways. Identify the type of biasing in B & C and justify your answer. (3)



21. Explain the following: (3)
    (i) In the active state of the transistor, the emitter base junction acts as a low resistance while base collector region acts as high resistance.
    (ii)Output characteristics are controlled by the input characteristics in common emitter transistor amplifier.
    (iii)LEDs are made of compound semiconductor and not by elemental semiconductors.

22. (i) Write the factors that prevent a baseband signal of low frequency to be transmitted over long distances.
    (ii) What is to be done to overcome these factors? Draw a block diagram to obtain the desired signal. (3)

Section D

23. Ria recently read about earth's magnetic field and its causes. She became so much fascinated by the topic that she further studied it in detail. She collected information as follows: (4)
    - The magnitude of magnetic field at the Earth's surface ranges from 0.25 to 0.65 gauss.
    - The Earth's magnetic field varies with time. There are short term and long term variations.

- One the scale of million years, the Earth's magnetic field reverses its direction, and much more.

She made a power point presentation on the same and shared all this information with her classmates.

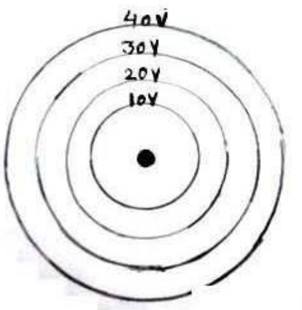
(i) Suggest another activity related to the same topic, which will help a student to internalize the same values gained by Ria.
(ii) Draw a labelled diagram showing the three magnetic elements of earth.

Section E

24. (a) Two isolated metal spheres A and B have radii R and 2R respectively, and same charge q. Find which of the two spheres have greater : (i) Capacitance and (ii) energy density just outside the surface of the spheres. (2)

(b) (i) Show that the equipotential surfaces are closed together in the regions of strong field and far apart in the regions of weak field. Draw equipotential surfaces for an electric dipole. (1+1)

(ii) Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it. (1)



OR

(a) Compare the individual dipole moment and the specimen dipole moment for H_2O molecule and O_2 molecule when placed in

Page **9** of **23**

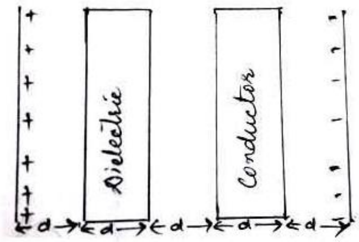
(i) Absence of external electric field (2)

(ii) Presence of external electric field. Justify your answer. (3)

(b) Given two parallel conducting plates of area A and charge densities $+\sigma$ & $-\sigma$. A dielectric slab of constant K and a conducting slab of thickness d each are inserted in between them as shown.

(i) Find the potential difference between the plates.

(ii) Plot E versus x graph, taking x=0 at positive plate and x=5d at negative plate. (2)



25. (a) With the help of a diagram, explain the principle and working of a device which produces current that reverses its direction after regular intervals of time. (3)

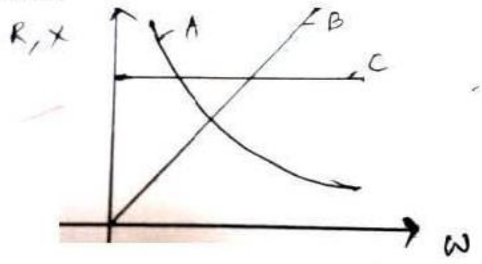
(b) If a charged capacitor C is short circuited through an inductor L, the charge and current in the circuit oscillate simple harmonically.

(i) In what form the capacitor and the inductor stores energy?

(ii) Write two reasons due to which the oscillations become damped. (2)

OR

(a) Figure shows the variation of resistance and reactance versus angular frequency. Identify the curve which corresponds to inductive reactance and resistance.

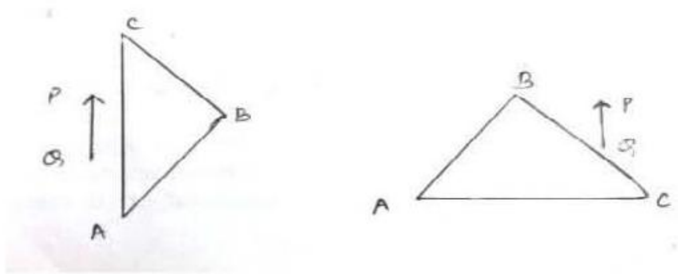


(b) Show that series LCR circuit at resonance behaves as a purely resistive circuit. Compare the phase relation between current and voltage in series LCR circuit for (i) $X_L > X_C$ (ii) $X_L = X_C$ using phasor diagrams.

(c) What is an acceptor circuit and where it is used? (1+3+1)

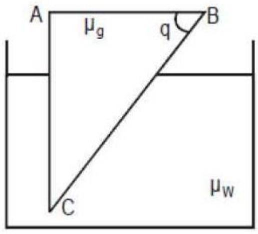
26 (a) Draw a ray diagram to show the formation of the real image of a point object due to a convex spherical refracting surface, when a ray of light is travelling from a rarer medium of refractive index μ1 to a denser medium of refractive index μ2. Hence derive the relation between object distance, image distance and radius of curvature of the spherical surface. (3)

(b) An object is placed in front of right angled prism ABC in two positions as shown. The prism is made of crown glass with critical angle of 41^0. Trace the path of the two rays from P & Q. (2)



OR

(a) Calculate the value of θ, for which light incident normally on face AB grazes along the face BC. $\mu_g = 3/2$ $\mu_w = 4/3$. (2)



(b) Draw a graph showing the variation of angle of deviation 'δ' with that of angle of incidence 'i' for a monochromatic ray of light passing through a glass prism of refracting angle 'A'. What do you interpret from the graph? Write a relation showing the dependence of angle of deviation on angle of incidence and hence derive the expression for refractive index of the prism. (3)

Class XII Physics

Sample Question Paper

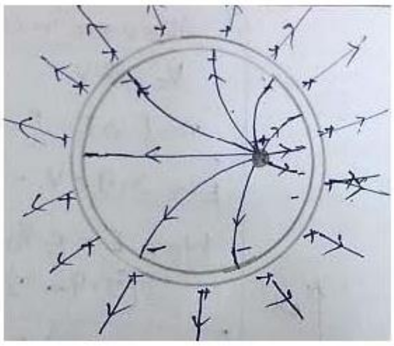
(Applicable for March 2016 Examination)

(Marking Scheme)

Time Allowed: 3 Hours *Maximum Marks: 70*

Section A

1.



Inside (1/2)
Outside (1/2)

2. (i) Cu (metals, alloys) (1/2)
   (ii) Si (semiconductor) (1/2)

3. (i) A (1/2)
   (ii) Capacitor (1/2)

4. $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, $\frac{1}{f} = (\frac{\mu l}{\mu m} - 1)\ (\frac{1}{R1} - \frac{1}{R2})$ (1/2)
   If μ_m increases, 1/f decreases , ∴ v increases. (1/2)

5. LAN (1)

SECTION B

6. $\boldsymbol{\varepsilon}_{eq} = (\frac{\varepsilon 1}{r1} + \frac{\varepsilon 2}{r2}) / (\frac{1}{r1} + \frac{1}{r2})$ (1/2)

$\boldsymbol{\varepsilon}_{eq}$ = (10/10 – 2/5)/ (1/10 + 1/5) (1)

$\boldsymbol{\varepsilon}_{eq}$ = 2V (1/2)

7. $I_1 = I_o/2$ (1/2)
$I_2 = I_1 \cos^2 60^0$ (1/2)
$I_2 = I_o/8$ (1)

OR

7. Huygens' Principle (1)

Ray diagram using Huygen's construction (1)

8. $P = 5 \times 10^{-3}$ W
$n = \frac{P}{E}$,
$E = \frac{P}{n} = 6.25 \times 10^{-19}$ J (1/2)
E = 3.9 eV (1/2)
$W_o = E - eV_o$ (1/2)
$= (3.9 - 2)\ eV_o$
$W_o = 1.9$ eV (1/2)

9. $R = Ro\ e^{-\lambda t}$ (1/2)
$\ln R = \ln Ro - \lambda t$
$\ln R = -\lambda t + \ln Ro$ (1/2)
slope of ln R v/s t is '-λ'
$-\lambda = \frac{0-1.52}{218-164}$ (1/2)
$\lambda = 0.028$ minute^{-1} (1/2)

10.

	Frequency range	Use
Ground wave	500-1500KHz (1/2)	Standard AM broadcast (1/2)
Space wave	Above 40 MHz (1/2)	Television (1/2)

SECTION C

11. (i) at A, $E = \frac{\sigma}{2\varepsilon o}$ (1/2)

$E = 1.1 \times 10^{28}$ N/C (1/2)

Directed away from the sheet (1/2)

(ii) Point Y (1/2)

Because at 50cm, the charge sheet acts as a finite sheet and thus the magnitude remains same towards the middle region of the planar sheet.

(1)

12. (i) V = Ir (without voltmeter) R_v

$V' = \frac{I\,r\,Rv}{r+Rv} = \frac{I\,r}{1+\frac{r}{Rv}}$ (1/2)

$V' < V$ (1/2)

(ii) Percentage error

$\left(\frac{V-V'}{V}\right) \times 100$ (1/2)

$= \left(\frac{r}{r+Rv}\right) \times 100$ (1)

(iii) $Rv \rightarrow \infty$, $V' = I\,r = V$ (1/2)

OR

12 (a) $I = \frac{\varepsilon}{R+\frac{\rho 1\, l}{A1}}$ for Set A (1/2)

$I = \frac{\varepsilon}{R+\frac{\rho 1\, l}{2A1}+\frac{\rho 2 l}{2A2}}$ for set B (1/2)

Equating the above two expressions and simplifying

$$\frac{\rho 1}{A1} = \frac{\rho 2}{A2}$$ (1/2)

(b) Potential gradient of the potentiometer wire for set A, $K = I\frac{\rho 1}{A1}$

Potential drop across the potentiometer wire in set B

$$V = I\left(\frac{\rho 1 l}{2A1} + \frac{\rho 2 l}{2A2}\right)$$

$$V = \frac{I}{2}\left(\frac{\rho 1}{A1} + \frac{\rho 2}{A2}\right) l$$ (1/2)

$K' = \frac{I}{2}\left(\frac{\rho 1}{A1} + \frac{\rho 2}{A2}\right)$, using the condition obtained in part (i) (1/2)

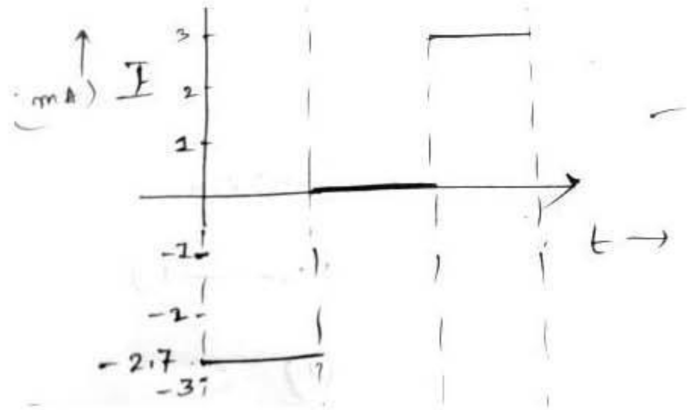
$K' = I\frac{\rho 1}{A1}$, which is equal to K.

Therefore, balancing length obtained in the two sets is same. (1/2)

13. (i) Machine : Cyclotron (1/2)
Diagram (1/2)
Resonance condition (1)
(ii) Particle will accelerate and decelerate alternately. However, the radius of the path will remain unchanged (1)

14. $\varepsilon = -\frac{d\phi}{dt}$,
ε = -0.023 V ,
$I = \varepsilon/R$ = -2.7 mA for $0<t<2s$.

	0<t<2s	2<t<4s	4<t<6s
ε (V)	-0.023	0	+0.023
I (A)	-2.7	0	+2.7



(3)

15.

	Type of wave	Application
(a)	Gamma rays (1/2)	Treatment of tumors (1/2)
(b)	Radio waves (1/2)	Radio and television Communication systems (1/2)
(c)	X- rays (1/2)	Study of crystals (1/2)

16. $T_2P = D + x$, $T_1 P = D - x$ (1/2)

$S_1 P = [\,(S_1T_1)^2 + (PT_1)^2]^{1/2}$ (1/2)

$= [D_2 + (D - x)^2]^{1/2}$ (1/2)

$S_2P = [D^2 + (D + x)^2]^{1/2}$ (1/2)

Minima will occur when $S_2P - S_1P = \lambda/2$ (1/2)

$D = \dfrac{\lambda}{2(\sqrt{5}-1)}$ (1/2)

17. $\frac{1}{fe} = \frac{1}{ve} - \frac{1}{ue}$ solving u_e = -4.2 cm (1)

$\frac{1}{fo} = \frac{1}{vo} - \frac{1}{uo}$, solving u_o= -1.1 cm (1)

$m = \frac{v}{u}\left(1+\frac{D}{f_e}\right) = -44$ (1)

18. Explanation of Photo electric effect (1)
Explanation of the effect using particle concept (1)
Explanation of the failure of wave theory in the explanation (1)

19. $mv^2/r = e^2/4\pi\varepsilon_o r^2$
$v^2 = e^2/m\,4\pi\varepsilon_o r$ (1/2)
Bohr's quantisation condition
$Mvr = nh/2\pi$ (1/2)
Solving, $v = e^2/2\varepsilon_o h$, $r = \varepsilon_o h^2/\pi me^2$ (1/2)
Magnetic field at the centre
$B = \mu_o I/2r$ (1/2)
$I = ev/2\pi r$ (1/2)
$B = \mu_o e^7 \pi m^2/8\varepsilon_o^3 h^5$ (1/2)

20. B : reverse biased (1/2)
C: forward biased (1/2)
Justification (2)

21. (i) Emitter base junction is forward biased whereas base collector junction is reverse biased. (1)
(ii) Small change in the current I_B in the base circuit controls the larger current I_C in the collector circuit. $I_C = \beta I_B$ (1)
(iii) Elemental semiconductor's band gap is such that the emitted wavelength lies in IR region. Hence cannot be used for making LED (1)

22. (i) size of the antenna (1/2)
Effective power radiated by the antenna (1/2)
Mixing up of signals from different transmitters (1/2)
(ii) modulation (1/2)
Block diagram of amplitude modulation (1)

SECTION D

23. (i) Any meaningful activity and values which could be inculcated (2)
(ii) Diagram with labelling three magnetic elements of earth (1+1)

SECTION E

24. (a) (i) $C_A = 4\pi\boldsymbol{\varepsilon}_o R$, $C_B = 4\pi\boldsymbol{\varepsilon}_o(2R)$ (1/2)
$C_B > C_A$ (1/2)
(ii) $u = \frac{1}{2}\boldsymbol{\varepsilon}_o E^2$ (1/2)
$E = \frac{\sigma}{\varepsilon o} = \frac{Q}{A\varepsilon o}$, $u \alpha 1/A^2$
$\therefore u_A > u_B$ (1/2)
(b) (i) $E = -\frac{dV}{dr}$ (1/2)

For same change in dV, $E \alpha 1/dr$ (1/2)

where 'dr' represents the distance between equipotential surfaces.

Diagram of equipotential surface due to a dipole (1)

(ii) Polarity of charge – negative (1/2)

Direction of electric field – radially inward (1/2)

OR

24 (a)

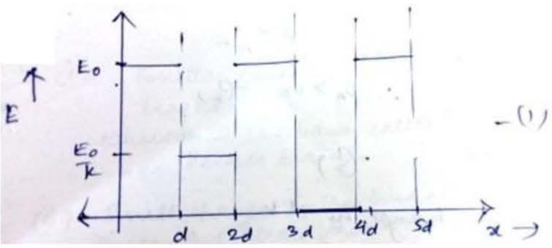
	Non-Polar (O_2) –(1/2)	Polar (H_2O)- (1/2)
Absence of electric field (1)		
Individual	No dipole moment exists	Dipole moment exists
Specimen	No dipole moment exists	Dipoles are randomly oriented. Net **P**=0

Presence of electric field(1)		
Individual	Dipole moment exists (molecules become polarised)	Torque acts on the molecules to align them parallel to **E**
Specimen	Dipole moment exists	Net dipole moment exists parallel to Dipole moment exists **E**.

(b) (i) $V = E_o d + \frac{E_o}{k} d + E_o d + 0 + E_o d$ (1/2)

$V = 3\,E_o d + \frac{E_o}{k} d$ (1/2)

(ii) Graph (1)



25. (a) AC generator

Diagram (1)

Principle (1)

Working (1)

(b) (i) Capacitor – electric field (1/2)

Inductor – magnetic field (1/2)

(ii) resistance of the circuit (1/2)

Radiation in the form of EM waves (1/2)

OR

25 (a) B : inductive reactance (1/2)

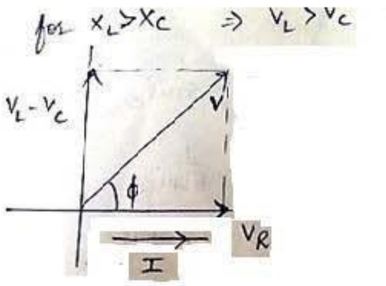
C: resistance (1/2)

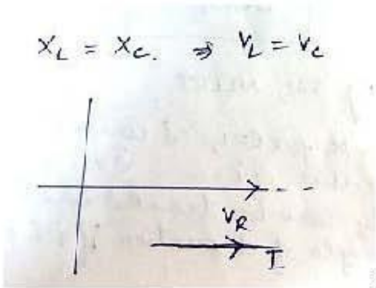
(b) At resonance $X_L = X_C$ (1/2)

$Z = [(X_L - X_C)^2 + R^2]^{1/2}$, $Z = R$ (1/2)

Phasor diagrams (1+1)

phase difference is ϕ





same phase

(c) Acceptor circuit: Series LCR circuit (1/2)

Sin $i_c = 8/9$ (1/2)

(b) Graph (1)

Interpretation: Path of the ray can be traced back resulting in same angle of deviation if i & e are interchanged (1/2)

$\delta + A = i + e$ (1/2)

To derive $\mu = \frac{\sin(A+\delta m)/2}{\sin A/2}$ (1)

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Sample Paper(2016-17)

Time allowed: 3 hours **PHYSICS (XII)** Maximum Marks: 70

General Instructions:

(i) All questions are compulsory.
(ii) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and one question of five marks. You have to attempt only one of the choices in such questions. This paper has five distinct sections.
(iii) Section A has Question numbers **1** to **5.** They are very short answer type questions, carrying **one** mark each.
(iv) Section B has Question numbers **6** to **10.** They are short answer type questions, carrying **two** marks each.
(v) Section C has Question numbers **11** to **22.** They are also short answer type questions, carrying **three** marks each.
(vi) Section D has Question number **23**. It is a value based question, carrying **four** marks.
(vii) Question numbers **24** to **26** are long answer type questions, carrying **five** marks each.
(viii) Use of calculators is not permitted. However, you may use log tables, if necessary.
(ix) You may use the following values of physical constants wherever necessary:

$c = 3 \times 10^{8}\ ms^{-1}$
$h = 6.6 \times 10^{-34}$ Js
$e = 1.6 \times 10^{-19}$ C
$\mu_0 = 4\Pi \times 10^{-7}$ T m A^{-1}
Mass of neutron $m_n = 1.675\times10^{-27 kg}$
Mass of proton $m_p = 1.672\times10^{-27 kg}$
Boltzmann's constant $k = 1.38 \times 10^{-23}$ J K^{-1}
Avogadro's number NA = 6.023×10^{23} / mole
1 MeV = 1.602×10^{-13} J

SECTION A

1. Represent graphically the variation of electric field with distance, for a uniformly charged plane sheet. (1)

2. Draw a graph to show a variation of resistance of a metal wire as a function of its diameter keeping its length and material constant. (1)

3. A rod of length L, along East-West direction is dropped from a height H. If B be the magnetic field due to earth at that place and angle of dip is θ, then what is the magnitude of induced emf across two ends of the rod when the rod reaches the earth? (1)

10. Distinguish between any two types of propagation of electromagnetic waves based on a) frequency range over which they are applicable and b) communication systems in which they are used. (2)

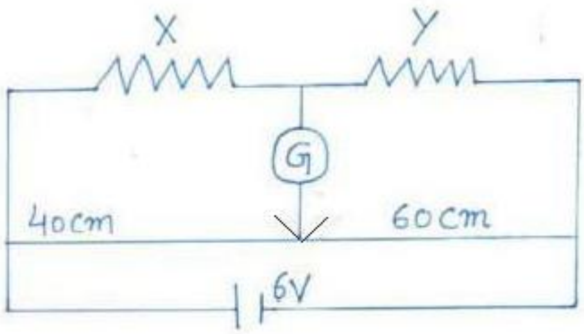
SECTION C

11. If N drops of same size each having the same charge, coalesce to form a bigger drop. How will the following vary with respect to single small drop? (3)

(i) Total charge on bigger drop
(ii) Potential on the bigger drop
(iii) Capacitance

12. In the given circuit, a metre bridge is shown in the balanced state. The metre bridge wire has a resistance of 1 Ω cm^{-1}. Calculate the unknown resistance X and the current drawn from the battery of a negligible internal resistance if the magnitude of Y is 6 Ω. If at the balancing point, we interchange the position of galvanometer and the cell, how it will affect the position of the galvanometer?

