

DIRECTORATE OF EDUCATION
GNCT of Delhi, Delhi Government

SUPPORT MATERIAL
(2020-2021)
Class : XII

PHYSICS

Under the Guidance of

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MESSAGE

The importance of adequate practice during examinations can never be overemphasized. I am happy that support material for classes IX to XII has been developed by the Examination Branch of Directorate of Education. This material is the result of immense hard work, co-ordination and cooperation of teachers and group leaders of various schools. The purpose of the support material is to impart ample practice to the students for preparation of examinations. It will enable the students to think analytically & rationally, and test their own capabilities and level of preparation.

The material is based on latest syllabus prepared by the NCERT and adopted by the CBSE for the academic session 2020-21 and covers different levels of difficulty. I expect that Heads of Schools and Teachers will enable and motivate students to utilize this material during zero periods, extra classes and regular classes best to their advantage.

I would like to compliment the team of Examination Branch for their diligent efforts of which made it possible to accomplish this work in time. I also take this opportunity to convey my best wishes to all the students for success in their endeavours.

(Manisha Saxena)

BINAY BHUSHAN, IAS



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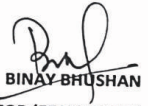
Dear Students,

Directorate of Education is committed to providing qualitative and best education to all its students. The Directorate is continuously engaged in the endeavor to make available the best study material for uplifting the standard of its students and schools.

Every year, the expert faculty of Directorate reviews and updates Support Material. The expert faculty of different subjects incorporates the changes in the material as per the latest amendments made by CBSE to make its students familiar with new approaches and methods so that students do well in the examination.

The book in your hand is the outcome of continuous and consistent efforts of senior teachers of the Directorate. They have prepared and developed this material especially for you. A huge amount of money and time has been spent on it in order to make you updated for annual examination.

Last, but not the least, this is the perfect time for you to build the foundation of your future. I have full faith in you and the capabilities of your teachers. Please make the fullest and best use of this Support Material.


BINAY BHUSHAN
DIRECTOR (EDUCATION)

Dr. (Mrs.) Saroj Bala Sain

Addl. Director of Education
(School / Exam / EVGB/IEB/ VOC.)



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D.O. No. PA/ADD. DE (Sch)/86
Date : 03-10-2019

I am very much pleased to forward the Support Material for classes IX to XII. Every year, the Support Material of most of the subjects is updated/revised as per the most recent changes made by CBSE. The team of subject experts, officers of Exam Branch, members of Core Academic Unit and teachers from various schools of Directorate has made it possible to make available unsurpassed material to students.

Consistence use of Support Material by the students and teachers will make the year long journey seamless and enjoyable. The main purpose to provide the Support Material for the students of government schools of Directorate is not only to help them to avoid purchasing of expensive material available in the market but also to keep them updated and well prepared for exam. The Support Material has always been a ready to use material, which is matchless and most appropriate.

I would like to congratulate all the Team Members for their tireless, unremitting and valuable contributions and wish all the best to teachers and students.

(Dr. Saroj Bala Sain)
Addl.DE (School/Exam)

DIRECTORATE OF EDUCATION
Govt. of NCT, Delhi

SUPPORT MATERIAL
(2020-2021)

PHYSICS

Class : XII

NOT FOR SALE

PUBLISHED BY : DELHI BUREAU OF TEXTBOOKS

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भारत का संविधान

भाग 4क

नागरिकों के मूल कर्तव्य

अनुच्छेद 51क

मूल कर्तव्य — भारत के प्रत्येक नागरिक का यह कर्तव्य होगा कि वह —

1. संविधान का पालन करे और उसके आदर्शों, संस्थाओं, राष्ट्र ध्वज और राष्ट्रगान का आदर करें।
2. स्वतंत्रता के लिए हमारे राष्ट्रीय आंदोलन को प्रेरित करने वाले उच्च आदर्शों को हृदय में संजोए रखे और उनका पालन करे।
3. भारत की प्रभुता, एकता और अखंडता की रक्षा करे और उसे अक्षुण्ण रखे।
4. देश की रक्षा करे।
5. भारत के सभी लोगों में समरसता और समान भ्रातृत्व की भावना का निर्माण करे।
6. हमारी सामाजिक संस्कृति की गौरवशाली परंपरा का महत्त्व समझे और उसका निर्माण करे।
7. प्राकृतिक पर्यावरण की रक्षा और उसका संवर्धन करे।
8. वैज्ञानिक दृष्टिकोण और ज्ञानार्जन की भावना का विकास करे।
9. सार्वजनिक संपत्ति को सुरक्षित रखे।
10. व्यक्तिगत एवं सामूहिक गतिविधियों के सभी क्षेत्रों में उत्कर्ष की ओर बढ़ने का सतत् प्रयास करे।
11. माता—पिता या संरक्षक द्वारा 6 से 14 वर्ष के बच्चों हेतु प्राथमिक शिक्षा प्रदान करना (86वां संशोधन)।

CONSTITUTION OF INDIA

Part IV A (Article 51 A)

Fundamental Duties

Fundamental Duties : It shall be the duty of every citizen of India —

1. to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;
2. to cherish and follow the noble ideals which inspired our national struggle for freedom;
3. to uphold and protect the sovereignty, unity and integrity of India;
4. to defend the country and render national service when called upon to do so;
5. to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;
6. to value and preserve the rich heritage of our composite culture;
7. to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures.
8. to develop the scientific temper, humanism and the spirit of inquiry and reform;
9. to safeguard public property and to adjure violence;
10. to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement.
11. who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between the age of six and fourteen years.

भारत का संविधान

उद्देशिका

हम, भारत के लोग, भारत को एक (सम्पूर्ण प्रभुत्व—सम्पन्न समाजवादी पंथनिरपेक्ष लोकतंत्रात्मक गणराज्य) बनाने के लिए, तथा उसके समस्त नागरिकों को :

सामाजिक, आर्थिक और राजनैतिक न्याय,

विचार, अभिव्यक्ति, विश्वास, धर्म

और उपासना की स्वतंत्रता,

प्रतिष्ठा और अवसर की समता

प्राप्त करने के लिए,

तथा उन सब में,

व्यक्ति की गरिमा और (राष्ट्र की एकता

और अखंडता) सुनिश्चित करने वाली बंधुता

बढ़ाने के लिए

हम दृढ़संकल्प होकर इस संविधान को आत्मार्पित करते हैं।

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a **(SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC)** and to secure to all its citizens :

JUSTICE, social, economic and political,

LIBERTY of thought, expression, belief, faith and worship,

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the **(unity an integrity of the Nation)**;

WE DO HEREBY GIVE TO OURSELVES THIS CONSTITUTION.

COURSE STRUCTURE

CLASS - XII (2020-21)

Time : 3 hrs.

Marks : 70

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

Unit I: Electrostatics

22 Periods

Chapter - 1: Electric Charges and Fields

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).

Chapter - 2: Electrostatic Potential and Capacitance

Electric 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

20 Periods

Chapter - 3: 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, color 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.

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

22 Periods

Chapter - 4: Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment.

Biot - Savart law and its application to current carrying circular loop.

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.

Unit IV: Electromagnetic Induction and Alternating Currents 20 Periods

Electromagnetic induction; Faraday's laws, induced EMF and current; Lend's Law, Eddy currents. Self and mutual induction.

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, power factor, watt less current. AC generator and transformer.

04 Periods

Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Unit VI: Optics

27 Periods

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and its applications, optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lensometer's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.

Scattering of light - blue color of sky and reddish appearance of the sun at sunrise and sunset.

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

Chapter - 10: Wave Optics

Wave optics: Wave front and Huygen's 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 microscope and astronomical telescope, polarization, plane polarized light, Brewster's law, uses of plane polarized light and Polaroids.

Unit VII: Dual Nature of Radiation and Matter

08 Periods

Chapter - 11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Leonard's observations; Einstein's photoelectric equation-particle nature of light.

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

Unit VIII: Atoms and Nuclei

15 Periods

Chapter - 12: Atoms

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

Chapter - 13: Nuclei

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, nuclear fusion.

Unit IX: Electronic Devices

12 Periods

Chapter - 14: Semiconductor Electronics: Materials, Devices and Simple Circuits

Energy bands in conductors, semiconductors and insulators (qualitative ideas only)

Semiconductor diode - I-V characteristics in forward and reverse bias, diode as a rectifier;

Special purpose p-n junction diodes: LED, photodiode, solar cell and Zener diode and their characteristics, Zener diode as a voltage regulator.

PRACTICALS

(Total Periods 60)

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

- Record of at least 15 Experiments [with a minimum of 6 from each section], to be performed by the students.
- Record of at least 5 Activities [with a minimum of 2 each from section A and section B], to be demonstrated by the teachers.
- The Report of the project to be carried out by the students.

Evaluation Scheme

Time Allowed: Three hours

Max. Marks: 30

Two experiments one from each section	8+8 Marks
Practical record [experiments and activities]	6 Marks
Investigatory Project	3 Marks
Viva on experiments, activities and project	5 Marks
Total	30 marks

SECTION-A

Experiments

1. To determine resistance per cm of a given wire by plotting a graph for potential difference versus current.
2. To find resistance of a given wire using metre bridge and hence determine the resistivity (specific resistance) of its material.
3. To verify the laws of combination (series) of resistances using a metre bridge.
4. To verify the laws of combination (parallel) of resistances using a metre bridge.
5. To compare the EMF of two given primary cells using potentiometer.
6. To determine the internal resistance of given primary cell using potentiometer.
7. To determine resistance of a galvanometer by half-deflection method and to find its figure of merit.
8. To convert the given galvanometer (of known resistance and figure of merit) into a voltmeter of desired range and to verify the same.
9. To convert the given galvanometer (of known resistance and figure of merit) into an ammeter of desired range and to verify the same.
10. To find the frequency of AC mains with a sonometer.

Activities (*For the purpose of demonstration only*)

1. To measure the resistance and impedance of an inductor with or without iron core.
2. To measure resistance, voltage (AC/DC), current (AC) and check continuity of a given circuit using multimeter.
3. To assemble a household circuit comprising three bulbs, three (on/off) switches, a fuse and a power source.
4. To assemble the components of a given electrical circuit.
5. To study the variation in potential drop with length of a wire for a steady current.
6. To draw the diagram of a given open circuit comprising at least a battery, resistor/rheostat, key, ammeter and voltmeter. Mark the components that are not connected in proper order and correct the circuit and also the circuit diagram.

SECTION-B

Experiments

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 find the focal length of a concave lens, using a convex lens.
5. To determine angle of minimum deviation for a given prism by plotting a graph between angle of incidence and angle of deviation.
6. To determine refractive index of a glass slab using a travelling microscope.
7. To find refractive index of a liquid by using convex lens and plane mirror.
8. To draw the I-V characteristic curve for a p-n junction in forward bias and reverse bias.
9. To draw the characteristic curve of a zener diode and to determine its reverse breaks down voltage.
10. To determine the wavelength of a laser beam by diffraction.

Activities (*For the purpose of demonstration only*)

1. To identify a diode, an LED, a resistor and a capacitor from a mixed collection of such items.
2. Use of multimeter to see the unidirectional flow of current in case of a diode and an LED and check whether a given electronic component (e.g., diode) is in working order.

3. To study effect of intensity of light (by varying distance of the source) on an LDR.
4. To observe refraction and lateral deviation of a beam of light incident obliquely on a glass slab.
5. To observe polarization of light using two Periods.
6. To observe diffraction of light due to a thin slit.
7. To study the nature and size of the image formed by a (i) convex lens, (ii) concave mirror, on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).
8. To obtain a lens combination with the specified focal length by using two lenses from the given set of lenses.

Suggested Investigatory Projects

1. To study various 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 in
 - (a) the power of the incandescent lamp, used to 'illuminate' the LDR (keeping all the lamps at a fixed distance).
 - (b) the distance of a 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 (made from a glass of known refractive index) 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 factor on which the self-inductance of a coil depends by observing the effect of this coil, when put in series with a resistor/(bulb) in a circuit fed up by an A.C. source of adjustable frequency.
9. To study the earth's magnetic field using a tangent galvanometer.