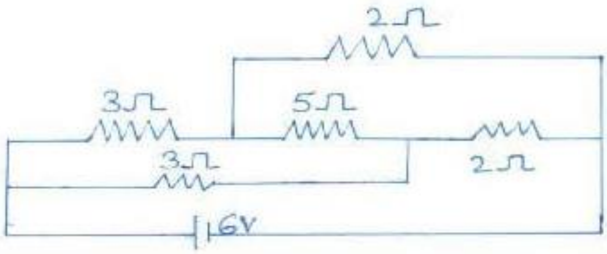
(3)



OR

Calculate the current drawn from the battery in the given network shown here.

State Kirchhoff's loop law and name the law on which it is based on. (3)



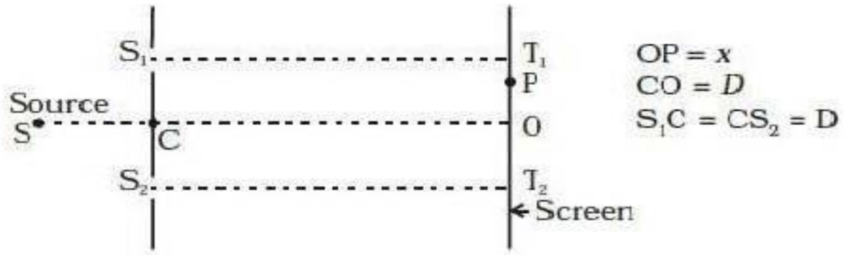
13. A metallic ring of mass m and radius l is falling under gravity in a region having

a magnetic field. If z is the vertical direction, the z-component of magnetic field is $B_z = B_0 (1+\lambda z)$. If R is the resistance of the ring and if the ring falls with a velocity v, find the energy lost in the resistance. If the ring has reached a constant velocity, use the conservation of energy to determine v in terms of m, B, λ and acceleration due to gravity g. (3)

14.
(a) Consider two different hydrogen atoms. The electron in each atom is in an excited state. Is it possible for the electrons to have different energies but same orbital angular momentum according to the Bohr model? Justify your answer.
(b) If a proton had a radius R and the charge was uniformly distributed, calculate using Bohr theory, the ground state energy of a H – atom when R = 10 A°. (3)

15. Describe the concept used for the selection of velocity of a charged particle. Explain the principle of the device with the help of a diagram where the same concept is used. What is the resonating condition for the said device? (3)

16. Consider a two slit interference arrangements such that the distance of the screen from the slits is half the distance between the slits.



Obtain the value of D in terms of λ such that the fist minima on the screen falls at a distance D from the centre O. (3)

17. Draw a labelled ray diagram of an astronomical telescope in the normal adjustment position and find the magnitudes of
a) The length of the telescope
b) The magnification of the telescope
if the focal length of the objective lens is = 15 m and the focal length of an eye lens is 5 cm. (3)

18. Radiation of frequency 10^{15} Hz is incident on three photo sensitive surfaces A, B and C. Following observations are recorded:
a) no photoemission occurs
b) photoemission occurs but the photoelectrons have zero kinetic energy.

c) photo emission occurs and photoelectrons have some kinetic energy.

Based on Einstein's photo-electric equation, explain the three observations. (3)

19. A proton and an alpha particle enter at right angles into a uniform magnetic field of intensity B. Calculate the radii of their paths when they enter the field with the same

a) momentum and
b) kinetic energy

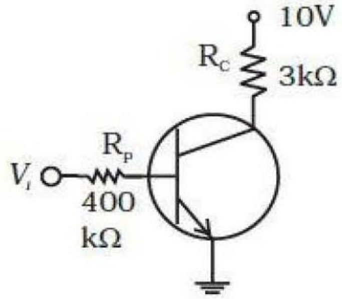
(3)

20. Explain:

a) Three photo diodes D_1, D_2 and D_3 are made of semiconductors having band gaps of 2.5 eV, 2 eV and 3 eV respectively. Which one will be able to detect light of wavelength 6000 A°? (2)

b) Why an elemental semiconductor cannot be used to make visible LEDs? (1)

21. In the circuit shown, when the input voltage of the base resistance is 10 V, V_{BE} is zero and V_{CE} is also zero, find the values of I_B, I_C and β. (3)



22. Explain with reason:

a) In amplitude modulation, the modulation index μ is kept less than or equal to 1.

b) The maximum amplitude of an amplitude modulated wave is found to be 15 V while its minimum amplitude is found to be 3 V. What is the modulation index?

c) Why amplitude modulated signal be noisier than a frequency modulated signal upon transmission through a channel? (3)

SECTION D

23. Muthuswami a resident of Kundakulam was all set to leave everything and shift to another place in view of the decision of Government to start nuclear thermal power plant at Kundakulam. His granddaughter Prachi, a science student was

really upset on the ignorant decision of her grandfather. She could finally convince him not to shift, since adequate safety measures to avoid any nuclear mishap have already been taken by the Government before starting nuclear thermal power plants.

(i) What is the value displayed by Prachi in convincing her grandfather?
(ii) What is the principle behind working of nuclear reactor?
(iii) What are the main component of nuclear reactor?
(iv) Why is heavy water used as moderator? (4)

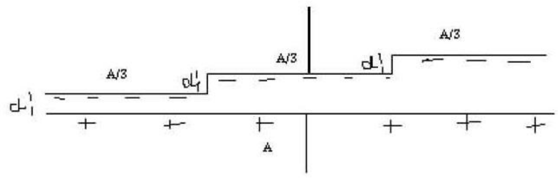
SECTION E

24. Find the expression for the energy stored in the capacitor. Also find the energy lost when the charged capacitor is disconnected from the source and connected in parallel with the uncharged capacitor. Where does this loss of energy appear? (2+2+1)

OR

(a) An electric dipole is held in uniform electric field.
(i) Using suitable diagram, show that it does not undergo any translatory motion.
(ii) Define torque, giving its SI unit; derive an expression for the torque acting on this dipole. (1+2)

(b) A capacitor is made of a flat plate of area A and second plate having a stair like structure as shown in figure below. If width of each stair is A/3 and height is d. Find the capacitance of the arrangement. (2)



25.

a) Derive the condition for the resonance to occur in LCR series circuit. (2)
b) In a series L-R circuit, L = 35 mH and R = 11 Ω, $V = V_o \sin \omega t$ of $V_{rms} = 220$ V and frequency 50 Hz are applied. Find the current amplitude in the circuit and phase of current with respect to voltage. Draw reactance-frequency graph. (3)

OR

a) An a.c. source generating a voltage $V = V_o \sin \omega t$ is connected to a capacitor of capacitance C. Find the expression for the current I flowing through it. Plot a graph of V and I versus ωt to show that the current is $\pi/2$ ahead of the voltage. (3)

b) A resistor of 200 Ω and a capacitor of 15 μF are connected in series to a 220 V, 50 Hz a.c. source. Calculate the current in the circuit and the rms voltage across the resistor and the capacitor. Why the algebraic sum of these voltages is more than the source voltage? (2)

26.

a) For same value of angle of incidence, the angles of refraction in three media are 15^{o}, 20^{o} and 25^{o} respectively. In which medium, the velocity of light will be minimum? (2)

b) Derive the relationship between angle of incidence, angle of prism and angle of minimum deviation for an equilateral prism. (3)

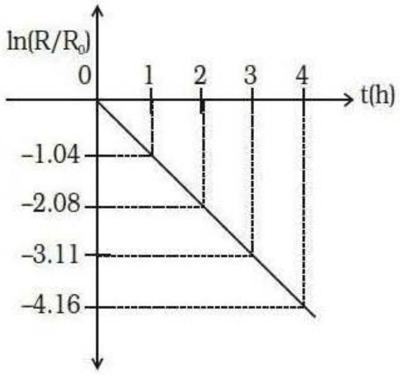
OR

a) State the conditions for total internal reflection to occur. (2)

b) A right angled prism of refractive index n has a plate of refractive index n_1 so that $n_1 < n$, cemented to its diagonal face. The assembly is in air. A ray is incident on AB.

i. Calculate the angle of incidence at AB for which the ray strikes the diagonal face at the critical angle.

ii. Assuming n = 1.352, calculate the angle of incidence at AB for which the refracted ray passes through the diagonal face undeviated. (3)



b) slope of graph = - λ

λ = - [- 4.16 + 3.11 /1] = 1.05 h (½)

$t_{1/2}$ = 0.693 / 1.05 = 39.6 or appro. 40 min (½)

10.

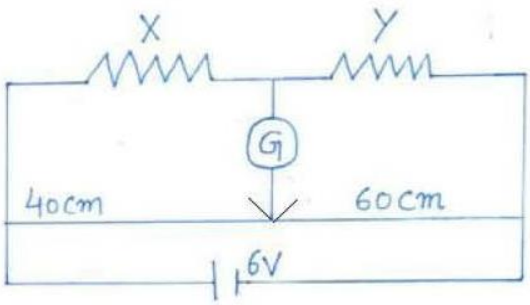
Any correct answer 1 mark each

SECTION C

11.

a) Q = ± N q (1)
b) V = Q/C v = q / c V / v = N (r/R) = $N^{2/3}$ (1)
c) C = $N^{1/3}$ c (1)

12.



$X/Y = 40/60 = 2/3$

$X = 4\ \Omega$ (½)

$4\ \Omega$ and $6\ \Omega$ are in series, $= 10\ \Omega$

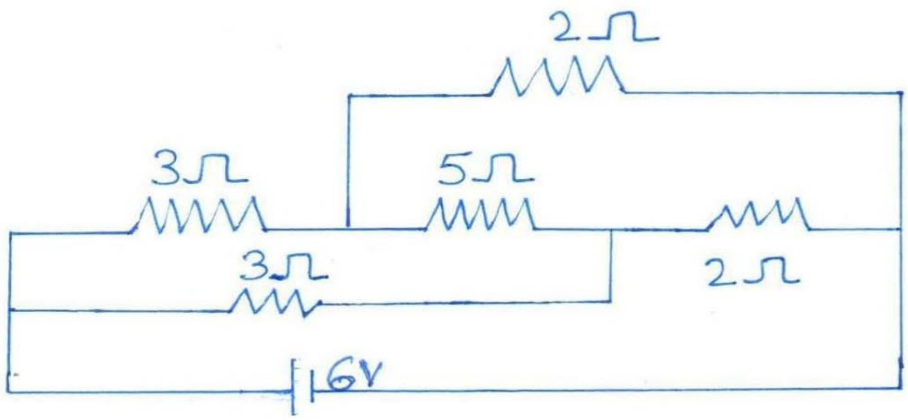
$40\ \Omega$ and $60\ \Omega$ are in series, $= 100\ \Omega$

$10\ \Omega$ and $100\ \Omega$ are in parallel, $= 1000/110\ \Omega = 9.09\ \Omega$ (1)

There will be no change in the balancing length. (½)

Formula for series and parallel (½) each

OR



Balanced Wheatstone bridge (½)

Resultant resistance of the circuit $= 2.5\ \Omega$ (½)

Current in the circuit $= 6/2.5 = 2.4$ A (1)

Statement and conservation of energy (½) each.

13.

Rate of change of flux $= d\Phi/dt = (\pi l^2)\ B_o\ l\ dz/dt = IR$ (½)

$I = (\pi l^2 \lambda) B_o\ v / R$ (½)

Energy lost per second $= I^2 R = (\pi l^2 \lambda)^2\ B_o^2\ v^2 / R$ (½)

Rate of change in PE $= m\ g\ dz/dt = m\ g\ v$ (½)

$mgv = (\pi l^2 \lambda)^2\ B_o^2\ v^2 / R$ (½)

$v = mgR / (\pi l^2 \lambda)^2\ B_o^2$ (½)

14.

a) In absence of magnetic field, the energy is determined by the principle quantum number n, while the orbital quantum number ι. If an electron is in nth state then the magnitude of the angular momentum is (h/2π) l (l+1) where l = 0, 1, 2,.......,(n-1), Since l = 0, 1, 2, . . . , (n− 1), different values of A are compatible with the same value of n. For example, when n= 3, the possible values of l are 0, 1, 2, and when n= 4, the possible values of l are 0, 1, 2, 3. Thus, the electron in one of the atoms could have n= 3, l= 2, while the electron in the other atom could have n= 4, l= 2. Therefore, according to quantum mechanics, it is possible for the electrons to have different energies but have the same orbital angular momentum.

b)

For a point nucleus in H-atom:

Ground state: $mvr = \text{h}. \dfrac{mv^2}{r_B} = -\dfrac{e^2}{{r_B}^2} . \dfrac{1}{4\pi\varepsilon_0}$

$$\therefore m \frac{\text{h}^2}{m^2 {r_B}^2} . \frac{1}{r_B} = + \left(\frac{e^2}{4\pi\varepsilon_0} \right) \frac{1}{{r_B}^2}$$

$$\therefore \frac{\hbar^2}{m} . \frac{4\pi\varepsilon_0}{e^2} = r_B = 0.51\,\text{Å}$$

If $R >> r_B$: the electron moves inside the sphere with radius r'_B (r'_B = new Bohr radius).

Charge inside $r'^{\,4}_B = e\left(\dfrac{r'^{3}_B}{R^3}\right)$

(1)

16.

$T_2P = D + x,\ T_1P = D - x$

$S_1P = \sqrt{(S_1T_1)^2 + (PT_1)^2}$

$= [D^2 + (D - x)^2]^{1/2}$

$S_2P = [D^2 + (D + x)^2]^{1/2}$

Minima will occur when

$$[D^2 + (D + x)^2]^{1/2} - [D^2 + (D - x)^2]^{1/2} = \frac{\lambda}{2}$$

If $x = D$

$$(D^2 + 4D^2)^{1/2} = \frac{\lambda}{2}$$

$$(5D^2)^{1/2} = \frac{\lambda}{2}, \quad \therefore D = \frac{\lambda}{2\sqrt{5}}.$$

17.

Diagram (1)

L = length of the telescope = fo + fe = 15.05 m (1)

m = fo/fe = 15/0.05 =300 (1)

18. A – Incident energy is less than the work function of the metal (1)

B – Incident energy is equal to the work function of the metal (1)

C – Incident energy is greater than the work function of the metal (1)

19.

Proton	alpha particle
e	2e
1 u	4 u

r = mv/Bq

For same momentum: p = mv $\quad r \propto 1/q$ (1)

R(proton) > r(alpha) (½)

For same kinetic energy: KE = ½ m v^2 (1)

$$r^2 \propto m/q^2$$

Radius is independent of KE (½)

20. a)

$E = h\mu$ (½)

$= hc/\lambda = hc / \lambda e$ (½)

$= 2\ eV$ (½)

Hence D_1 and D_3 can detect light. (½)

b)

Number of Free electrons are very small leading to negligible conduction. Hence not possible. (1)

21.

As $V_{be} = 0$, potential drop across R_b is 10V.

$$\therefore I_b = \frac{10}{400 \times 10^3} = 25\mu A$$

Since $V_{ce} = 0$, potential drop across R_c, i.e. $I_c R_c$ is 10V.

$$\therefore I_c = \frac{10}{3 \times 10^3} = 3.33 \times 10^{-3} = 3.33\text{mA}.$$

$$\therefore \beta = \frac{I_c}{I_b} = \frac{3.33 \times 10^{-3}}{25 \times 10^{-6}} = 1.33 \times 10^2 = 133.$$

22. a)

μ is kept less than 1 so that the noise level can be kept small in the signal. (1)

b)

μ = a(max) + a(min) / a(max) - a(min) = 18/12= 9/6 = 3/2 = 1.5 (1)

c)

Fading of a signal is prominent in case of amplitude modulation and hence noise level is more in AM than FM (1)

SECTION D

23.

i) Any one relevant value (1)
ii) Nuclear fission (1)
iii) Fuel, moderator, cadmium rods, any two (1)
iv) to slow down the speed of neutrons (1)

SECTION E

24.

$U = \frac{1}{2} CV^2$ (2)
Loss in energy (2)
It appears in the form of heat. (1)

OR

Diagram (½)

Net force = 0 no translator motion (½)

Defination of torque (½)

SI unit (½)

troque = pE sin θ (1)

$C_{eq} = 11/6\ C$ (½)

where $C = A\ \varepsilon o/3d$, (½)

$C1 = C$, $C2 = C/2$, $C3 = C/3$ (½)

and all of these capacitors are connected in parallel. (½)

25. a)

$X_C = X_L$ (2)

b)

$I_o = V_o / \sqrt{(R^2 + X_L^2)}$ (½)

$Vo = \sqrt{2}\ V_{rms}$ (½)

$X_L = 2\pi fL$ (½)

Two voltages are out of phase. Hence they are added vectorially and hence the difference is! (½)

26. a)

$\mu = c/v = \sin i / \sin r$, (1)

$v \propto \sin r$ Hence v_{min} for light will be for $r = 15^\circ$. (1)

Diagram (1)
derivation (1½)
final expression (½)

OR

a. The ray coming from the object has to pass from denser to rarer medium and angle of incidence is greater than the critical angle. (1+1)

b.

i) $\sin c = n_1 / n$ $(90 - r_1) + 45 + (90 - c) = 180$

$r_1 = 45 - c$ (½)

$\sin i / \sin r_1 = n$ $\sin i = n \sin r_1 = n \sin (45 - c)$

$= n (\sin 45 \cos c - \cos 45 \sin c)$

$= n/\sqrt{2} (\cos c - \sin c)$ (½)

$= n/\sqrt{2} (\sqrt{[1 - \sin^2 C]} - \sin c)$

$= 1/\sqrt{2} (\sqrt{n^2 - n_1^2}) - n_1$

$i = \sin^{-1} (1/\sqrt{2} (\sqrt{n^2 - n_1^2}) - n_1)$ (½)

ii) $r_2 = 0$ $r_1 + r_2 = 45$ $r_1 = 45$ (½)

$\sin i / \sin r_1 = n$

$\sin i = n \sin r_1 = 1.352 \sin 45 = 0.956$ (½)

$i = \sin^{-1} (0.956) = 72.58$ (½)

Sample Question Paper (PHYSICS)
CLASS-XII (2017-18)

Time Allowed: 3Hours **Maximum Marks: 70**

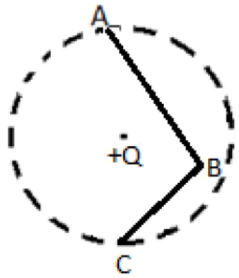
General Instructions

1. All questions are compulsory. There are 26 questions in all.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains twelve questions of three marks each, Section D contains one value based question of four marks and Section E contains three questions of five marks each.
4. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all the three questions of five marks weightage. You have to attempt only one of the choices in such questions.
5. You may use the following values of physical constants wherever necessary.

c = 3 X 108 m/s
h = 6.63 X 10-34 Js
e = 1.6 X 10-19 C
μo = 4 X 10-7 T m A-1
ε0 = 8.854 X 10-12 C2 N-1 m-2
= 9 X 109 N m2 C-2
me = 9.1 X 10-31 kg
mass of neutron = 1.675 X 10-27 kg
mass of proton = 1.673 X 10-27 kg
Avogadro's number = 6.023 X 1023 per gram mole
Boltzmann constant = 1.38 X 10-23 JK-1 2

Section – A

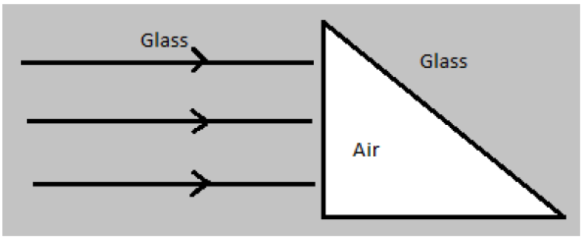
1. In the given figure, charge +Q is placed at the centre of a dotted circle. Work done in taking another charge +q from A to B is W1 and from B to C is W2. Which one of the following is correct: W1 > W2, W1=W2 and W1 < W2?



2. Plot a graph showing the variation of current 'I' versus resistance 'R', connected to a cell of emf E and internal resistance 'r'.

3. State the factors on which the refractive index of a material medium for a given wavelength depends.

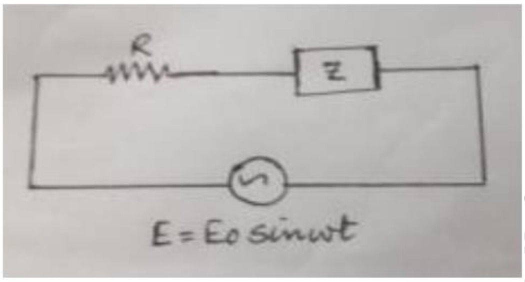
4. Sketch the emergent wavefront.



5. In the wave picture of light, intensity of light is determined by square of the amplitude of wave. What determines the intensity of light in the photon picture of light?

Section – B

6. (a)An alternating voltage E = Eo sinωt is applied to a circuit containing a resistor R connected in series with a black box. The current in the circuit is found to be I = Io sin (ωt + π/4).



(i) State whether the element in the black box is a capacitor or inductor.
(ii) Draw the corresponding phasor diagram and find the impedance in terms of R.

7. The magnetic field in a plane electromagnetic wave is given by:

By = 12 × 10–8 sin (1.20 × 107 z + 3.60 × 1015 t) T. Calculate the
(i) Energy density associated with the Electromagnetic wave
(ii) Speed of the wave

8. A spherical convex surface of radius of curvature 20 cm, made of glass (μ = 1.5) is placed in air. Find the position of the image formed, if a point object is placed at 30 cm in front of the convex surface on the principal axis.

9. Name the optoelectronic device used for detecting optical signals and mention the biasing in which it is operated. Draw its I- V characteristics.

10. Give reason, why high frequency carrier waves are needed for effective transmission of information signals.

OR

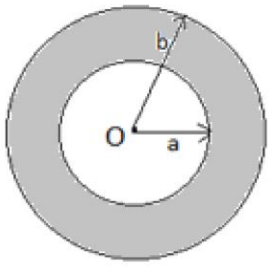
What is the range of frequencies used for T.V. transmission? State two factors by which the range of TV signals can be increased.

Section – C

11. (a)How many electrons must be added to one plate and removed from the other so as to store 25.0 J of energy in a 5.0 nF parallel plate capacitor?

(b) How would you modify this capacitor so that it can store 50.0 J of energy without changing the charge on its plates?

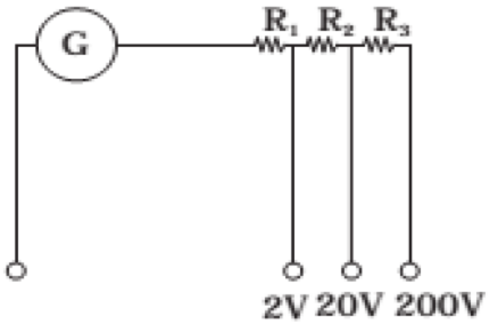
12. A point charge +Q is placed at the centre O of an uncharged hollow spherical conductor of inner radius 'a' and outer radius 'b'. Find the following:
(a) The magnitude and sign of the charge induced on the inner and outer surface of the conducting shell.
(b) The magnitude of electric field vector at a distance (i) r = , and (ii) r = 2b, from the centre of the shell.



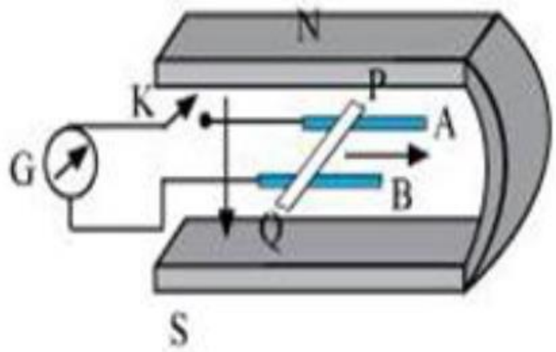
13. The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following:
(a) The magnitude of the electric field within them,
(b) The drift speed of electrons through them, and
(c) The current density within them.

Wire no.	**Length**	**Diameter**	**Potential Difference**
1	L	3d	V
2	2L	d	V
3	3L	2d	2V

14. A multirange voltmeter can be constructed by using a galvanometer circuit as shown in the figure. We want to construct a voltmeter that can measure 2V, 20V and 200V using a galvanometer of resistance 10Ω and that produces maximum deflection for current of 1 mA. Find the value of R1, R2 and R3 that have to be used.



15. Figure shows a metal rod PQ of length *l*, resting on the smooth horizontal rails AB positioned between the poles of a permanent magnet. The rails, rod and the magnetic field B are in three mutually perpendicular directions. A galvanometer G connects the rails through a key 'k'. Assume the magnetic field to be uniform. Given the resistance of the closed loop containing the rod is R.
(i) Suppose K is open and the rod is moved with a speed v in the direction shown. Find the polarity and the magnitude of induced emf.
(ii) With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ even though they do experience magnetic force due to the motion of the rod. Explain.
(iii) What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?



16. With the help of a diagram, explain the principle of a device which changes a low voltage into a high voltage but does not violate the law of conservation of energy. Give any one reason why the device may not be 100% efficient.

17. In a double slit experiment, the distance between the slits is 3 mm and the slits are 2 m away from the screen. Two interference patterns can be seen on the screen one due to light with wavelength 480 nm, and the other due to light with wavelength 600 nm. What is the separation on the screen between the fifth order bright fringes of the two interference patterns?

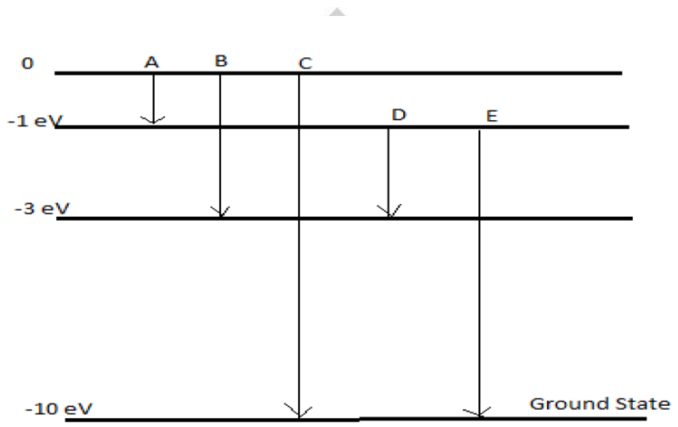
18. What do you understand by the statement 'Light from the sun is unpolarised'. Explain how does sunlight gets polarized by the process of scattering?

19. Explain how does (i) photoelectric current and (ii) kinetic energy of the photoelectrons emitted in a photocell vary if the frequency of incident radiation is doubled, but keeping the intensity same? Show the graphical variation in the above two cases.

OR

(i) Name the experiment which confirms the existence of wave nature of electrons. Derive the expression for de-Broglie wavelength of an electron moving under a potential difference of V volts. (ii) An electron and a proton have the same Kinetic Energy. Which of these particles has the shorter de-Broglie wavelength?

20. The energy levels of an atom of element X are shown in the diagram. Which one of the level transitions will result in the emission of photons of wavelength 620 nm? Support your answer with mathematical calculations.



21. Draw a graph showing the variation of binding energy per nucleon versus the mass number A. Explain with the help of this graph, the release of energy in the process of nuclear fission and fusion.

22. A message signal of frequency 20 KHz and peak voltage of 20 volts is used to modulate a carrier signal of frequency 2 MHz and peak voltage of 40 volts. Determine (i) modulation index, (ii) the side bands produced. Draw the corresponding frequency spectrum of amplitude modulated signal.

Section - D

23. When Deepak studied the electrical circuits and the current flowing through them, he became curious about the range of the currents we come across in daily life. He collected the data and presented in a tabular form as shown below. He then studied the instruments used to detect and measure current, however could not understand the difference between an ammeter and an ideal ammeter and thus went to his teacher for the explanation.

S.No.	Description	Magnitude of current
1	Domestic Appliance	Few amperes
2	Lightning	Ten thousand amperes
3	Nervous system	microamperes
4	Galvanometer	Few milliamperes
5	Semiconductors	Few milliamperes

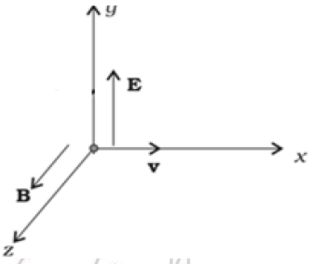
What values did Deepak have?

(ii) As domestic appliances carry electric current of the order of few amperes, write one safety precaution we should take while working with them.

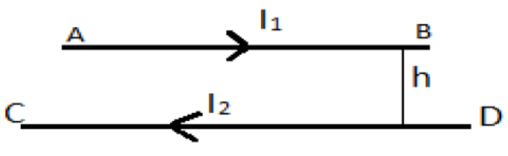
(iii) An ammeter of resistance RA is connected in series with a resistor R and a battery of emf E and internal resistance r. The current flowing through this circuit is IA. What will be the current flowing through the circuit if the given ammeter is replaced by an ideal ammeter and find the percentage error in measuring the current through an ammeter?

Section - E

24. (a) A particle of charge q is moving with velocity v in the presence of crossed Electric field E and Magnetic field B as shown. Write the condition under which the particle will continue moving along x- axis. How would the trajectory of the particle be affected if the electric field is switched off?



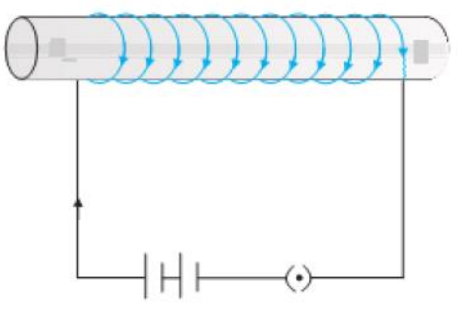
(b) A horizontal wire AB of length 'l' and mass 'm' carries a steady current I1, free to move in vertical plane is in equilibrium at a height of 'h' over another parallel long wire CD carrying a steady current I2, which is fixed in a horizontal plane as shown. Derive the expression for the force acting per unit length on the wire AB and write the condition for which wire AB is in equilibrium.



OR

(a) An electron in the ground state of Hydrogen atom is revolving in a circular orbit of radius R. Obtain the expression for the orbital magnetic moment of the electron in terms of fundamental constants.

(b) Draw the magnetic field lines for a current carrying solenoid when a rod made of (i) copper, (ii) aluminium and (iii) iron are inserted within the solenoid as shown.

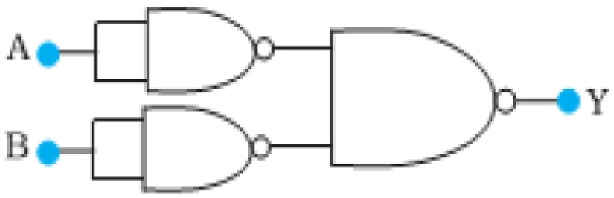


25. (a)Draw a ray diagram of compound microscope for the final image formed at least distance of distinct vision?
(b) An angular magnification of 30X is desired using an objective of focal length 1.25 cm and an eye piece of focal length 5 cm. How will you set up the compound microscope for the final image formed at least distance of distinct vision?

OR

(a) Draw a ray diagram of an astronomical telescope for the final image formed at least distance of distinct vision?
(b) An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and an eye piece is 36 cm and the final image is formed at infinity. Calculate the focal length of the objective and the focal length of the eye piece?

26. (a)With proper diagram, explain the movement of charge carriers through different parts of the transistor and hence show that $I_E = I_B + I_C$.
(b) Identify the logic operation carried out by the circuit shown below and write its truth table.



OR

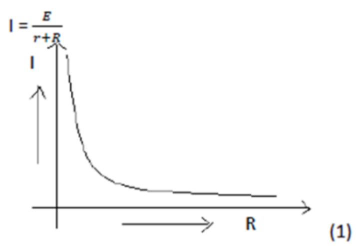
Draw a circuit diagram to study the input and output characteristics of an n-p-n transistor in its common emitter configuration.
Draw the typical input and output characteristics and explain how these graphs are used to calculate current amplification factor of the transistor.

Marking Scheme
PHYSICS
SAMPLE QUESTION PAPER-2018

Section- A

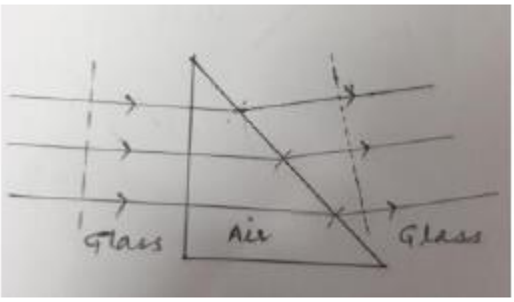
1. As VA – VB = VB – VC magnitude of work done is same. (1)

2.



3. Factors are :
(i) magnetic permeability of the medium (1/2)
(ii) electric permittivity of the medium (1/2)

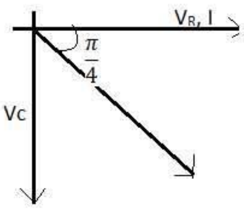
4. Diagram (1)



5. In photon picture, intensity is determined by the number of photons crossing per unit time. (1)

Section – B

6. As the current leads the voltage by , the element used in black box is a 'capacitor'.(½)
(ii) Phasor diagram (½)



$\tan\frac{\pi}{4} = V_c / V_R$
Vc = VR
Xc = R
Impedance Z = $\sqrt{(Xc^2 + R^2)}$ (½)
Z = R$\sqrt{2}$ (½)

7. (i) Energy density u = $\frac{B^2}{\mu_0}$ (½)
   u= 11.5 X 10^{-9} J/m^3. (½)

   (ii) Speed = $\frac{\omega}{k}$ (½)
   speed= 3 X 10^8 m/s (½)

8. $\mu_2/v - \mu_1/u = (\mu_2 - \mu_1)/R$ (½)
   correct sign convention (½)
   1.0/v – 1.5/-30 = (1.0 – 1.5) / 20 (½)
   v = - 13.3 cm (½)

9. Photodiode (½) Reverse biasing (½)
   I-V characteristics NCERT page no. 487 (1)

10. a) need for long antenna diminishes, with explanation (1)
   power is inversely proportional to $(\text{wavelength})^2$ (½),
   signals from different transmitters can be distinguished(½)

OR

Range: 76-88 MHz and 420-890 MHz (1)
Factors: by increasing height of transmitting antenna and using repeater stations. (1)

Section- C

11. (a) C = 5 X 10^{-9} F, U = 25 J
   U = Q^2/ 2C (½)
   Q^2 = 2 U C = 2 X 25 X 5 X 10^{-9}
   Q = 5 X 10^{-4} C (½)
   Q = n e (½)

2

$n = \frac{Q}{e} = 3.125 \times 10^{15}$ electrons (½)

(b) Without changing charge on the plates, we can make C half. $C = \frac{\varepsilon o\, A}{d}$, i.e. double the plate separation or inserting dielectric of dielectric of a value such that C becomes (1).