**Practical Examination for Visually Impaired Students of
Classes XI and XII Evaluation Scheme**

Time Allowed: Two hours

Max. Marks: 30

Identification/Familiarity with the apparatus	5 marks
Written test (based on given/prescribed practicals)	10 marks
Practical Record	5 marks
Viva	10 marks
Total	30 marks

General Guidelines

- The practical examination will be of two hour duration.
- A separate list of ten experiments is included here.
- The written examination in practical for these students will be conducted at the time of practical\ examination of all other students.
- The written test will be of 30 minutes duration.
- The question paper given to the students should be legibly typed. It should contain a total of 15 practical skill based very short answer type questions. A student would be required to answer any 10 questions.
- A writer may be allowed to such students as per CBSE examination rules.
- All questions included in the question papers should be related to the listed practical. Every question should require about two minutes to be answered.
- These students are also required to maintain a practical file. A student is expected to record at least five of the listed experiments as per the specific instructions for each subject. These practical should be duly checked and signed by the internal examiner.
- The format of writing any experiment in the practical file should include aim, apparatus required, simple theory, procedure, related practical skills, precautions etc.
- Questions may be generated jointly by the external/internal examiners and used for assessment.
- The viva questions may include questions based on basic theory/principle/ concept, apparatus/ materials/chemicals required, procedure, precautions, sources of error etc.

Class XII

A. Items for Identification/ familiarity with the apparatus for assessment in practical (All experiments)

Meter scale, general shape of the voltmeter/ammeter, battery/power supply, connecting wires, standard resistances, connecting wires, voltmeter/ammeter, meter bridge, screw gauge, jockey Galvanometer, Resistance Box, standard Resistance, connecting wires, Potentiometer, jockey, Galvanometer, Lichened cell, Daniel cell [simple distinction between the two vis-a-vis their outer (glass and copper) containers], rheostat connecting wires, Galvanometer, resistance box, Plug-in and tapping keys, connecting wires battery/power supply, Diode, Resistor (Wire-wound or carbon ones with two wires connected to two ends), capacitors (one or two types), Inductors, Simple electric/electronic bell, battery/power supply, Plug-in and tapping keys. Convex lens, concave lens, convex mirror, concave mirror, Core/hollow wooden cylinder, insulated wire, ferromagnetic rod, Transformer core, insulated wire.

B. List of Practical

1. To determine the resistance per cm of a given wire by plotting a graph between voltage and current.
2. To verify the laws of combination (series/parallel combination) of resistances by Ohm's law.
3. To find the resistance of a given wire using a meter bridge and hence determine the specific resistance (resistivity) of its material.
4. To compare the e.m.f of two given primary cells using a potentiometer.
5. To determine the resistance of a galvanometer by half deflection method.
6. To identify a resistor, capacitor, inductor and diode from a mixed collection of such items.
7. To understand the principle of (i) a NOT gate (ii) an OR gate (iii) an AND gate and to make their equivalent circuits using a bell and cells/battery and keys /switches
8. To observe the difference between
 - (i) a convex lens and a concave lens
 - (ii) a convex mirror and a concave mirror and to estimate the likely difference between the power of two given convex /concave lenses.
9. To design an inductor coil and to know the effect of
 - (i) change in the number of turns
 - (ii) Introduction of ferromagnetic material as its core material on the inductance of the coil.

10. To design a (i) step up (ii) step down transformer on a given core and know the relation between its input and output voltages.

Note: The above practical may be carried out in an experiential manner rather than recording observations.

Prescribed Books:

1. Physics, Class XI, Part -I and II, Published by NCERT.
2. Physics, Class XII, Part -I and II, Published by NCERT.
3. Laboratory Manual of Physics for class XII Published by NCERT.
4. The list of other related books and manuals brought out by NCERT (consider multimedia also).

QUESTION PAPER DESIGN (CLASS : XI/XII) (2020-21)

Board Examination – Theory

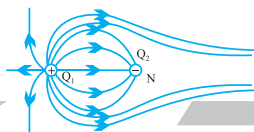
Maximum Marks : 70

Duration : 3 hrs.

S. No.	Typology of Questions	Very Objective Type 1 Mark	Short 2 Marks	Long 3 Marks	Long-II 5 Marks	Total Marks	%
1.	Remembering: Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	2	2	1	–	9	12%
2.	Understanding: Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas	6	2	2	1	21	30%
3.	Application Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way	6	2	1	2	23	33%
4.	Analysing and Evaluating: Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria	6	1	2	–	14	20%
5.	Creating: Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions	–	–	1	–	–	5%
	Total	20 × 1 = 20	7 × 2 = 14	7 × 3 = 21	3 × 5 = 15	70	100

Practical : 30

- Internal Choice. There is no overall choice in the paper. However, there will be a least 33% internal choice.
- The above template is only a sample. Suitable internal variations may be made for generating similar templates keeping the overall weightage to different form of questions and typology of questions same.



Unit I and II

Section - 1

KEY POINTS

Physical Quantity	Formulae Used	SI Unit
Quantization of charge	$q = \pm ne$	C
Coulomb's force	$ F = \frac{kq_1q_2}{r^2}$	N
In vector form	$\vec{F}_{12} = \frac{kq_1q_2}{r_{21}^3} \vec{r}_{21} = \frac{kq_1q_2}{r_{21}^2} \cdot \hat{r}_{21}$	
Dielectric constant (or relative permittivity)	$K_D = \epsilon_r = \frac{F_0}{F_m} = \frac{\epsilon_m}{\epsilon_0} = \frac{C_m}{C_0}$ $= \frac{\phi_0}{\phi_m} = \frac{E_0}{E_m}$	Unit less
Hence $F_0 \geq F_m$ as free space has minimum permittivity		
Linear charge density	$\lambda = \frac{q}{L}$	Cm^{-1}
Surface charge density	$\sigma = \frac{q}{A}$	Cm^{-2}
Volume charge density	$\rho = \frac{q}{V}$	Cm^{-3}
Electric field due to a point charge	$\vec{E} = \text{Lt}_{q_0 \rightarrow 0} \frac{\vec{F}}{q_0}$ (theoretical) (In numerical, we use $E = \frac{kq_1}{r^2}$)	

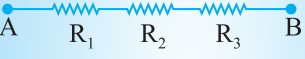
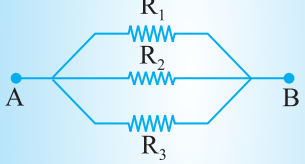


The components of electric field,	$E_x = \frac{1}{4\pi\epsilon_0} \frac{qx}{r^3}, E_y = \frac{1}{4\pi\epsilon_0} \frac{qy}{r^3},$ $E_z = \frac{1}{4\pi\epsilon_0} \frac{qz}{r^3}$	NC ⁻¹
Torque on a dipole in a uniform electric field	$\vec{\tau} = \vec{p} \times \vec{E} \text{ (or } \tau = pE \sin \theta)$	Nm
Electric dipole moment	$\vec{p} = q \cdot (2a) \text{ or } \vec{p} = q(2a)$	Cm
Potential energy of a dipole in a uniform electric field	$U = -\vec{p} \cdot \vec{E} \text{ (or } U = -pE \cos \theta)$	J
Electric field on axial line of an electric dipole	$E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \frac{2pr}{(r^2 - a^2)^2}$ <p>When $2a \ll r$, $E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$</p>	NC ⁻¹
Electric field on equatorial line of an electric dipole	$E_{\text{equatorial}} = \frac{1}{4\pi\epsilon_0} \frac{q2a}{(r^2 + a^2)^{\frac{3}{2}}}$ <p>When $2a \ll r$, $E_{\text{equatorial}} = \frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$</p>	
Electric field as a gradient of potential	$E = -\frac{dV}{dr} \text{ or } \vec{E} \cdot d\vec{r} = -dV$	
Electric potential differences between points A & B	$V_A - V_B = -\frac{W_{AB}}{q_0}$	Volts (or JC ⁻¹)
Electric potential at a point	$V_A = \frac{1}{4\pi\epsilon_0} \frac{q}{r_A} = \frac{W_{A\infty}}{q}$	

Common potential	$V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$	
Electric potential due to a system of charges	$V = \frac{1}{4\pi \epsilon_0} \sum_{i=1}^n \frac{q_i}{r_i}$	
Electric potential at any point due to an electric dipole	$V = \frac{1}{4\pi \epsilon_0} \frac{p \cos \theta}{(r^2 - a^2 \cos^2 \theta)}$ <p>When, $\theta = 0^\circ$ or $\theta = 180^\circ$,</p> $V = \frac{\pm 1}{4\pi \epsilon_0} \frac{p}{(r^2 - a^2)}$ <p>If $r \gg a$, $V = \frac{1}{4\pi \epsilon_0} \frac{p}{r^2}$</p> <p>When, $\theta = 90^\circ$, $V_{\text{equi}} = 0$</p>	
Total electric flux through a closed surface S	$\phi_e = \oint \vec{E} \cdot d\vec{S} = \frac{q_{\text{net}}}{\epsilon_0}$ <p>q_{net} = Net charge enclosed by a \Rightarrow Gaussian surface</p>	Nm^2C^{-1}
Electric field due to line charge	$E = \frac{1}{2\pi \epsilon_0} \frac{\lambda}{r}$	NC^{-1} (or V/m)
Electric field due to an infinite plane sheet of charge	$E = \frac{\sigma}{2\epsilon_0}$	
Electric field between two infinitely charged plane parallel sheets having charge density $+\sigma$ and $-\sigma$	$E = \frac{\sigma}{\epsilon_0}$	
Electric field due to a uniformly charged spherical shell	$E = \frac{\sigma}{\epsilon_0} \frac{R^2}{r^2}$ <p>When $r = R$, $E_0 = \frac{\sigma}{\epsilon_0}$</p> <p>When $r < R$, $E \times 4\pi r^2 = 0$</p> <p>$\therefore E = 0$</p>	

Loss of energy (in Parallel combination of two capacitors)	$\Delta U = \frac{1}{2} \frac{C_1 C_2}{(C_1 + C_2)} (V_1 - V_2)^2$	
Electrical capacitance	$C = \frac{q}{V}$	F(SI Unit)
Capacitance of an isolated sphere	$C_0 = 4\pi\epsilon_0 r$	
Capacitance of a parallel plate	$C = \frac{A\epsilon_0}{d}$	
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	
Capacitors in parallel	$C = C_1 + C_2 + C_3$	
Capacitance of a parallel plate capacitor with dielectric slab between plates	$C = \frac{\epsilon_0 A}{d - t \left(1 - \frac{1}{K_D} \right)}$	
Capacitance of a parallel plate capacitor with conducting slab between plates	$C = \frac{C_0}{\left(1 - \frac{t}{d} \right)}$	
Energy stored in a charged capacitor	$U = \frac{q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} qV$	J
Resultant electric field in a polarised dielectric slab	$\vec{E} = \vec{E}_0 - \vec{E}_p, \text{ where}$	Cm^{-1}
polarization	$\vec{E}_0 = \text{Applied electric field and}$ $\vec{E}_p = \text{Electric field due to}$	
Polarization density	$P = \epsilon_0 \chi E$	$\text{Vm}^{-1} \text{ or } \text{Nc}^{-1}$
Dielectric constant (in terms of electric susceptibility or atomic polarisability)	$K_D = 1 + \chi$ Where K is dielectric Contant	