12.(a) As the electrostatic field inside a conductor is zero, using Gauss's law,
charge on the inner surface of the shell = -Q (½)
Charge on the outer surface of the shell = +Q (½)

(b) To show using Gauss's law expression
Expression for electric field for radius, $r=\frac{a}{2}$: $E = \frac{1}{4\pi\varepsilon o}\frac{4Q}{a^2}$ (1)
Expression for electric field for radius, r = 2b : $E = \frac{1}{4\pi\varepsilon o}\frac{Q}{4b^2}$ (1)

13. (i) $E1 = \frac{V}{L}$, $E2 = \frac{V}{2L}$, $E3 = \frac{2V}{3L}$ (½)
E2 < E3 < E1 (½)

(ii) $V_d \propto E$ (½)
$V_{d2} < V_{d3} < V_{d1}$ (½)

(iii) $I = nAe\, V_d$ / $J = \sigma E$ (½)
$J = n\, e\, V_d$
J2 < J3<J1 (½)

14.NCERT Exemplar Q4.21 R_1, R_2, R_3 (each 1 mark)

15.NCERT pg no. 301 Q6.14 (1 mark each part)

16.Device : Transformer (½)
Diagram on page number 260 NCERT part I (1)
Principle: statement of mutual induction (1)
Efficiency: Assuming no energy losses, the transformer is 100% efficient i.e. $I_pV_p = I_sV_s$. (½)

17.$\beta = \lambda\, D / d$ (½)
5^{th} bright = $5\beta_1 = 5\lambda_1 D/d = 5 \times 480 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 16 \times 10^{-4}$m (1)
5^{th} bright = $5\beta_2 = 5\lambda_2 D/d = 5 \times 600 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 20 \times 10^{-4}$ m (1)
distance between two 5^{th} bright fringes = $(20 - 16) \times 10^{-4} = 4 \times 10^{-4}$ m (½)

18. 'Light from the sun is unpolarised' means the electric field vector vibrates in all possible directions in the transverse plane rapidly and randomly. (1)

Polarisation of sunlight by the method of scattering: page number 379 of NCERT part II : Diagram + explanation. (1+1)

19. i) Page no. 391 figure 11.4 +explanation (½ +1)

ii) Page no. 392 + explanation (½ + 1)

OR

(i) Davisson- Germer experiment (½)

An electron of charge e, mass m accelerated through a potential difference of v volts, Kinetic energy equals the work done (eV) on it by the electric field:

K = eV (½)

K $=\frac{p^2}{2m}$, p = $\sqrt{(2mk)}$ (½)

p= $\sqrt{(2meV)}$

the de- Broglie wavelength λ of the electron is :

λ = $\frac{h}{p}$ (½)

λ= $\frac{h}{\sqrt{(2meV)}}$ (½)

(ii) For same KE, λ α $\frac{1}{\sqrt{m}}$

As mass of proton is greater than that of electron, ∴ $\lambda_p < \lambda_e$. (½)

20. E = hc / λ = 6.6. x 10^{-34} x 3 x 10^{8} / 620 x 10^{-9} (1)

= 3.2 x 10^{-19} J (½)

= 3.2 x 10^{-19} / 1.6 x 10^{-19} = 2 eV (½)

This corresponds to the transition "D" (1)

21. NCERT figure 13.1 on page no. 444 (1)

Fission (1) , Fusion (1)

22. (i) Modulation Index = A_m/ A_c = 20/40 = 0.5 (½ + ½)

The side bands are (2000 + 20) KHz

= 2020 KHz and (2000 - 20) KHz

= 1980 KHz (½ + ½)

Amplitude versus ω for amplitude modulated signal : page number 525 NCERT part (ii) Figure 15.9, Ac = 40 volts, $\mu A_c/2$ = 10 volts. (1)

Section -D

23. (a) critical thinking, hard working (1)

(b) One should not touch electrical appliances with wet hands/ any one precaution. (1)

(c) $I_A = \frac{E}{r+R+R_A}$ (½)

For an ideal ammeter $R_A = 0$

$I = \frac{E}{r+R}$ (½)

Percentage error: $(\frac{I-I_A}{I})$ X 100 = $(\frac{R_A}{R+r+R_A})$ X 100 (1)

Section –E

24. (a) Condition qE = q vB (½)

$v = \frac{E}{B}$ (½)

Trajectory becomes helical about the direction of magnetic field (1)

(b) To derive the expression of magnetic force acting per unit length of the wire:

$\frac{F_m}{l} = \frac{\mu_0 I_1 I_2}{2\pi h}$, upwards on wire AB (2)

At equilibrium Magnetic Force per unit length = mass per unit length X g

$\frac{\mu_0 I_1 I_2}{2\pi h} = \frac{m}{l} g$ (1)

OR

(a) Using the condition $mvr = \frac{nh}{2\pi}$ (1/2)

For H-atom n=1, $v = \frac{h}{2\pi mr}$

Time period $T = \frac{2\pi r}{v}$

$\therefore T = \frac{4\pi^2 mr^2}{h}$, $I = \frac{Q}{T} = \frac{eh}{4\pi^2 mr^2}$ (1/2)

M = I A (1/2)

$M = (\frac{eh}{4\pi^2 mr^2})(\pi r^2)$

$M = \frac{eh}{4\pi m}$ (1/2)

(b) Diagram for magnetic field lines Cu- diamagnetic (1)

Al- Paramagnetic (1)

Fe- Ferromagnetic (1)

25. (a) Diagram (2) + labelling (½)

(b) m_e = 1 + 25/5 = 6 (½)

m_o = 30 / m_e = 5 (½)

$m_o = v_o / -u_o v_o = -5\ u_o$

5

$1/f_o = 1/v_o - 1/u_o f_o = -(5/6)\ u_o$ (½)

$u_o = 1.5$ cm , $v_o = 7.5$ cm

$u_e = -4.17$ cm (½)

Length of the tube = $u_e + v_o = 11.67$ cm (½)

OR

(a) Diagram (2) + labelling (½)

(b) $m = -f_o / f_e$ (½)
$f_o = 5 f_e$ (½)
$L = f_o + f_e$ (½)
$f_e = 36/6 = 6$ cm (½)
$f_o = 30$ cm (½)

26. (a) circuit diagram (1)
NCERT page no.492 (explanation: 2)

(b) NCERT page no. 511 Q. No.14.17 Logic operation (1) Truth table (1)

OR
Diagram (1 ½)
Input Characteristics (1 ½)
Output Characteristics (1 ½)
Current amplification factor (½)

Class XII
Physics (042)
Sample Question Paper 2018-19

Time allowed: 3 hours. **Max. Marks: 70**

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3. Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, and Section D contains three questions of five marks each.
4. There is no overall choice. However, internal choices have been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.
5. You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}$ $C^2 N^{-1} m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$ N $m^2 C^{-2}$

$m_e = 9.1 \times 10^{-31}$ kg

mass of neutron $= 1.675 \times 10^{-27}$ kg

mass of proton $= 1.673 \times 10^{-27}$ kg

Avogadro's number $= 6.023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

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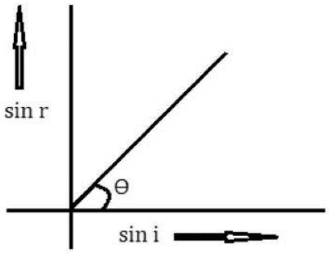
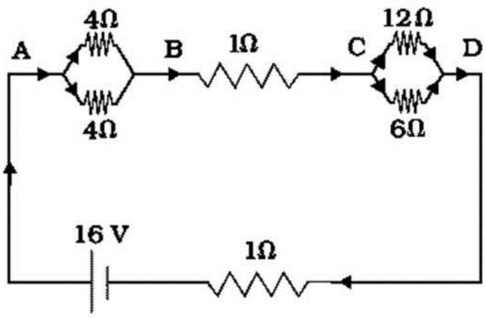
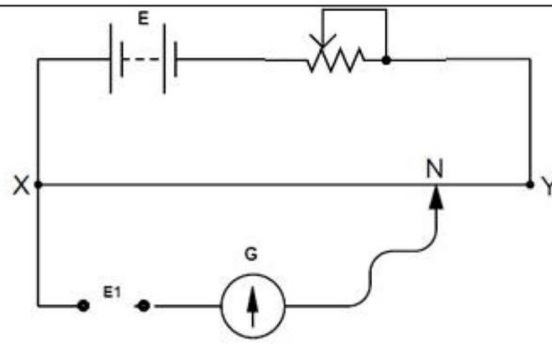
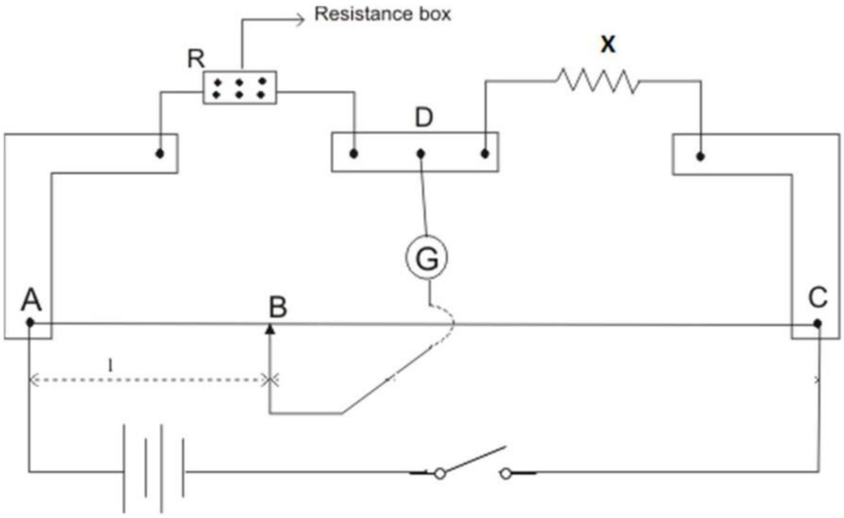
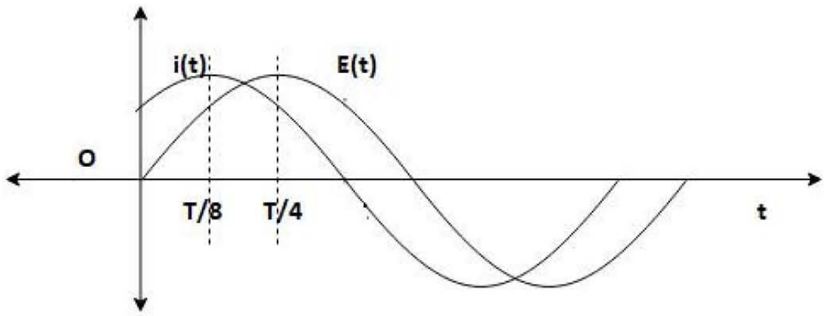
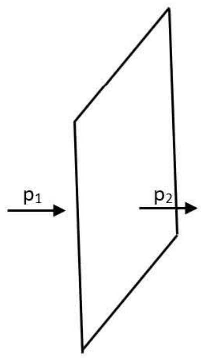
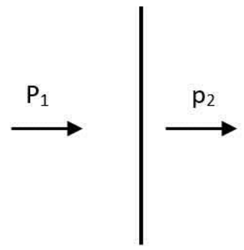
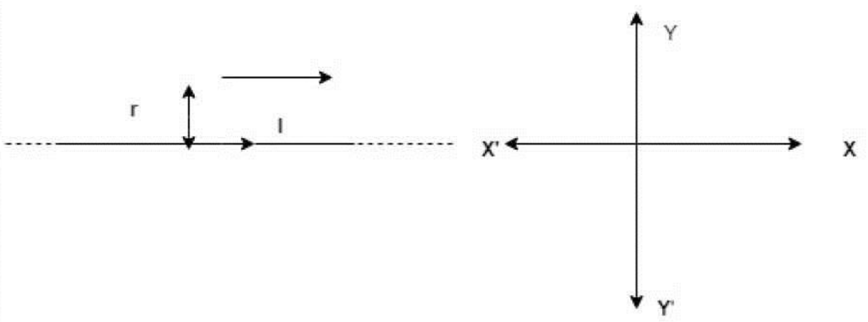
Section-A		
1.	State the SI unit of the electric polarization vector **P**	**1**
2.	Define temperature coefficient of resistivity	**1**

3.	Name the electromagnetic waves that are widely used as a diagnostic tool in medicine.	**1**
	OR	
	Name the current which can flow even in the absence of electric charge.	
4.	A ray of light is incident on a medium with angle of incidence 'i' and is refracted into a second medium with angle of refraction 'r'. The graph of sin i versus sin r is as shown. Find the ratio of the velocity of light in the first medium to the velocity of light in the second medium. 	**1**
5.	Two particles have equal momenta. What is the ratio of their de-Broglie wavelengths?	**1**
	OR	
	Monochromatic light of frequency $6.0\text{x } 10^{14}$ Hz is produced by a laser. What is the energy of a photon in the light beam?	
	Section-B	
6.	A network of resistors is connected to a 16 V battery with internal resistance of 1 Ω., as shown in the following figure. Compute the equivalent resistance of the network. 	**2**
	OR	
	A 9 V battery is connected in series with a resistor .The terminal voltage is found to be 8 V. Current through the circuit is measured as 5 A. What is the internal resistance of the battery?	
7.	The diagram below shows a potentiometer set up. On touching the jockey near to the end X of the potentiometer wire, the galvanometer pointer deflects to left. On touching the jockey near to end Y of the potentiometer, the galvanometer pointer again deflects to left but now by a larger amount. Identify the fault in the circuit and explain, using appropriate equations or otherwise, how it leads to such a one-sided deflection.	**2**

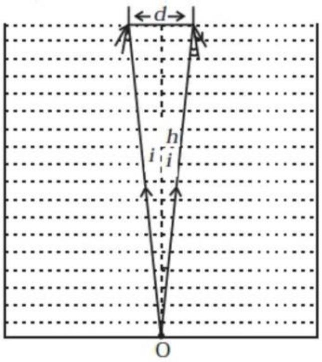
2

		
	OR	
7	Following circuit was set up in a meter bridge experiment to determine the value X of an unknown resistance.  **(a)** Write the formula to be used for finding X from the observations. **(b)** If the resistance R is increased, what will happen to balancing length?	2
8.	The figure shows two sinusoidal curves representing oscillating supply voltage and current in an ac circuit.	2

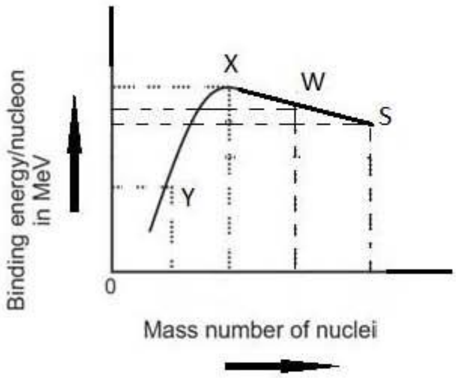
	 Draw a phasor diagram to represent the current and supply voltage appropriately as phasors. State the phase difference between the two quantities.	
9.	Compare the following (i) Wavelengths of the incident solar radiation absorbed by the earth's surface and the radiation re-radiated by the earth. (ii) Tanning effect produced on the skin by UV radiation incident directly on the skin and that coming through glass window.	**2**
10.	A narrow slit is illuminated by a parallel beam of monochromatic light of wavelength λ equals to 6000 Å and the angular width of the central maxima in the resulting diffraction pattern is measured. When the slit is next illuminated by light of wavelength λ', the angular width decreases by 30%. Calculate the value of the wavelength λ'.	**2**
11.	What are universal gates? How can AND gate be realized using an appropriate combination of NOR gates?	**2**
12.	A TV transmission tower antenna is at a height of 20 m. How much range can it cover if the receiving antenna is at a height of 25 m?	**2**
	Section-C	
13.	A particle, having a charge +5 μC, is initially at rest at the point x = 30 cm on the x axis. The particle begins to move due to the presence of a charge Q that is kept fixed at the origin. Find the kinetic energy of the particle at the instant it has moved 15 cm from its initial position if (a) Q =+15μC and (b) Q = -15μC	**3**
14.	(a) An electric dipole is kept first to the left and then to the right of a negatively charged infinite plane sheet having a uniform surface charge density. The arrows p_1 and p_2 show the directions of its electric dipole moment in the two cases.  Identify for each case, whether the dipole is in stable or unstable equilibrium. Justify each answer.	**3**

	(b) Next, the dipole is kept in a similar way (as shown), near an infinitely long straight wire having uniform negative linear charge density.  Will the dipole be in equilibrium at these two positions? Justify your answer.	
15.	Two material bars A and B of equal area of cross-section, are connected in series to a DC supply. A is made of usual resistance wire and B of an n-type semiconductor. (a) In which bar is drift speed of free electrons greater? (b) If the same constant current continues to flow for a long time, how will the voltage drop across A and B be affected? Justify each answer.	**3**
16.	Derive an expression for the velocity $\mathbf{v_C}$ of a positive ions passing undeflected through a region where crossed and uniform electric field E and magnetic field B are simultaneously present. Draw and justify the trajectory of identical positive ions whose velocity has a magnitude less than $|\mathbf{v_C}|$. **OR** A particle of mass m and charge q is in motion at speed v parallel to a long straight conductor carrying current I as shown below.  Find magnitude and direction of electric field required so that the particle goes undeflected.	**3**
17.	A sinusoidal voltage of peak value 10 V is applied to a series LCR circuit in which resistance, capacitance and inductance have values of 10 Ω, 1μF and 1H respectively. Find (i) the peak voltage across the inductor at resonance (ii) quality factor of the circuit.	**3**
18.	a) What is the principle of transformer?	**3**

5

	b) Explain how laminating the core of a transformer helps to reduce eddy current losses in it c) Why the primary and secondary coils of a transformer are preferably wound on the same core	
	OR	
	Show that in the free oscillations of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant in time.	
19.	Draw a labelled ray diagram to show the image formation in a refracting type astronomical telescope in the normal adjustment position. Write two drawbacks of refracting type telescopes.	**3**
	OR	
	(a)Define resolving power of a telescope. Write the factors on which it depends. (b) A telescope resolves whereas a microscope magnifies. Justify the statement.	
20.	A jar of height h is filled with a transparent liquid of refractive index μ. At the centre of the jar on the bottom surface is a dot. Find the minimum diameter of a disc, such that when it is placed on the top surface symmetrically about the centre, the dot is invisible  	**3**
21.	(a) In photoelectric effect, do all the electrons that absorb a photon come out as photoelectrons irrespective of their location? Explain. (b) A source of light, of frequency greater than the threshold frequency, is placed at a distance 'd' from the cathode of a photocell. The stopping potential is found to be V. If the distance of the light source is reduced to d/n (where n>1), explain the changes that are likely to be observed in the (i) photoelectric current and (ii) stopping potential.	**3**
22.	A monochromatic radiation of wavelength 975 Å excites the hydrogen atom from its ground state to a higher state. How many different spectral lines are possible in the resulting spectrum? Which transition corresponds to the longest wavelength amongst them?	**3**
23.	Binding energy per nucleon versus mass number curve is as shown. ${}^{A}_{Z}S$, ${}^{A1}_{Z1}W$, ${}^{A2}_{Z2}X$ *and* ${}^{A3}_{Z3}Y$ are four nuclei indicated on the curve.	**3**