CURRENT ELECTRICITY

IMPORTANT FORMULA

1. Drift Velocity	$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$	\vec{E} – electric field
2. Relation b/w current and Drift Velocity	$I = neAv_d$	τ = Relaxation time e = charge on electrons. m = mass of electron n = number density of electrons A = Cross Section Area
3. Ohm's Law	$V = RI$	
4. Resistance	$R = \frac{\rho l}{A}$	V = potential difference across conductor l = length of conductor
5. Specific Resistance or Resistivity	$\rho = \frac{RA}{l} = \frac{m}{ne^2\tau}$	
6. Current density	$j = I/A = neV_d$	
7. Electrical Conductivity	$\sigma = 1/\rho$	
8. Resistances in Series	$R_{eq} = R_1 + R_2 + R_3$	
Parallel Combination	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	
9. Temperature Dependence of Resistance	$R_t = R_0 (1 + \alpha t)$	R_t = Resistance at $t^\circ\text{C}$ α = Coefficient of temperature t = Temperature R_0 = Resistance at 0°C
10. Internal Resistance of a cell	$r = \left(\frac{E}{V} - 1\right) R$	
11. Power	$P = VI = I^2R = \frac{V^2}{R}$	
12. Cells in Series	$E_{eq} = E_1 + E_2$	
Equivalent emf	$E_{eq} = E_1 - E_2$	
Equivalent Internal Resistance	$r_{eq} = r_1 + r_2$	E_1 & E_2 are emf of two cells
Mobility (μ)	$\frac{v_d}{E}$	CGS unit $\rightarrow \text{cm}^2\text{s}^{-1}\text{V}^{-1}$ SI unit $\rightarrow \text{m}^2\text{s}^{-1}\text{V}^{-1}$

Equivalent Current	$I = \frac{nE}{R + nr}$	r_1 and r_2 are their internal resistances respectively n = no. of cells in series.
13. Cells in parallel	Equivalent e.m.f. $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ Equivalent resistance $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$	
Equivalent Current	$I = \frac{mE}{mR + r}$	m = number of cells in parallel
14. Kirchoff's Laws	$\Sigma i = 0$ (at a junction) $\Sigma iR = \Sigma E$ or $\Sigma iR = 0$ (in a closed loop)	i = Current R = Resistance
15. Wheatstone Bridge (balanced condition)	$\frac{P}{Q} = \frac{R}{S}$	E = e.m.f. P, Q, R and S are resistances in Ohm in four arms of Wheatstone Bridge.
16. Slide wire Bridge or metre Bridge	$S = \left(\frac{100 - l}{l} \right) R$	
17. Potentiometer		
Comparison of Emf	$\frac{E_1}{E_2} = \frac{l_1}{l_2}$	l_1 and l_2 are balancing lengths on potentiometer wire for cells E_1 and E_2
Internal Resistance	$r = \left(\frac{l_1 - l_2}{l_2} \right) R$ $= \left(\frac{E}{V} - 1 \right) R$	l_1 and l_2 are balancing lengths on potentiometer wire for emf E and Pot. diff. V across R .

UNIT-I & UNIT-II

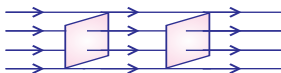
ELECTROSTATICS AND CURRENT ELECTRICITY

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 MARK)

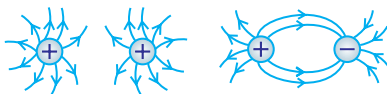
1. Draw schematically an equipotential surface of a uniform electrostatic field along x -axis.

Ans.



2. Sketch field lines due to (i) two equal positive charges near each other (ii) a dipole.

Ans.



3. Name the physical quantity whose SI unit is volt/meter. Is it a scalar or a vector quantity ?

Ans. Electric field intensity. It is a vector quantity.

4. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same distance apart in air ?

Ans. $\epsilon_r = \frac{F_0}{F_m} \Rightarrow F_0 = \epsilon_r F_m \Rightarrow F_0 = 81 F_m$

5. Electric dipole moment of CuSO_4 molecule is 3.2×10^{-28} Cm. Find the separation between copper and sulphate ions.

Ans. $p = q(2a) \Rightarrow \text{Length of dipole } a = \frac{3.2 \times 10^{-28}}{2 \times 1.6 \times 10^{-19}} = 10^{-9} \text{ cm}$

6. Net capacitance of three identical capacitors connected in parallel is 12 microfarad. What will be the net capacitance when two of them are connected in (i) parallel (ii) series ?

Ans. $C_p = 12 \mu\text{f} \Rightarrow C = \frac{12}{3} = 4 \mu\text{F}.$
 $C_p = C_1 + C_2 = 8 \mu\text{F}$

$$C_s = \frac{C_1 C_2}{C_1 + C_2} = \frac{16}{8} = 2\mu\text{F}$$

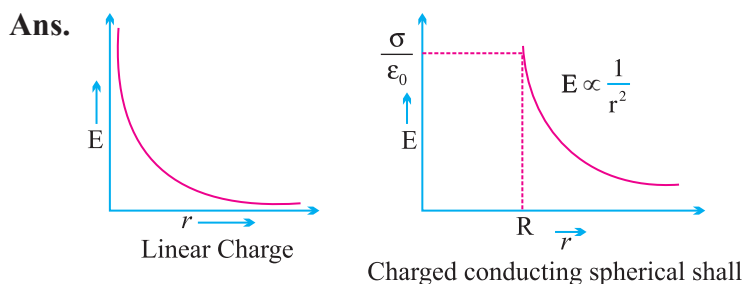
7. A charge q is placed at the centre of an imaginary spherical surface. What will be the electric flux due to this charge through any half of the sphere.

Ans.

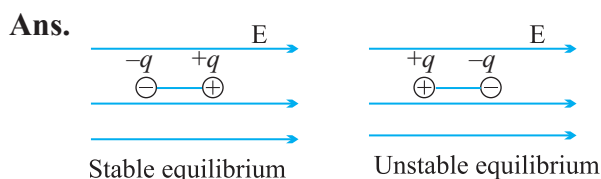
$$\phi = \frac{q}{\epsilon_0}$$

$$\phi' = \frac{\phi}{2} = \frac{q}{2\epsilon_0}$$

8. Draw the electric field vs distance (from the centre) graph for (i) a long charged rod having linear charge density $\lambda > 0$ (ii) spherical shell of radius R and charge $Q > 0$.



9. Diagrammatically represent the position of a dipole in (i) stable (ii) unstable equilibrium when placed in a uniform electric field.



10. A charge Q is distribution over a metal sphere of radius R . What is the electric field and electric potential at the centre ? **Ans.** $E = 0$, $V = kQ/R$

Ans. Electric field inside conductor $E = 0$

$$E = \frac{dV}{dr} = 0 \Rightarrow V = \text{Constant} = \frac{Q}{4\pi\epsilon_0 R} = k \frac{Q}{R}$$

11. If a body contains n_1 electrons and n_2 protons then what is the total charge on the body ?

Ans. $Q = q_1 + q_2 + \dots + q_n$, (Additive property of charge)

$$Q = (n_2 - n_1)e$$

12. What is the total positive or negative charge present in 1 molecule of water.

Ans. H_2O has 10 electrons (2 of hydrogen and 8 of oxygen)

Total charge = $10e$

13. How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in a uniform electric field.

Ans. Work done $= pE (\cos 180^\circ - \cos 0^\circ)$
 $= -2pE$

i.e., energy decreases.

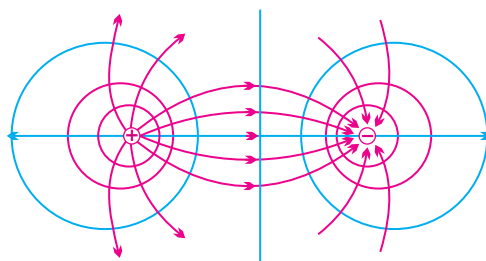
14. Write the ratio of electric field intensity due to a dipole at a point on the equatorial line to the field at a point on the axial line, when the points are at the same distance from the centre of dipole.

Ans. $E_{\text{axial}} = \frac{2kp}{r^3}$ $E_{\text{equatorial}} = \frac{kp}{r^3}$

$\therefore E_{\text{axial}} = 2E_{\text{equatorial}}$

15. Draw equipotential surface for a dipole.

Ans.



16. An uncharged conductor A placed on an insulating stand is brought near a charged insulated conductor B. What happens to the charge and potential of B ?

Ans. Total charge = $0 + q = q$ remains same.

P. D. decreases due to induced charge on A.

17. A point charge Q is placed at point O shown in Fig. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative charge.



Ans. $V_A - V_B > 0$ for $Q > 0$ and $V_A - V_B < 0$ for $Q < 0$

As electric field lines are in the direction of decreasing potential.

18. An electron and proton are released from rest in a uniform electrostatic field. Which of them will have larger acceleration ?

Ans. $\text{acceleration} = \frac{\text{force}}{\text{mass}}, m_p > m_e$
 $a_p < a_e$

19. In an uniform electric field of strength E , a charged particle Q moves point A to point B in the direction of the field and back from B to A. Calculate the ratio of the work done by the electric field in taking the charge particle from A to B and from B to A.

Ans. $\frac{W_{AB}}{W_{BA}} = -1$

$\therefore W_{AB} + W_{BA} = 0$
 $|W_{AB}| = |-W_{BA}|$

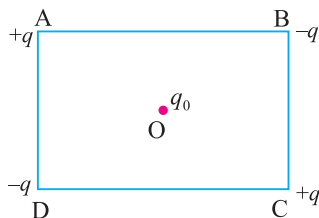
20. If a dipole having charge $\pm 2\mu\text{C}$ is placed inside a sphere of radius 2 m, what is the net flux linked with the sphere.

Ans. $\text{Net flux} = \frac{\text{Net charge}}{\epsilon_0} = \frac{+q - q}{\epsilon_0} = 0$

21. Four charges $+q, -q, +q, -q$ are placed as shown in the figure. What is the work done in bringing a test charge from ∞ to point O.

Here, $OA = OB = OC = OD$

& $q_0 = \text{Test charge}$



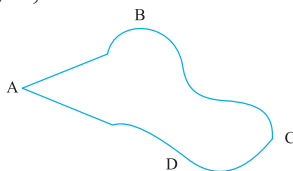
Ans. $V_0 = \frac{kq}{AO} + \frac{kq}{OC} - \frac{kq}{OB} - \frac{kq}{OD} = 0$
 $W = q_0 \times V_0 = 0$

22. Calculate electric flux linked with a sphere of radius 1 m and charge of 1 C at its centre.

Ans. Electric flux linked with the sphere (closed surface)

$$\phi_e = \frac{q}{\epsilon_0} = \frac{1}{\epsilon_0}$$

23. If the metallic conductor shown in the figure is continuously charged from which of the points A, B, C or D does the charge leak first. Justify.



Ans. Charge leaks from A first as surface charge density (σ) at A (sharp ends) is more.

24. What is dielectric strength ? Write the value of dielectric strength of air.

Ans. Maximum electric field which can be safely applied across a dielectric before its break down is called dielectric strength.

Dielectric strength of air = 3×10^6 V/m.

25. Two charges $-q$ and $+q$ are located at points A $(0, 0, -a)$ and B $(0, 0, +a)$. How much work is done in moving a test charge from point $(b, 0, 0)$ to Q $(-b, 0, 0)$?

Ans. $W = \vec{F} \cdot \vec{dr} = q\vec{E} \cdot \vec{dr} = q E dr \cos 90^\circ = 0$

\therefore E along equatorial line of dipole is anti-parallel to dipole moment, hence perpendicular to displacement or $W = 20 \times q_0 \times V_{\text{equatorial}} = q_0 \times 0 = 0$ J.

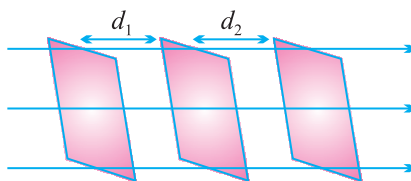
26. If an electron is accelerated by a Potential difference of 1 Volt, Calculate the gain in energy in Joule and electron volt.

Ans. Gain in Energy = $eV = 1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}$ J

or $\Delta KE = 1e \times 1 \text{ volt} = 1.6 \times 10^{-19} \text{ C} \times 1 \text{ volt} = 1.6 \times 10^{-19} \text{ J}$

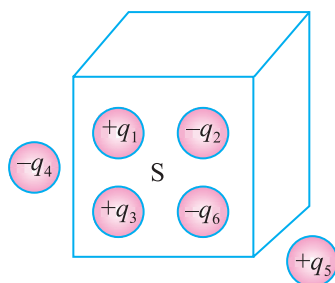
27. Draw schematically the equipotential surface corresponding to a field that uniformly increases in magnitude but remains in a constant (say z) direction.