6



	Based on the graph: (a)Arrange X, W and S in the increasing order of stability. (b) Write the relation between the relevant A and Z values for the following nuclear reaction. $S \longrightarrow X + W$ (c)Explain why binding energy for heavy nuclei is low.	
	OR	
	How are protons, which are positively charged, held together inside a nucleus? Explain the variation of potential energy of a pair of nucleons as a function of their separation. State the significance of negative potential energy in this region?	
24.	A sinusoidal carrier wave of amplitude A_c **and angular frequency** ω_c is modulated in accordance with a sinusoidal information signal of amplitude A_m **and angular frequency** ω_m. **Show that the amplitude modulated signal contains three frequencies centered around** ω_c. Draw the frequency spectrum of the resulting modulated signal.	**3**
	Section-D	
25.	(a)Write the expression for the equivalent magnetic moment of a planer current loop of area A, having N turns and carrying a current i. Use the expression to find the magnetic dipole moment of a revolving electron. (b) A circular loop of radius r, having N turns and carrying current I, is kept in the XY plane. It is then subjected to a uniform magnetic field $\mathbf{B} = B_x\,\mathbf{i} + B_y\,\mathbf{j} + B_z\,\mathbf{k}$. Obtain expression for the magnetic potential energy of the coil-magnetic field system.	**5**
	OR	
	(a) A long solenoid with air core has n turns per unit length and carries a current I. Using Ampere's circuital law, derive an expression for the magnetic field B at an interior point on its axis. Write an expression for magnetic intensity **H** in the interior of the solenoid. (b) **A (small) bar of material, having magnetic susceptibility χ, is now put along the axis and** near the centre, of the solenoid which is carrying a d.c. current through its coils. After some time, the bar is taken out and suspended freely with an unspun thread. Will the bar orient **itself in magnetic meridian if (i) $\chi < 0$ (ii) $\chi > 1000$?** Justify your answer in each case.	
26.	(a)There are two sets of apparatus of Young's double slit experiment. In set A, the phase difference between the two waves emanating from the slits does not change with time,	**5**

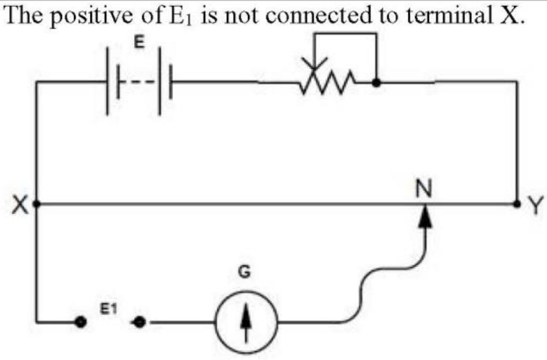
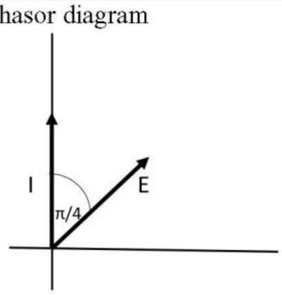
	whereas in set B, the phase difference between the two waves from the slits changes rapidly with time. What difference will be observed in the pattern obtained on the screen in the two set ups? (b) Deduce the expression for the resultant intensity in both the above mentioned set ups (A and B), assuming that the waves emanating from the two slits have the same amplitude A and same wavelength λ.	
	OR	
	(a) The two polaroids, in a given set up, are kept 'crossed' with respect to each other. A third polaroid, now put in between these two polaroids, can be rotated. Find an expression for the dependence of the intensity of light I, transmitted by the system, on the angle between the pass axis of first and the third polaroid. Draw a graph showing the dependence of I on Θ. (b) When an unpolarized light is incident on a plane glass surface, find the expression for the angle of incidence so that the reflected and refracted light rays are perpendicular to each other. What is the state of polarisation, of reflected and refracted light, under this condition?	
27.	(a) Draw the circuit diagram to determine the characteristics of a pnp transistor in common emitter configuration. Explain, using I-V characteristics, how the collector current changes with the base current. How can (i) output resistance and (ii) current amplification factor be determined from the I-V characteristics?	**5**
	OR	
	(a) Why are photodiodes preferably operated under reverse bias when the current in the forward bias is known to be more than that in reverse bias? The two optoelectronic devices: - Photodiode and solar cell, have the same working principle but differ in terms of their process of operation. Explain the difference between the two devices in terms of (i) biasing, (ii) junction area and (iii) I-V characteristics.	

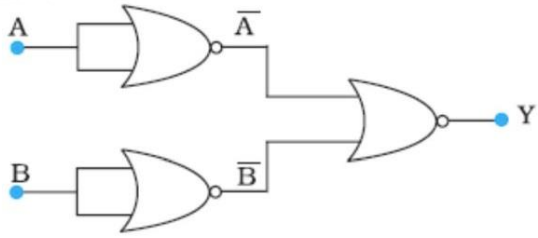
Class: XII
Physics (042)
Marking Scheme 2018-19

Time allowed: 3 hours Maximum Marks: 70

Q No	SECTION A	Marks
1.	C/m^2	**1**
2.	Fractional change in resistivity per unit change in temperature.	**1**
3.	X-rays	**1**
	OR	
	Displacement current	**1**
4.	From the graph $\tan\Theta = \frac{\sin r}{\sin i}$ $\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$ $\frac{v_1}{v_2} = \cot\theta$	**1/2** **1/2**
5.	$P_1 = P_2$ Ratio $\lambda 1/\lambda 2 = 1:1$	**1/2** **1/2**
	OR	
	Each photon has an energy ,E=h.ν $= (6.63 \times 10^{-34}\text{ J s})(6.0 \times 10^{14}\text{ Hz})$ $= 3.98 \times 10^{-19}\text{ J}$	**1/2** **1/2**
	SECTION B	
6.	Equivalent Resistance = R1.R2/ (R1+R2) +R3+ R4.R5/(R4+R5) $= [(4 \times 4)/(4 + 4)] + 1 + [(12 \times 6)/(12 + 6)]\ \Omega$ $= 7\ \Omega$. **OR** $r = \frac{\mathcal{E} - V}{I}$ $= \frac{9\text{ V} - 8\text{ V}}{5\text{ A}}$ $= 0.2\ \Omega$	**1** **1/2** **1/2** **1** **1/2** **1/2**

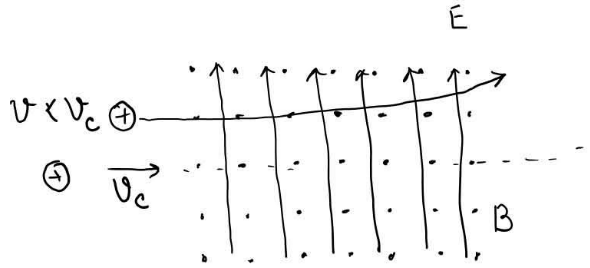
1

7.	The positive of E_1 is not connected to terminal X.  In loop PGJX, $E_1 - V_G + E_{XN}=0$ $V_G = E_1 + E_{XN}$ $V_G = E_1 + k\,\ell$ So, V_G (or deflection) will be maximum when ℓ is maximum i.e. when jockey is touched near end Y. Also, V_G (or deflection) will be minimum when ℓ is minimum i.e. when jockey is touched near end X.	**1/2** **1/2** **1/2** **1/2**
	OR	
(a)	$X = (100 - \ell)\, R/\ell$	**1**
(b)	Balancing length will increase on increase of resistance R.	**1**
8.	Phasor diagram  Equal length of phasors current leads voltage phase difference is $\pi/4$	**1/2** **1/2** **1**
9.	(i) Radiation re-radiated by earth has greater wavelength (ii)Tanning effect is significant for direct UV radiation; it is negligible for radiation coming through the glass.	**1** **1**
10.	Angular width $2\Theta = 2\lambda/d$ Given $\lambda = 6000$ Å In Case of new λ (assumed λ' here), angular width decreases by 30% $= (\frac{100-30}{100})2\,\Theta$ $= 0.70\,(2\,\Theta)$	**1/2** **1/2** **1/2**

	$2\ \lambda'/d = 0.70\ X\ (2\ \lambda/d)$ $\therefore \lambda' = 4200$ Å	1/2
11.	Universal gates (like the NAND and the NOR gates) are gates that can be appropriately combined to realize all the three basic gates. 	1 1
12.	Range $d = \sqrt{2hR} + \sqrt{2h_R R}$ $d = 33.9$ km	1 1
	SECTION: C	
13.	From energy conservation, $U_i + K_i = U_f + K_f$ $kQq/r_i + 0 = kQq/r_f + K_f$ $K_f = kQq\ (1/r_i - 1/r_f)$	1/2 1/2
	When Q is +15 μC, q will move 15 cm away from it. Hence $r_f = 45$ cm $K_f = 9\text{x}\ 10^9 \text{ x } 15 \text{ x } 10^{-6} \text{ x } 5 \text{ x } 10^{-6}\ [\ 1/(30 \text{ x } 10^{-2}) - 1/(45 \text{ x } 10^{-2})]$ $= 0.75$ J	1/2 1/2
	When Q is -15 μC, q will move 15 cm towards it. Hence $r_f = 15$ cm $K_f = 9\text{x}\ 10^9 \text{ x } (-15 \text{ x } 10^{-6}) \text{ x } 5 \text{ x } 10^{-6}\ [\ 1/(30 \text{ x } 10^{-2}) - 1/(15 \text{ x } 10^{-2})]$ $= 2.25$ J	1/2 1/2
14.	**(a)** p_1: stable equilibrium p_2: unstable equilibrium The electric field, on either side, is directed towards the negatively charged sheet and its magnitude is independent of the distance of the field point from the sheet. For position p_1, dipole moment and electric field are parallel. For position p_2, they are antiparallel.	1/2 1/2+1/2
	(b) The dipole will not be in equilibrium in any of the two positions. The electric field due to an infinite straight charged wire is non- uniform (E α 1/r). Hence there will be a net non-zero force on the dipole in each case.	1/2 1/2 1/2
15.	**(a)** Drift speed in B (n-type semiconductor) is higher Reason: $I = neAv_d$ is same for both n is much lower in semiconductors.	1/2 1/2
	(b) Voltage drop across A will increase as the resistance of A increases with increase in temperature. Voltage drop across B will decrease as resistance of B will decrease with increase in temperature.	1/2+1/2 1/2+1/2
16.	$\mathbf{E} = E\ \mathbf{j}$ and $\mathbf{B} = B\ \mathbf{k}$ Force on positive ion due to electric field $\mathbf{F_E} = qE\mathbf{j}$ Force due to magnetic field $\mathbf{F_B} = q\ (\mathbf{v_c} \text{ x } \mathbf{B})$	1/2 1/2
	For passing undeflected, $\mathbf{F_E} = -\ \mathbf{F_B}$ $qE\mathbf{j} = -\ q\ (\mathbf{v_c} \text{ x } B\mathbf{k})$ This is possible only if $q\mathbf{v_c} \text{ x } B\mathbf{k} = qv_cB\mathbf{j}$ or $\mathbf{v_c} = (E/B)\mathbf{i}$	1/2

3

The trajectory would be as shown. **1/2**



Justification: For positive ions with speed $v < v_c$

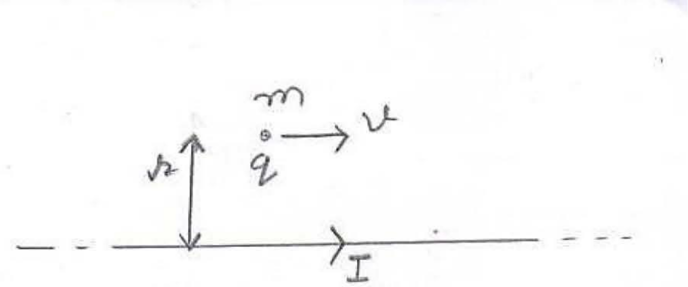
Force due to electric field = $F'_E = qE = F_E$

due to magnetic field $F'_B = qvB < F_B$ since $v < v_c$ **1/2**

Now forces are unbalanced, and hence, ion will experience an acceleration along **E**. **1/2**

Since initial velocity is perpendicular to E, the trajectory would be parabolic.

OR



1/2

For the charged particle to more undeflected

Net force $\bar{F} = \overline{F_E} + \overline{F_m} = 0$

$\grave{F}_E = - F_m$ (1)

$\overline{F_E}$ → electric force, $\overline{F_m}$ →magnetic force **1/2**

$|\overline{F_E}| = 1 - |\overline{F_m}|$ (2)

qE = Bqv sin90° = Bqv **1/2**

E = VB (3)

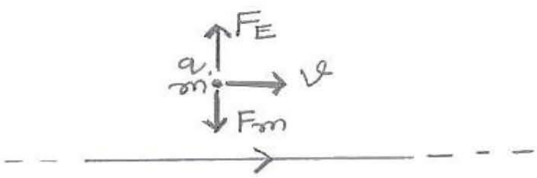
$B = \frac{MoI}{2\pi r}$ (4) **1**

Using (4) and (3)

$E = \frac{VMoI}{2\pi r}$ (5) **1/2**

Magnetic force F_m is towards wire.

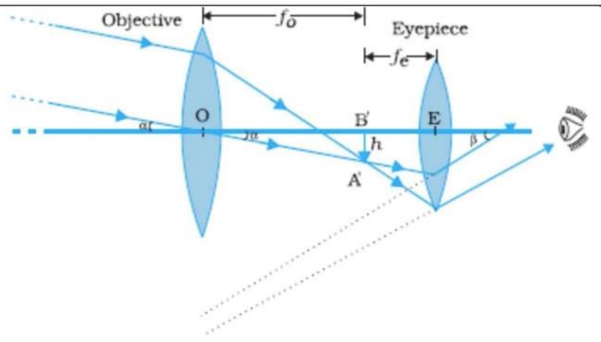
∴ Electric force and electric field should be away from the line.



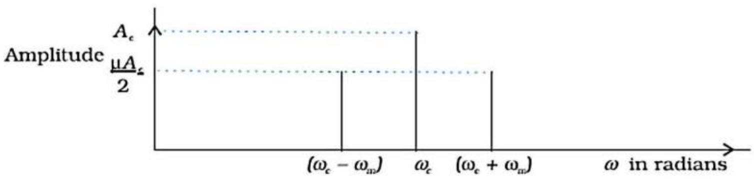
4

17.	$I_0 = V_0/R = 10/10 = 1$ A $\omega_r = 1/\sqrt{LC} = 1/\sqrt{(1 \times 1 \times 10^{-6})} = 10^3$ rad/s $V_0 = I_0 X_L = I_0 \omega_r L$ $= 1 \times 10^3 \times 1 = 10^3$ V $Q = \omega_r L/R$ $= (10^3 \times 1)/10 = 100$	1/2 1/2 1/2 1/2 1/2 1/2
18.	**a)** Principle of transformer b) Laminations are thin, making the resistance higher. Eddy currents are confined within each thin lamination. This reduces the net eddy current. c) For maximum sharing of magnetic flux and magnetic flux per turn to be the same in both primary and secondary.	1 1 1
	OR	
	At an instant t, charge q on the capacitor and the current i are given by: $q(t) = q_0 \cos \omega t$ $i(t) = -q_0 \omega \sin \omega t$ Energy stored in the capacitor at time t is $U_E = \frac{1}{2} C V^2 = \frac{1}{2}\frac{q^2}{C} = \frac{q_0^2}{2C} \cos^2(\omega t)$ Energy stored in the inductor at time t is $U_M = \frac{1}{2} L i^2$ $= \frac{1}{2} L q_0^2 \omega^2 \sin^2(\omega t)$ $= \frac{q_0^2}{2C} \sin^2(\omega t) \quad (\because \omega = 1/\sqrt{LC})$ Sum of energies $U_E + U_M = \frac{q_0^2}{2C}\left(\cos^2 \omega t + \sin^2 \omega t\right)$ $= \frac{q_0^2}{2C}$ This sum is constant in time as q_0 and C, both are time-independent.	1 1 1
19.	Ray diagram: (2)	

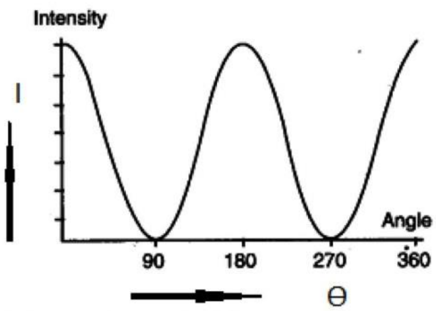
5

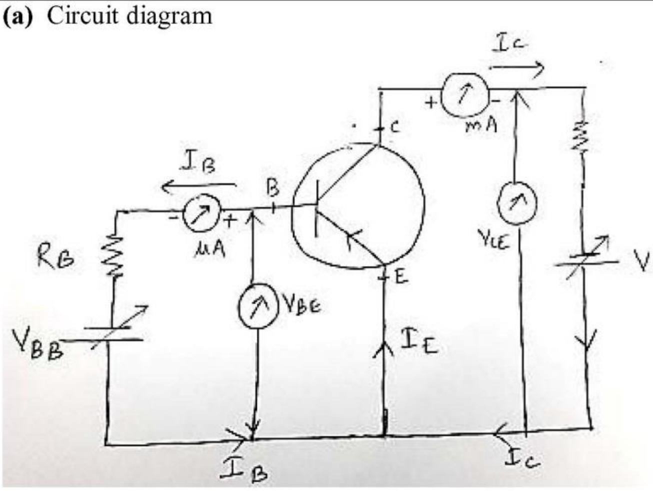
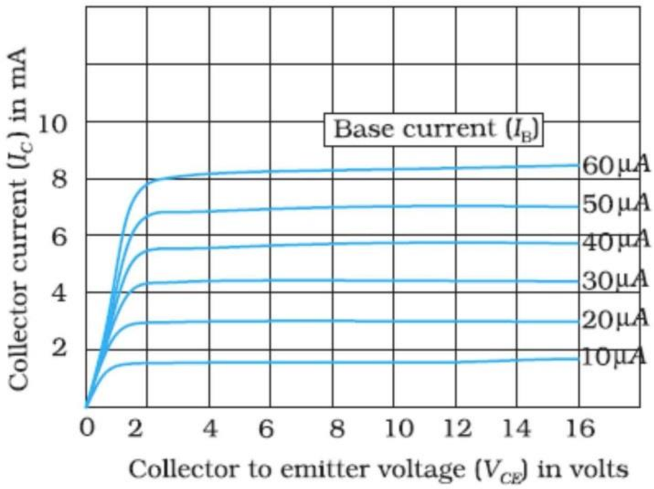
	 Drawbacks: (i)Large sized lenses are heavy and difficult to support (ii) large sized lenses suffer from chromatic and spherical aberration.	**1/2** **1/2**
	OR **(a)** Resolving power of a telescope is the reciprocal of the smallest angular separation between the two objects which can be just distinctly seen. Factors: diameter of the objective, wavelength of the incident light	**1** **1/2+1/2**
	(b) a telescope produces image of far objects nearer to our eye. Objects which are not resolved at far distance, can be resolved by telescope. A microscope, on the other hand magnifies objects nearer to us and produces their large image.	**1**
20.	Let d be the diameter of the disc. The spot shall be invisible if the incident rays from the dot at O, at the center of the disc, are incident at the critical angle of incidence Let i be the critical angle of incidence. Then Sin i = $\frac{1}{\mu}$ Now, $\frac{d/2}{h} = \tan i$ $\Rightarrow \frac{d}{2} = h \tan i = h\left[\sqrt{\mu^2 - 1}\right]^{-1}$ $\therefore d = \frac{2h}{\sqrt{\mu^2 - 1}}$	**1** **1/2** **1/2** **1/2** **1/2**
21.	**(a)** No, it is not necessary that if the energy supplied to an electron is more than the work function, it will come out. The electron after receiving energy, may lose energy to the metal due to collisions with the atoms of the metal. Therefore, most electrons get scattered into the metal. Only a few electrons near the surface may come out of the surface of the metal for whom the incident energy is greater than the work function of the metal.	**1** **1**
	(b) on reducing the distance, intensity increases. Photoelectric current increases with the increase in intensity. Stopping potential is independent of intensity, and therefore remains unchanged.	**1/2** **1/2**
22.	Energy corresponding to the given wavelength: E (in eV) = $\frac{12400}{\lambda\,(\text{in Å})}$ = 12. 71 eV The excited state: $E_n - E_1 = 12.71$ $\frac{-13.6}{n^2} + 13.6 = 12.71$ $\therefore\ n = 3.9 \approx 4$ Total no. of spectral lines emitted: $\frac{n\,(n-1)}{2} = 6$ Longest wavelength will correspond to the transition	**1** **1/2** **1/2** **1/2**

6

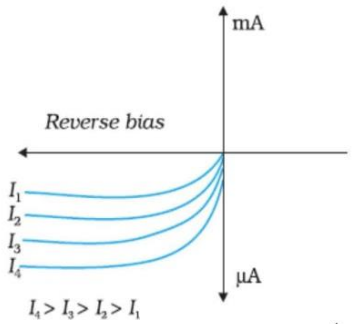
	n = 4 to n = 3	**1/2**
23.	**(a)** S,W,X	**1**
	(b) Z = Z1 + Z2 A = A1 + A2	**1/2** **1/2**
	(c) Reason for low binding energy:- In heavier nuclei, the Coulombian repulsive effects can increase considerably and can match/ offset the attractive effects of the nuclear forces. This can result in such nuclei being unstable.	**1**
	OR	
	Nuclear force binds the protons inside the nucleus. For Graph and explanation, refer to NCERT page no 445 Significance of negative potential energy: Force is attractive in nature	**1/2** **2** **1/2**
24.	The modulated signal: $C_m(t) = (A_c + A_m \sin\omega_m t)\sin\omega_c t$ $= A_c\left(1 + \frac{A_m}{A_c}\sin\omega_m t\right)\sin\omega_c t$ $C_m(t) = A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t$ $C_m(t) = A_c \sin\omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)\, t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)\, t$ Frequency Spectrum :- 	**1/2** **1/2** **1/2** **1/2** **1**
	SECTION: D	
25.	**(a)** The equivalent magnetic moment is given by μ = NiA The direction of **μ** is perpendicular to the plane of current carrying loop. It is directed along the direction of advance of a right-handed screw rotated along the direction of flow of current derivation of expression for **μ** of electron revolving around a nucleus	**1/2** **1/2** **2**
	(b) for the loop, **μ** = N (πr^2) i (±**k**) Magnetic potential energy = **μ.B** = N (πr^2) i (±**k**).(B_x **i** + B_y **j** + B_z **k**) = $\pm\pi r^2$ N I B_z	**1/2** **1/2** **1/2** **1/2**
	OR	
	(a) Derivation H = nI The direction of **H** is along the axis of the solenoid, directed along the direction of advance of a right-handed screw rotated along the direction of flow of current	**2.5** **1/2**
	(b) (i) Not necessarily. Reason: material is diamagnetic. After removal of magnetising field, no magnetisation will remain in the material and hence earth's magnetic field	**1/2** **1/2**

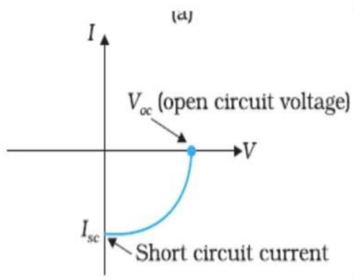
7

	will not affect it. (ii) Yes Reason: The material is ferromagnetic. It will remain magnetised even after removal from the solenoid and hence align with magnetic meridian.	 **1/2** **1/2**
26.	**(a)** Set A: stable interference pattern, the positions of maxima and minima does not change with time. Set B : positions of maxima and minima will change rapidly with time and an average uniform intensity distribution will be observed on the screen.	**1** **1**
	(b) Expression for intensity of stable interference pattern in set –A If the displacement produced by slit S1 is $y_1 = a \cos \omega t$ then, the displacement produced by S_2 would be $y_2 = a \cos (\omega t + \phi)$ and the resultant displacement will be given by $y = y_1 + y_2$ $= a [\cos \omega t + \cos (\omega t + \phi)]$ $= 2\, a \cos (\phi/2) \cos (\omega t + \phi/2)$ The amplitude of the resultant displacement is $2a \cos (\phi/2)$ and therefore the intensity at that point will be $I = 4\, I_0 \cos^2 (\phi/2)$ $\Phi = 0$ $\therefore$ I = 4 I0 In set B, the intensity will be given by the average intensity $< I > = 4 I_0 < \cos^2 (\phi/2) >$ $I = 2\, I_0$	**2** **1**
	OR	
	(a) Refer to NCERT example 10.8 on page no. 378 	**2** **1**
	(b) Expression for incident angle: $\mu = \frac{\sin i_B}{\sin r} = \frac{\sin i_B}{\sin(\pi/2 - i_B)}$ $= \frac{\sin i_B}{\cos i_B} = \tan i_B$ Nature of polarisation: Reflected light: Linearly polarised	**1** **1/2**

<table>
<tr><td></td><td>Refracted light: Partially polarised</td><td>1/2</td></tr>
<tr><td>27.</td><td>(a) Circuit diagram

</td><td>2</td></tr>
<tr><td></td><td>(b) output characteristics is the variation of collector current with collector -emitter voltage for different fixed value of I_B.
If VBE is increased by a small amount, both the hole current and electron current in the base region increases. As a result, both I_B and I_C increases proportionately.


Output resistance is the ratio of change in collector-emitter voltage to the change in collector current.
Current amplification factor is ratio of change in collector current to the change in base current at constant collector- emitter voltage.</td><td>1
1/2
1/2</td></tr>
<tr><td></td><td>OR</td><td></td></tr>
<tr><td></td><td>(a) The fractional change in majority charge carriers is very less compared to the fractional change in minority charge carriers on illumination.</td><td>1</td></tr>
<tr><td></td><td>(b) The difference in the working of two devices:</td><td></td></tr>
</table>

<table>
<tr><th></th><th>Photodiode</th><th>Solar cell</th></tr>
<tr><td>Biasing</td><td>Used in Reverse biasing (½)</td><td>No external biasing is given (½)</td></tr>
<tr><td>Junction Area</td><td>Small (½)</td><td>Large for solar radiation to be incident on it.
(½)</td></tr>
<tr><td>I-V characteristics</td><td>

(1)</td><td>

(1)</td></tr>
</table>

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CLASS - XII

PHYSICS (042)

SAMPLE QUESTION PAPER (2019-20)

Time allowed: 3 hours Max. Marks: 70

General Instructions:

1. All questions are compulsory. There are 37 questions in all.
2. This question paper has four sections: Section A, Section B, Section C and Section D.
3. Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each, and Section D contains three questions of five marks each.
4. There is no overall choice. However, internal choices have been provided in two questions of one mark each, two questions of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.
5. You may use the following values of physical constants where ever necessary.

$c = 3 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ Js

$e = 1.6 \times 10^{-19}$ C

$\mu_o = 4\pi \times 10^{-7}$ T m A^{-1}

$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$ N $m^2 C^{-2}$

$m_e = 9.1 \times 10^{-31}$ kg

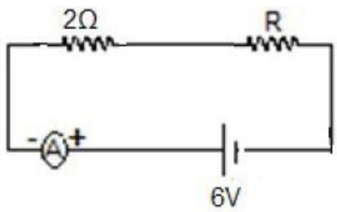
mass of neutron = 1.675×10^{-27} kg

mass of proton = 1.673×10^{-27} kg

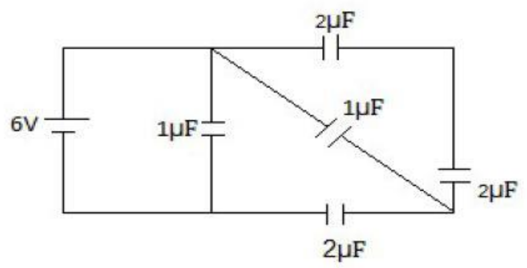
Avogadro's number = 6.023×10^{23} per gram mole

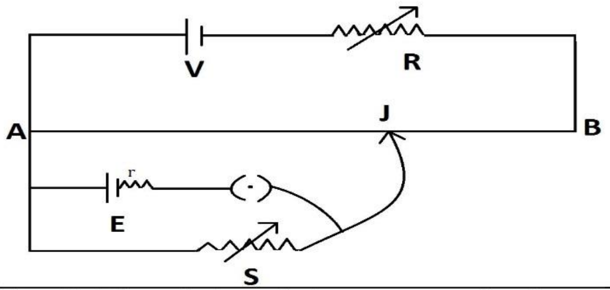
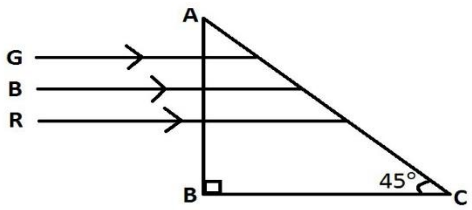
Boltzmann constant = 1.38×10^{-23} JK^{-1}

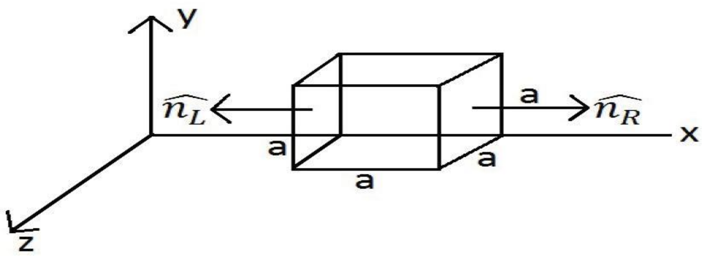
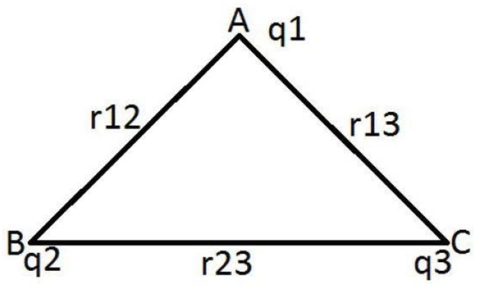
Section – A

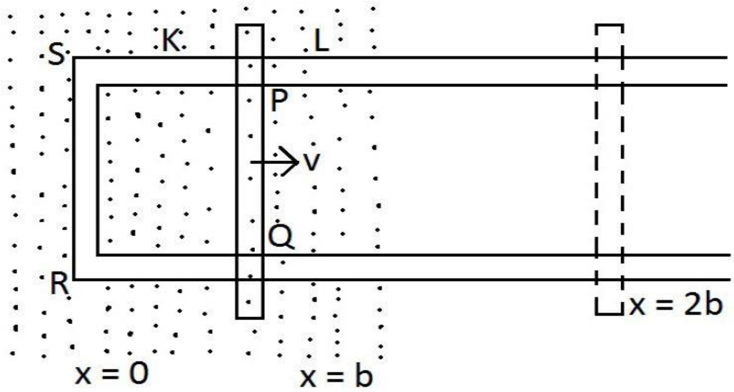
Directions (Q1-Q10) Select the most appropriate option from those given below each question		
1.	A charge q is placed at the point of intersection of body diagonals of a cube. The electric flux passing through any one of its face is (a) $\frac{q}{6\epsilon_0}$ (b) $\frac{3q}{\epsilon_0}$ (c) $\frac{6q}{\epsilon_0}$ (d) $\frac{q}{3\epsilon_0}$	1
2.	The electric potential of earth is taken to be zero because earth is a good (a) Insulator (b) conductor (c) semiconductor (d) dielectric	1
3.	If the ammeter in the given circuit shown in the diagram reads 2A, the resistance R is (a) 1Ω (b) 2Ω (c) 3Ω (d) 4Ω 	1
4.	The heat produced by 100W heater in 2 minutes is equal to (a) 10.5kJ (b) 16.3kJ (c) 12.0kJ (d) 14.2kJ	1
5.	Time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of (a) speed of the particle (b) mass of the particle (c) charge of the particle (d) magnetic field	1
6.	The final image formed in an astronomical refracting telescope with respect to the object is (a) Real inverted (b) Real erect (c) Virtual erect (d) Virtual inverted	1
7.	The shape of the interference fringes in Young's double slit experiment when D (distance between slit and screen) is very large as compared to fringe width is nearly (a) straight line (b) parabolic (c) circular (d) hyperbolic	1

8.	Unpolarized light is incident on a plane glass surface having refractive index $\sqrt{3}$. The angle of incidence at which reflected and refracted rays would become perpendicular to each other is : (a) 15° (b) 30° (c) 45° (d) 60°	1
9.	Photoelectric emission from a given surface of metal can take place when the value of a 'physical quantity' is less than the energy of incident photon. The physical quantity is : (a) Threshold frequency (b) Work function of surface (c) Threshold wave length (d) Stopping Potential	1
10.	A photon beam of energy 12.1eV is incident on a hydrogen atom. The orbit to which electron of H-atom be excited is (a) 2^{nd} (b) 3^{rd} (c) 4^{th} (d) 5^{th}	1
Directions (Q11 –Q15) Fill in the blanks with appropriate answer.		
11	Horizontal and vertical components of earth's magnetic field at a place are equal. The angle of dip at that place is ________. **OR** A free floating magnetic needle at North pole is __________to the surface of earth.	1
12	The magnetic flux linked with a coil changes by 2×10^{-2}Wb when the current changes by 0.01A. The self inductance of the coil is_______.	1
13	If the angular speed of the armature of a dynamo is doubled then the amplitude of the induced e.m.f will become_______.	1
14	An electron is accelerated through a potential difference of 100 V , then de-Broglie wavelength associated with it is approximately ____________A°	1
15	An equilateral prism is made up of material of refractive index $\sqrt{3}$. The angle of minimum deviation of light passing through the prism is_________.	1
Directions (Q16 –Q20) Answer the following		
16.	Which physical quantity in a nuclear reaction is considered equivalent to the Q-value of the reaction?	1
17.	Zener diode is used in reverse bias. When its reverse bias is increased, how does the thickness of the depletion layer change?	1
18	The initial concentration of a radioactive substance is N_o and its half life is 12 hours. What will be its concentration after 36 hours?	1
19.	Work function of Sodium is 2.75eV. What will be KE of emitted electron when photon of energy 3.54eV is incident on the surface of sodium?	1

20.	From the information of energy band gaps of diodes, how do you decide which can be light emitting diodes? **OR** Give any one advantage of LEDs over conventional incandescent low power lamps	1
21	Derive the expression for drift velocity of free electron in terms of relaxation time and electric field applied across a conductor.	2
22	Find total energy stored in capacitors given in the circuit 	2
23	An α - particle and a proton are accelerated through same potential difference. Find the ratio (V_α/ V_p)of velocities acquired by two particles.	2
24	What is Brewster's angle? Derive relation between Brewster angle and refractive index of medium which produces Plane Polarized light.	2
25	The work function of Cs is 2.14eV.Find (a) threshold frequency for Cs (b) Wavelength of incident light if the photo current is brought to zero by stopping potential of 0.6 V.	2
26	Derive an expression for the radius of n^{th} Bohr's orbit in Hydrogen atom. **OR** Energy of electron in first excited state in Hydrogen atom is -3.4eV. Find KE and PE of electron in the ground state.	2
27	Draw energy band diagram of p & n type semiconductors. Also write two differences between p and n type semiconductors. **OR** Energy gap in a p – n photodiode is 2.8 eV. Can it detect a wavelength of 6000 nm? Justify your answer.	2

	<u>Section – C</u>	
28	State working principle of potentiometer. Explain how the balance point shifts when value of resistor R increases in the circuit of potentiometer, given below. 	3
29	Using Biot-Savart's law, derive an expression for magnetic field at any point on axial line of a current carrying circular loop. Hence, find magnitude of magnetic field intensity at the centre of circular coil.	3
30	Obtain the resonant frequency and Q – factor of a series LCR circuit with L = 3H, C = 27μF, R = 7.4Ω. It is desired to improve the sharpness of resonance of circuit by reducing its full width at half maximum by a factor of 2. Suggest a suitable way.	3
31	State the conditions of total internal reflection. Refractive indices of the given prism material for Red, Blue and Green colors are respectively 1.39, 1.48 and 1.42 respectively. Trace the path of rays through the prism. 	3
32	Define resolving power of an astronomical refracting telescope and write expression for it in normal adjustment.Assume that light of wave length 6000Å is coming from a star, what is the limit of resolution of a telescope whose objective has a diameter of 2.54m? **OR** Write the basic assumptions used in the derivation of lens – maker's formula and hence derive this expression.	3 3

33	Show that $^{238}_{92}U$ can not spontaneously emit a proton. Given: $^{238}_{92}U$ = 238.05079u, $^{237}_{91}Pa$ = 237.05121u $^{1}_{1}H$ = 1.00783u	3
34	Suggest an idea to convert a full wave bridge rectifier to a half wave rectifier by changing the connecting wire/s. Draw the diagram and explain your answer.	3
	Section – D	
35	**(a)** Using Gauss's law, derive expression for intensity of electric field at any point near the infinitely long straight uniformly charged wire. **(b)**The electric field components in the following figure are $E_x = \alpha x$, $E_y = 0$, $E_z = 0$; in which α = 400 N/C m. Calculate (i) the electric flux through the cube, and (ii) the charge within the cube assume that a = 0.1m.  **OR** **a)** Define electrostatic potential at a point. Write its SI unit. Three charges q_1 , q_2 and q_3 are kept respectively at points A, B and C as shown in figures. Write the expression for electrostatic potential energy of the system.  **b)** Depict the equipotential surfaces due to (i) an electric dipole (ii) two identical negative charges separated by a small distance.	5 5
36	In the following diagram, the arm PQ of the rectangular conductor is moved from x = 0; outwards.	5

	 The uniform magnetic field is perpendicular to the plane and extends from x = 0 to x = b and is zero for x >b. Only the arm PQ possesses substantial resistance 'r'. consider the situation when the arm PQ is pulled outwards from x = 0 to x = 2b, and is then moved back to x = 0 with constant speed 'v'. Obtain expressions for the (i) electric flux, (ii) the induced emf,(iii)the force necessary to pull the arm and (iv) the power dissipated as Joule heat. Sketch the variation of these quantities with distance. **OR** Write working principle of cyclotron and with a suitable diagram explain its working. Give any two applications of cyclotron.	5
37	Derive mirror equation for a convex mirror. Using it, show that a convex mirror always produces a virtual image, independent of the location of object. **OR** **(a)** Draw a ray diagram for final image formed at distance of distinct vision (D) by a compound microscope and write expression for its magnifying power. **(b)** An angular magnification (magnifying power) of 30x is desired for a compound microscope using as objective of focal length 1.25cm and eye piece of focal length 5cm. How will you set up the compound microscope?	5 5

Class -XII
PHYSICS
SQP Marking Scheme
2019-20

Section – A		
1.	a , $\phi = \frac{q}{6\epsilon_0}$ (for one face)	1
2.	b , Conductor	1
3.	a , 1Ω.	1
4.	c ,12.0kJ	1
5.	a , speed	1
6.	d, virtual and inverted	1
7.	a, straight line	1
8.	d, 60^{o}	1
9.	b, work function	1
10.	b, third orbit	1
11.	45^{o} or vertical	1
12.	2 H	1
13.	double	1
14.	1.227 A^{o}	1
15.	60°	1
16.	Difference in initial mass energy and energy associated with mass of products Or Total Kinetic energy gained in the process	1
17.	Increases	1
18.	$N_o/8$	1
19.	0.79 eV	1
20.	Diodes with band gap energy in the visible spectrum range can function as LED	1

OR

Any one use

Section – B

21. When electric field E is applied on conductor force acting on free electrons

$$\vec{F} = -e\,\vec{E}$$

$$m\vec{a} = -e\vec{E}$$

$\vec{a} = \frac{-e\vec{E}}{m}$

Average thermal velocity of electron in conductor is zero 1

$(u_t)_{av} = 0$

Average velocity of electron in conductors in τ (relaxation time) = v_d (drift velocity)

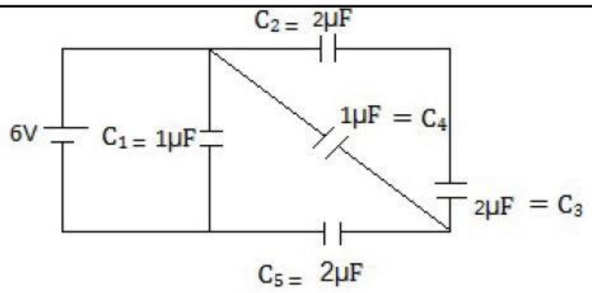
$$v_d = (u_t)_{av} + a\,\tau$$

$$v_d = 0 + \frac{-eE\tau}{m}$$

1

$\vec{v_d} = \frac{-e\vec{E}\tau}{m}$

22.