Ans.



E increases therefore, equipotential surface are closer *i.e.*, $d_1 > d_2$.

28. Figure shows six charged lumps of plastic coin. The cross-section of a Gaussian surface S is indicated. What is the net electric flux through the surface ?



Ans.

$$\phi = \frac{+q_1}{\epsilon_0} - \frac{q_2}{\epsilon_0} + \frac{+q_3}{\epsilon_0} - \frac{q_4}{\epsilon_0}.$$

- 29.** Without referring to the formula $C = \epsilon_0 A/d$. Explain why the capacitance of a parallel plate capacitor reduces on increasing the separation between the plates ?

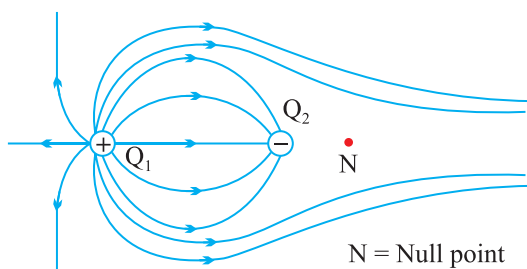
Ans.

$$P. D. = V = E \times d$$

'd' increases hence V increases.

as $C = \frac{Q}{V}$, \therefore C decreases.

- 30.** Draw field lines to show the position of null point for two charges $+Q_1$ and $-Q_2$ when magnitude of $Q_1 > Q_2$ and mark the position of null point.



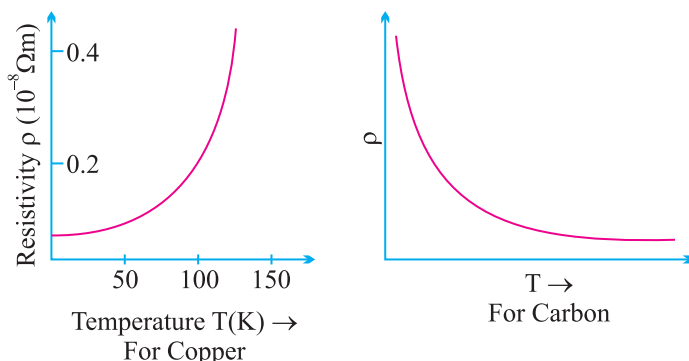
Ans. $|Q_1| > |Q_2|$, N is the neutral point.

- 31.** How does the relaxation time of electron in the conductor change when temperature of the conductor decreases.

Ans. When temperature of the conductor decreases, ionic vibration in the conductor decreases so relaxation time increases.

- 32.** Sketch a graph showing variation of resistivity with temperature of (i) Copper (ii) Carbon.

Ans.



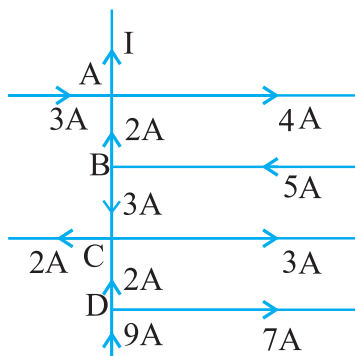
33. The emf of the driver cell (Auxiliary battery) in the potentiometer experiment should be greater than emf of the cell to be determined. Why ?

Ans. If emf of a driver cell is less, then null point will not be obtained on the potentiometer wire.

34. You are required to select a carbon resistor of resistance $47k\Omega \pm 10\%$ from a large collection. What should be the sequence of color bands used to code it ?

Ans. Yellow, Violet, Orange, Silver.

35. Find the value of i in the given circuit :



Ans. On applying Kirchoff current law on junction A, at junction A

$$2 + 3 = I + 4$$

so,

$$I = +1A$$

36. Two wire one of copper and other of manganin have same resistance and equal length. Which wire is thicker ?

Ans. $R = \rho_c \frac{l_c}{A_c} = \rho_m \frac{l_m}{A_m} \Rightarrow \frac{\rho_c}{\rho_m} = \frac{A_c}{A_m} < 1$

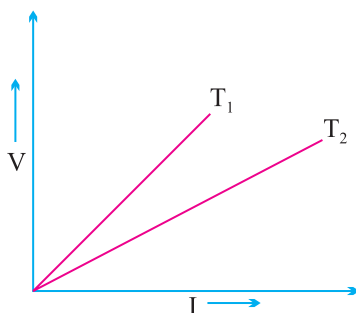
\therefore Manganin is thicker.

37. You are given three constant wires P, Q and R of length and area of cross-section (L, A) , $\left(2L, \frac{A}{2}\right)$, $\left(\frac{L}{2}, 2A\right)$ respectively. Which has highest resistance ?

Ans. $R_P = \rho \frac{L}{A}$, $R_Q = \frac{\rho(2L)}{\frac{A}{2}} = \frac{4\rho L}{A}$
 $\Rightarrow R_R = \frac{\rho L}{4A} \Rightarrow R_Q = 4R_P, R_R = \frac{1}{4}R_P$

Q has the highest resistance,

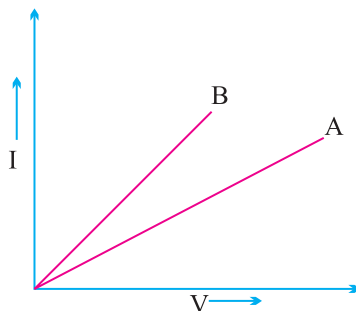
38. V – I graph for a metallic wire at two different temperatures T_1 and T_2 is as shown in the figure. Which of the two temperatures is higher and why ?



- Ans. Slope of T_1 is large, so T_1 represents higher temperature as resistance increases with temperature for a conductor

$$R = \frac{V}{I} = \text{slope}.$$

39. Out of V – I graph for parallel and series combination of two metallic resistors, which one represents parallel combination of resistors ? Justify your answer.