C_2 and C_3 are in series

$\frac{1}{c'} = \frac{1}{2} + \frac{1}{2} = 1$

$c' = 1\mu f$ 1

c' & C_4 are in ||

$C'' = 1 + 1 = 2\mu f$

C'' & c_5 are in series

$\frac{1}{c'''} = \frac{1}{2} + \frac{1}{2} \Longrightarrow c''' = 1\mu f$

c''' & c_1 are in ||

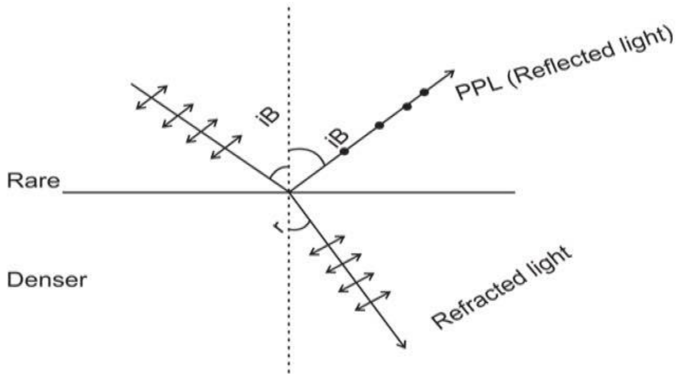
$C_{eq} = 1 + 1 = 2\mu f$

Energy stored 1

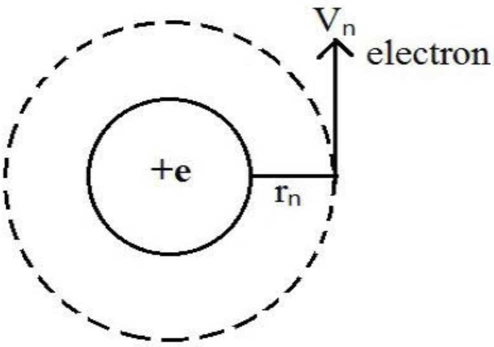
$U = \frac{1}{2}cv^2 = \frac{1}{2} \times 2 \times 10^{-6} \times 6^2$

$= 36 \times 10^{-6} J$

2

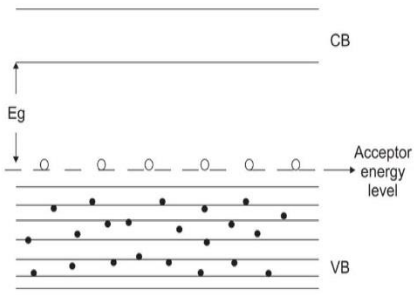
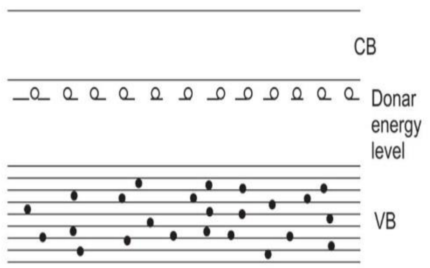
23.	Gain in KE of particle = Qv $\frac{1}{2}m_p v_p^2 = K_P = q_p V_p$ ----------(i)$V_p = V_\propto = V$ $\frac{1}{2}m_\alpha v_\alpha^2 = K_\propto = q_\propto V_\propto$ -----------(ii) (ii)/(i) $\frac{m_\alpha v_\alpha^2}{m_p v_p^2} = \frac{q_\alpha}{q_p} = \frac{2}{1}$ $\frac{v_\alpha^2}{v_p^2} = \frac{m_p \times 2}{m_\alpha \times 1} = \frac{2m_p}{4m_p \times 1} = \frac{1}{2}$ $v_\propto : v_p = 1:\sqrt{2}$	1 1
24.	"The angle of incidence at which the reflected light is completely plane polarized, is called as Brewster's angle (i_B)  At $i = i_B$, reflected beam ⊥ to refracted beam $\therefore i_B + r = 90 \Rightarrow r = 90 - i_B$ Using snell's law $\frac{Sin\ i}{Sin\ r} = \mu$ $\frac{Sin\ i_B}{Sin\ (90-i_B)} = \mu \Rightarrow \frac{Sin\ i_B}{Cos\ i_B} = \mu$ $\mu = \tan\ i_B$	1 1
25.	wave function $\omega = 2.14eV$ (a) Threshold frequency $\omega = h\nu_0$ $\nu_0 = \frac{\omega}{h} = \frac{2.14 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34}}$	1

3

	$= 5.17 \times 10^{14} H_z$ (b) As $k_{max} = eV_0 = 0.6eV$ Energy of photon $E = k_{max} + \omega = 0.6eV + 2.14eV$ $= 2.74eV$ Wave length of photon $\lambda = \frac{hc}{E} = \frac{6.62\times10^{-34}\times3\times10^{-8}}{2.74\times1.6\times10^{-19}}$ $= 4530Å$	1
26.	 centripetal force = electrostatic attraction $\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon0}\frac{e^2}{r_n^2}$ $mv_n^2 = \frac{1}{4\pi\varepsilon0}\frac{e^2}{r_n}$ --------(i) as $mv_n r_n = n \cdot \frac{h}{2\pi}$ $v_n = \frac{nh}{2\pi m r_n}$ put in (i) $m \cdot \frac{n^2h^2}{4\pi^2m^2r_n^2} = \frac{1}{4\pi\varepsilon0}\frac{e^2}{r_n}$ $r_n = \frac{\varepsilon0 n^2h^2}{\pi me^2}$ **OR** Energy of electron in n = 2 is -3.4eV $E_n = \frac{x}{n^2} \Rightarrow -3.4eV = \frac{x}{2^2} \Rightarrow$ ∴ energy in ground state = -13.6eV energy in ground state x = - 13.6eV. kE = -TE = +13.6eV	1 1 1
		4

<table>
<tr><td></td><td>PE = 2TE = -2×13.6eV = -27.2eV</td><td>1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>27.</td><td>
<table>
<tr><th>P-type semiconductor</th><th>n-type semiconductor</th></tr>
<tr><td>1. Density of holes >> density of electron

2. Formed by doping trivalent impurity</td><td>1. density of electron>>density of holes

2. formed by doping pentavalent impurity</td></tr>
<tr><td>Energy band diagram for p-type
</td><td>Energy band diagram of n-type semiconductor
</td></tr>
</table>

<u>OR</u>

Energy of photon E = $\frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^{8}}{6000\times10^{-9}\times1.6\times10^{-19}}$eV =2.06eV

As E<E_g (2.8eV), so photodiode cannot detect this photon.
</td><td>Any 2x1 =1

1

1</td></tr>
<tr><td colspan="3"><u>Section – C</u></td></tr>
<tr><td>28.</td><td>Principle of potentiometer, when a constant current flows through a wire of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length.
Let resistance of wire AB be R_1 and its length be ‘l’ then current drawn from driving cell –
I = $\frac{V}{R+R1}$ and hence
P.D. across the wire AB will be
V_{AB} = IR_1 = $\frac{V}{R+R1} \times \frac{\varrho l\theta}{a}$
Where ‘a’ is area of cross-section of wire AB
$\therefore \frac{VAB}{l} = \frac{V\varrho}{(R+R1).a}$ = constant = k
Where R increases, current and potential difference across wire AB will be</td><td>1

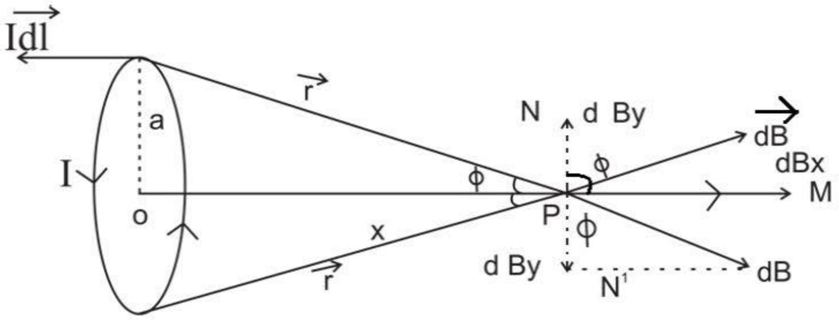
1

1</td></tr>
</table>

5

decreased and hence potential gradient 'k' will also be decreased. Thus the null point or balance point will shift to right (towards, B) side.

29.



1

According to Biot-Savart's law, magnetic field due to a current element is given by

$$\vec{dB} = \frac{\mu 0}{4\pi}\frac{I\vec{dl}\times\hat{r}}{r^2} \quad \text{where } r = \sqrt{x^2 + a^2}$$

$$\therefore dB = \frac{\mu 0}{4\pi}\frac{Idl\,\sin 90^0}{x^2+a^2}$$

1/2

And direction of $\vec{dB}$ is $\perp$ to the plane containing $I\vec{dl}$ and $\vec{r}$.

Resolving $\vec{dB}$ along the x – axis and y – axis.

$$dB_x = dB\sin\theta$$

$$dB_y = dB\cos\theta$$

taking the contribution of whole current loop we get

$$B_x = \oint dB_x = \oint dB\sin\theta = \int \frac{\mu 0}{4\pi}\frac{Idl}{x^2+a^2}\frac{a}{\sqrt{x^2+a^2}}.$$

$$B_x = \frac{\mu 0}{4\pi}\frac{I_a}{(x^2+a^2)^{3/2}}\oint dl = \frac{\mu 0}{4\pi}\frac{I_a \times 2\pi a}{(x^2+a^2)^{3/2}}$$

1/2

And $B_y = \oint dB_y = \oint dB\cos\theta = 0$

$$\therefore B_P = \sqrt{B_x^{\,2} + B_y^{\,2}} = B_x = \frac{\mu 0}{4\pi}\frac{2IA}{(x^2+a^2)^{3/2}}$$

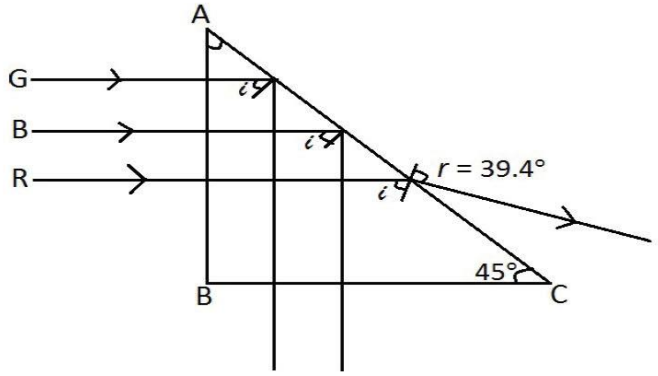
$$\therefore \vec{B_P} = \frac{\mu 0}{4\pi}\frac{2\vec{m}}{(x^2+a^2)^{3/2}} \left(\because \vec{m} = I\vec{A}\right)$$

1

For centre x = 0

$$\therefore \left|\vec{B_o}\right| = \frac{\mu 0}{4\pi}\frac{2I\pi a^2}{a^3} = \mu_0\left(\frac{I}{2a}\right) \text{ in the direction of } \vec{m}$$

6

30.	∵ resonant frequency for LCR circuit is given by $v_0 = \frac{1}{2\pi\sqrt{LC}}$ $= \frac{1}{2\times3.14\sqrt{3\times27\times10^{-6}}}$ $= 17.69\text{Hz}$ Or $\omega_0 = 2\pi v_0$= 111rad/s. ∵ quality factor of resonance $Q = \frac{\omega_0}{2\Delta w} = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$ $\therefore Q = \frac{1}{7.4}\sqrt{\frac{3}{27\times10^{-6}}} = 45.0$ To improve sharpness of resonance circuit by a factor 2, without reducing ω_0; reduce R to half of its value i.e. R = 3.7Ω	1 1 1
31.	 Two conditions for T IR – (a) Light must travel from denser to rarer medium (b) $i > i_c$ ∵ $\text{Sin } i_c = \frac{1}{\mu}$ $\therefore (i_c)_{Red} = \text{Sin}^{-1}\left(\frac{1}{1.39}\right) = 46°$ $(i_c)_{Green} = \text{Sin}^{-1}\left(\frac{1}{1.42}\right) = 44.8°$ $(i_c)_{Blue} = \text{Sin}^{-1}\left(\frac{1}{1.48}\right) = 43°$ ∵ Angle of incidence at face AC is 45° which is more than the critical angle for Blue and Green colours therefore they will show TIR but Red colour will refract to other medium.	1 1 1
32.	Resolving power (R.P) of an astronomical telescope is its ability to form separate images of two neighboring astronomical objects like stars etc. $\text{R.P.} = \frac{1}{d\theta} = \frac{D}{1.22\lambda}$ where D is diameter of objective lens and λ is wave length	1

7

of light used. 1

$$D = 100\text{inch} = 2.54\times100\text{cm} = 254\text{cm}$$
$$= 2.54\text{m}$$

$$\lambda = 6000\text{Å}$$

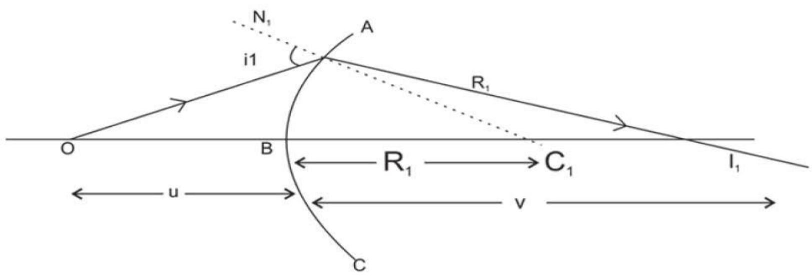
Limit of resolution $d\vartheta = \frac{1.22\lambda}{D}$ 1

$$= \frac{1.22\times6000\times10^{-10}m}{254\times10^{-2}m}$$

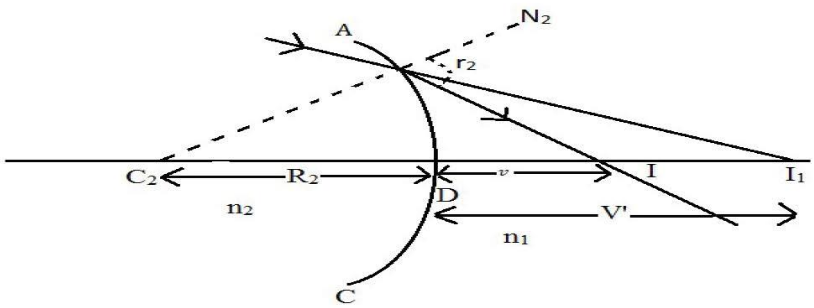
$$= 2.9\times10^{-10}$$

OR

Basic assumptions in derivation of Lens-maker's formula:
(i) Aperture of lens should be small
(ii) Lenses should be thin 1
(iii) Object should be point sized and placed on principal axis.



1

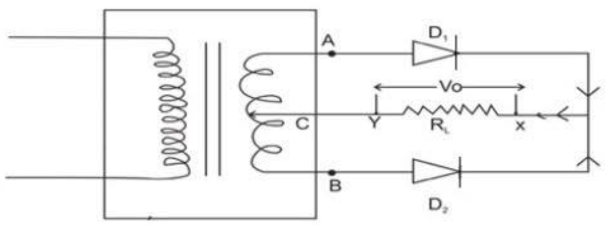


Suppose we have a thin lens of material of refractive index n_2, placed in a medium of refractive index n_1, let o be a point object placed on principle axis then for refraction at surface ABC we get image at I_1 ,

$$\therefore \frac{n_2}{V'} - \frac{n_1}{u} = \frac{n_2-n_1}{R_1} \text{ ---------(1)}$$

But the refracted ray before goes to meet at I_1 falls on surface ADC and refracts at I_2

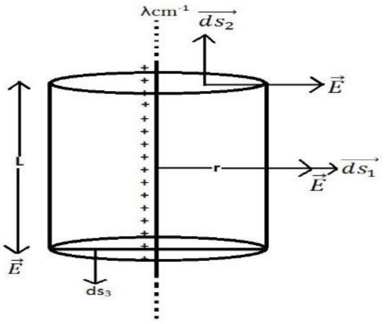
8

	finally; hence I_1 works as a virtual object 2^{nd} refracting surface $\therefore \frac{n_1}{V} - \frac{n_2}{V^1} = \frac{n_1 - n_2}{R_2}$ --------- (2) Equation (1) + (2) $\frac{n_1}{V} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $\therefore \frac{1}{V} - \frac{1}{u} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ --------(3) If $u = \infty$, $v = f$ $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$--------(4) Which is lens maker's formula.	1
33.	${}^{238}_{92}U \rightarrow {}^{237}_{91}Pa + {}^{1}_{1}H + Q$ $\because Q = [M_U - M_{Pa} - M_H]\, c^2$ $= [\,238.05079 - 237.05121 - 1.00783]\ u \times c^2$ $= -\,0.00825u \times 931.5\,\frac{MeV}{u}$ $= -\,7.68MeV$ $\because Q < 0$; therefore it can't proceed spontaneously. We will have to supply energy of 7.68MeV to ${}^{238}_{92}U$nucleus to make it emit proton.	1 1 1
34.	Circuit Diagram  One possible answer: Change the connection of R from point C to point B. Now No Current flowing through D_2 in the second half. 1 mark for any correct diagram 2 marks for correct explanation	1 2

9

Section – D

35. (a)



1

According the Gauss's law –

$$\oint N, d\vec{s} = \frac{1}{\epsilon 0}\{q\}$$

$$\int \vec{E}\,\overrightarrow{ds_1} + \int \vec{E}\,\overrightarrow{ds_2} + \int \vec{E}\,\overrightarrow{ds_3} = \frac{1}{\epsilon 0}(\lambda L)$$

$$\int Eds_1 Cos0 + \int Eds_2 Cos90^o + \int Eds_3 Cos90^o = \frac{\lambda L}{\epsilon 0}$$ 1

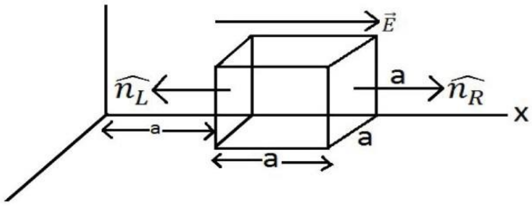
$$E\int ds_1 = \frac{\lambda L}{\epsilon 0}$$

$$E \times 2\pi rL = \frac{\lambda L}{\epsilon 0}$$

$$E = \frac{\lambda}{2\pi\epsilon 0 r}$$

$$\vec{E} = \frac{\lambda}{2\pi\epsilon 0 r}\hat{r}$$ 1

35. (b)



$\because E_x = \propto x = 400x$

$E_y = E_z = 0$

Hence flux will exist only on left and right faces of cube as $E_x \neq 0$

$$\because \overrightarrow{E_L}\,.\,a^2(n_2) + \overrightarrow{E_R}\,.\,a^2\widehat{n_R} = \frac{1}{\epsilon 0}\{qin\} = \phi$$ 1

$$-E_L\,.\,a^2(\bar{n}_2) + a^2 E_R = \phi_{Net}$$

$$\phi_{Net} = -(400a)a^2 + a^2(400 \times 2a)$$

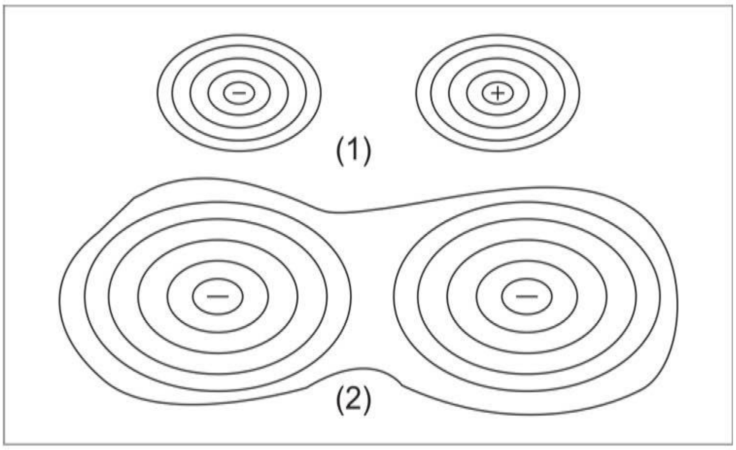
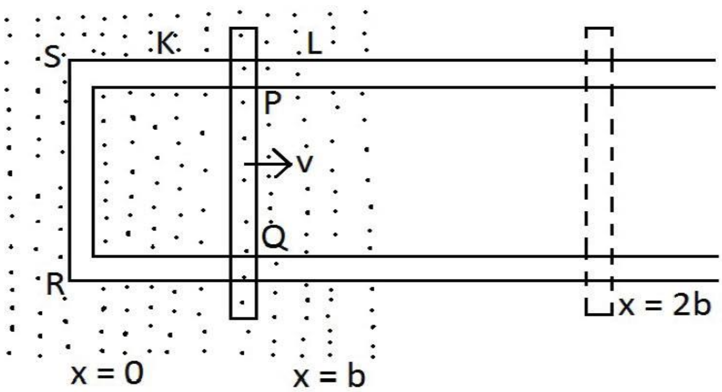
$= -400a^3 + 800a^3$

$= 400a^3$

$= 400 \times (.1)^3$

$\phi_{Net} = 0.4\ Nm^2c^{-1}$

10

	$\because \phi_{Net} = \frac{1}{\epsilon 0}\{qin\}$ $\therefore qin = \epsilon 0 \phi_{Net}$ $= 8.85 \times 10^{-12} \times 0.4$ $= 3.540 \times 10^{-12} c$	1
	OR	
(a)	Definition of electrostatic potential – SI unit J/c of Volt. Deduction of expression of electrostatic potential energy of given system of charges – $U = \frac{1}{4\pi\epsilon 0}\left[\frac{q1\,q2}{r12} + \frac{q1\,q3}{r13} + \frac{q2\,q3}{r23}\right]$	1 2
(b)		1 1
36.	For forward motion from x = 0 to x = 2b. The flux ϕ_B linked with circuit SPQR is 	

11

$\phi_B = Blx \qquad 0 \le x < b$ 1

$\quad\;\; Blb \qquad b \le x < 2b$

The induced emf is,

$e = \frac{-d\phi_B}{dt}$

$e = -Blv \qquad 0 \le x < b$ 1

$\;\; = 0 \qquad b \le x < 2b$

When induced emf is non-zero, the current I in the magnitude;

$I = \frac{e}{r} = \frac{Blv}{r}$

The force required to keep arm PQ in constant motion is F =IlB. Its direction is to the left. In magnitude

$F = IlB = \frac{B^2 l^2 v}{r}$; $\qquad 0 \le x < b$ 1

$\quad = 0$; $\qquad b \le x < 2b$

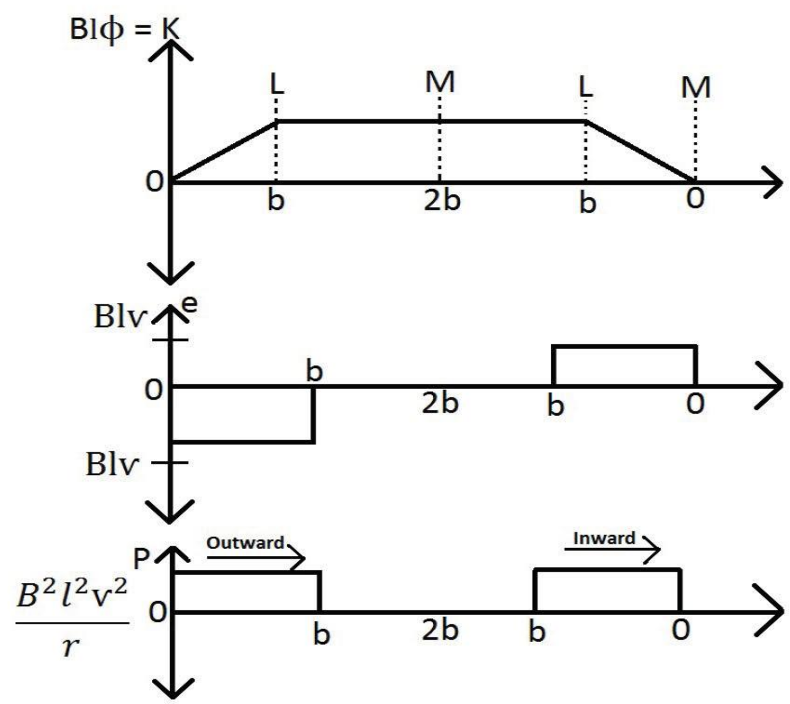
The Joule heating loss is

$P_J = I^2 r$

$= \frac{B^2 l^2 v^2}{r} \qquad 0 \le x < b$ 1

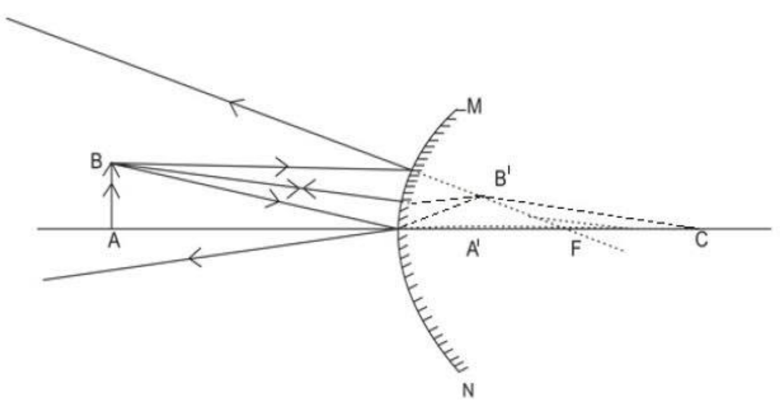
$= 0 \qquad b \le x < 2b$

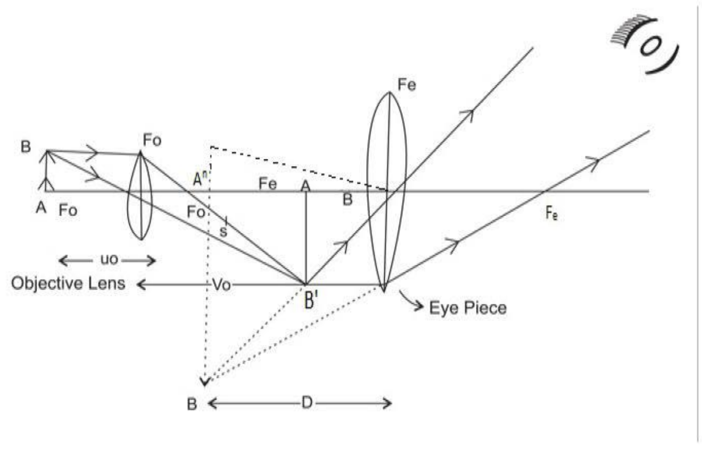
One obtains similar expressions for the inward motion from x = 2b to x = 0



1

12

	OR Working principle of cyclotron Diagram Working of cyclotron with explanation Any two appliations	1 1 2 1
37.	 Deduction of mirror formula $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ For a convex mirror f is always +ve. $\therefore f > c$ Object is always placed in front of mirror hence u < 0 (for real object) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ $\Rightarrow \frac{1}{v}=\frac{1}{f}-\frac{1}{u}$ As u < 0 u –ve hence $\frac{1}{v}> 0$ $\Rightarrow$ v> 0 i.e. +ve for all values of u. Image will be formed behind the mirror and it will be virtual for all values of u.	1 2 1 1
37. (a)	**OR** Ray Diagram : (with proper labeling)	1

	 Magnifying power $m = \frac{V_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ $m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$	1
37. (b)	$\because m = m_o\, m_e = -30$ (virtual, inverted) $\because f_o = 1.25cm$ $f_e = 5.0cm$ Let us setup a compound microscope such that the final image be formed at D, then $m_e = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 6$ and position of object for this image formation can be calculated – $\frac{1}{Ve} - \frac{1}{ue} = \frac{1}{fe}$ $\frac{1}{-25} - \frac{1}{ue} = \frac{1}{5}$ $-\frac{1}{ue} = \frac{1}{5} + \frac{1}{25} = \frac{6}{25}$ $ue = \frac{-25}{6} = -4.17cm.$ $\because m = m_o \times m_e$ $\therefore m_o = \frac{+Vo}{uo} = \frac{-30}{6} = -5$ $\therefore V = -5u_o$ $\frac{1}{Vo} - \frac{1}{uo} = \frac{1}{fo}$ $\frac{1}{-5uo} - \frac{1}{uo} = \frac{1}{1.25}$	1 1

	$\frac{-6}{5uo} = \frac{1}{1.25}$ $u_o = -1.5cm \Rightarrow v_o = 7.5cm$ Tube length = $V_o + \lvert u_e \rvert$ = 7.5cm + 4.17cm L = 11.67cm Object should be placed at 1.5cm distance from the objective lens.	1

Answer Key

Chapter 1: Field and Flux

Q5. $K4\sqrt{2}\, q/a^2$
Q6. (3/8)F
Q9. X=2/3 m from 4Q
X=1/3 m from Q
Q11. Q=26.562μC
Q12. Q = 3.89 μC (sign +ve)
Q13b. U= - 8J
Q16. 2 : 1
Q18 (i)Ø= 0.125Nm²/C
(ii) $Q=1.106 \times 10^{-12}$C

Chapter 2: Potential & capacitance

Q3. U=6V
Q4. K.E. = 24×10^{-3}J
Q7. K=5
Q8 V=400V
$U_f = U_i = 1$J
Q9 E= 3μJ
Q10. $C=10C_0$
Q11. $W=2.3 \times 10^{-8}$ J
Q12. $C_3=C_s$
Q13 $\theta=120^0$
Q14. Q= Nq
$V_{big}=N^{2/3}\, V_{small}$
$C_{big}=N^{1/3}\, C_{small}$
Q15. W=15 J
Q16. $Q =- q/2\sqrt{2}$
Q17. $\Delta\mu=2.67 \times 10^{-2}$ J
Q20. $C_{eq=}$ 6/7μF

Chapter 3: Current Electricity

Q1. $R_{B=}R_A$= 1:6
Q3. X=4 'Ω
I=0.66A, No change.
Q6. L =160 cm
Q10. R=13.8 'Ω
E=1.65V
Q12. I_2=(5/11)A
Q13. R=4 'Ω
Q14. E=2.25V
Q15. $R_{1:}R_2$=3:2
Q16. V=60 mv

Q19 E_{eq}=2V

Chapter 4: Magnetic Effect of current

Q1 $M_1=\sqrt{3}\ I\ a^2$
$M_2= 3Ia^2$
$M_3= 3\sqrt{3}\ I\ a^2$
Q2. $T= 1/4\sqrt{2}\ (V_0AB/R)$
Q4. $|dB| = 4 \times 10^{-8}$T along +Z axis
Q6. $R_A = 40 \times 10^{-3}\Omega$
$R_V = 400\ \Omega$
Q7. $B=6\times10^{-4}$ T
Q12 $B = 1.6 \times 10^{-3}$ T towards West
Q 13 $m_{new} : m_{original} = 1: 2$

Chapter 5: Magnetism & Matter

Q2. T′ = T/2
Q6. Apparent dip δ′=63.4°
Q7. Θ=30°
Q12. B=0.254G
δ = 62°
Q 16. $I =10^{-4}$A
B=1.23T
$M =8.16 \times 10^{-24}$ Am^2
Q17. Magnetic intensity = 1500A/m
Magnetisation = 7.5×10^6 A/m
Magnetic field = 9.4T
Q18. $B=\sqrt{5} \times 10^{-7}$T

Chapter 6: EMI

Q1. I=0
Q2. $\varnothing = 2B_0L^2$ Wb
Q8. $\mathcal{E}=1.5\ 10^{-3}$C
Q12. $q = 1.6\ 10^{-3}$C
Q15. N_s=10,000
I_p=5A
$\mathcal{E}_s$=20,000V
I_s= 0.05A
K=Ns/Np>1
Q19. $\mathcal{E}_0$=2250V
I_0=4.5A

Chapter 7: A.C.

Q1. Irms = $\sqrt{2.5}$ =1.6A
Q6. Z=171.4Ω
Q8 (i) Irms=0.65A (ii) L=1H (iii) C=5μF (iv) C′=10.1μF

Q9. Heat loss in primary coil = 746.61W
Heat loss in secondary coil= 242W

Q10. (i) Z=15Ω (ii) Irms= 8A (iii) W=632rad/S.

Q11. Pav=0

Q13. E=5V

Q15. $V_0 = 310.2V$
$V_{in} = 197.5V$

Q16. (i) $C=2.65 \times 10^{-4}F$
(ii) $L=9.459 \times 10^{-3}H$
(iii) Z=18.87Ω

Q18. $\mathcal{E}_0 = 0.314V$

Q20. Z=50Ω

Chapter 8: em waves

Q5. $E_0=38.8$ N/C
$B_0= 12.9 \times 10^{-8}T$

Q7. $I_D=I/2$

Chapter 9: Ray optics & optical instruments

Q1. f = 50cm.

Q2 (a) L=20cm (b) M=3

Q3. Option 3.

Q5. f = 50cm

Q6. f_l =62.5cm

Q7. Shift=36cm

Q8. f=10cm

Q12. P=1.5D

Q13. f=20cm

Q15. f_0=1.8cm

Q21. A) m = 35.

Chapter 10: Wave optics

Q4. Linear Width would change.

Q5. R=√7A

Q11. I=k/4

Q18. $I = I_0/4$

Chapter 11: Dual Nature of matter and Radiation

Q1. % increase in λ=9.1%

Q2. $K.E.=3.35 \times 10^{-21}J$

Q3 1:1

Q5. $\lambda_\alpha = \lambda_p$ =1:2√2

Q9. $\lambda_d = \lambda_\alpha$ =1:1

Q17. K.E.max=1.985eV

Q20. Electron,Electron

Q21. Proton, Proton

Chapter 12 &13: Atomic Nucleus

Q6. $R_x : R_y =$ 1:1

Q9. Q= 4.374MeV

Q11. $r_o = 2.88 \times 10^{-14}$ m =28 fm

Q13. $\lambda_{longest}$= 656.3nm

$\lambda_{shortest}$ = 365.0nm

Q16. Q=4.937MeV

K.Eα=4.85MeV

Q22. Halved, four times

Q23. 144.02×10^{15} Bq

Chapter 14: Semi Conductor

Q1. V=0.21V

K.E.=0.21eV

Q2. I=6.95mA.

Q3. V_0=10.2V

I_d= 1.82mA

Q4. (i) A=12.5V (ii) frequency of LSB=1490 KHz

Frequency of USB=1510KHz.

Q10. (i) I_B=0.1mA

(ii) I_C = 5.9mA

Q17. The Zener diode should have a current rating 17.5mA and a breaking voltage of 15V.

Q18. (i) βac=133 (ii) gm=0.2Ω^{-1} (iii) Av=1000

Q20. I_1=0.05A, I_2=0.025A, I_3=0

Chapter 15: Communication system

Q4. L=0.5m

Q5. Am=16

Q10. (a) d=45248m

(b) Population covered =76.37lacs

(c) h=480m

Q16. d = 16km

Up to 2MHz

Q20. (b) μ= 0.66

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▶ Answer/Explanation

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9. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system

(a) increases by a factor of 4.

(b) decreases by a factor of 2.

(c) remains the same.

(d) increases by a factor of 2.

▼ Answer/Explanation

Answer: b

Explaination: (b) Using, $V_c = \frac{V}{2}$, $U = \frac{1}{2}CV^2$.

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10. 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.