Ans. The resistance for parallel combination is lesser than for series combination for a given set of resistors. Hence B represents parallel combination since $\frac{I}{V}$ is more. Hence Resistance = $\frac{V}{I}$ is less.

40. Why is the potentiometer preferred to a voltmeter for measuring emf of a cell ?

Ans. Emf measured by the potentiometer is more accurate than cell because the cell is in open circuit giving no current.

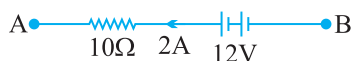
41. How can a given 4 wires potentiometer be made more sensitive ?

Ans. By connecting a resistance in series with the potentiometer wire in the primary circuit, the potential drop across the wire is reduced.

42. Why is copper not used for making potentiometer wires ?

Ans. Copper has high temperature coefficient of resistance and hence not preferred.

43. In the figure, what is the potential difference between A and B ?



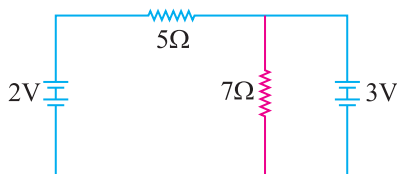
Ans. $V_A - V_B = -8$ volt.

44. A copper wire of resistance R is uniformly stretched till its length is increased to n times its original length. What will be its new resistance ?

Ans. $R' = n^2 R$

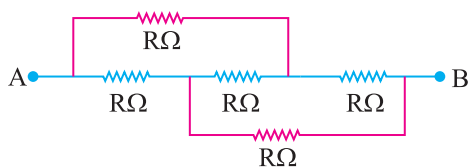
$$\therefore R' = \rho \frac{nL}{A/n} = \rho n^2 \frac{L}{A} = n^2 R$$

45. Two resistance 5Ω and 7Ω are joined as shown to two batteries of emf 2V and 3V. If the 3V battery is short circuited. What will be the current through 5Ω

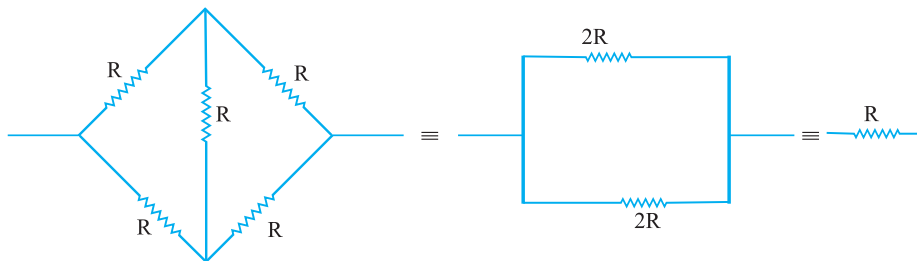


Ans. $I = \frac{2}{5}$ A.

46. Calculate the equivalent resistance between points A and B in the figure given below.



Ans. We obtain using wheatstone bridge balancing condition.



47. What is the largest voltage that can be safely put across a resistor marked 196Ω , 1W ?

Ans. $P = \frac{V^2}{R}$, $V^2 = P R = 1 \times 196 = 196$

$$V = 14 \text{ Volt.}$$

48. When does the terminal voltage of a cell become (i) greater than its emf
(ii) less than its emf ?

Ans. (i) When the cell is being charged terminal potential difference (V) becomes greater than emf (E), $V = E + Ir$

(ii) When the cell is discharged, then $V < E$

$$V = E - I r$$

49. A car battery is of 12V . Eight dry cells of 1.5V connected in series also give 12V , but such a combination is not used to start a car. Why ?

Ans. Dry cell used in series will have high resistance ($= 10\Omega$) and hence provide low current, while a car battery has low internal resistance (0.1Ω) and hence gives high current for the same emf, needed to start the car.

50. Two electric lamps A and B marked 220V , 100W and 220V , 60W respectively. Which of the two lamps has higher resistance ?

Ans. As $R = \frac{V^2}{P}$, 220V , 60W lamp has higher resistance.

51. Resistors of high value are made up of carbon. Why ?

Ans. High resistivity and low temperature Coefficient of resistance.

52. Draw graph showing the variation of electric field & electric potential with distances ' r ' due to a point charge.
53. Net capacitance of three identical capacitors in series is $1\mu\text{F}$. What will be their net capacitance if connected in parallel. Find the ratio of energy stored in two combinations connected across the same battery.
54. Distinguish with the help of a suitable diagram, the difference in the behaviour of conductor and a dielectric substance placed in an external electric field. How does the polarised dielectric modify the external field.
55. A parallel plate capacitor of capacitance C is charged to a potential of V volt. It is then connected across another uncharged capacitor of same capacitance. Find the ratio of initial energy of single capacitor to the final energy combination. **[Ans -2:1]**
56. An infinite large plane thin charged sheet has surface charge density σ . Obtain an expression for work done in carrying a point charge q from infinity to a point at a distance
57. A proton and an alpha particle are accelerated from rest through a potential difference of 100 volt. Find (i) Their KE in eV and Joule (ii) which particle will move faster.
[Ans: (1) 100 eV, 200 eV, $1.6 \times 10^{-17}\text{J}$, $3.2 \times 10^{-17}\text{J}$ (ii) Proton]
58. An electron starting from rest takes 14×10^{-9} sec to reach from one plate to other of a capacitor placed 2 cm apart. If charge to mass ratio of electron is $1.8 \times 10^{11} \text{ C/kg}$. Then find the potential difference between the plates.
[Ans: $V = 2400 \text{ Volt}$]
59. An alpha particle of charge $3.2 \times 10^{-19} \text{ C}$ and mass $6.8 \times 10^{-27} \text{ kg}$ is initially moving at speed 10^7 m/sec when it is at far distance from another fixed point charge $112 \times 10^{-19} \text{ C}$. Find the distance of closest approach.
[Ans: $r = 9.4 \times 10^{-15} \text{ m}$]
60. If the dielectric strength of air is $3 \times 10^6 \text{ V/m}$, what will be the maximum potential at the surface of a metal sphere of radius 1m.
[Ans: $V = 3 \times 10^6 \text{ Volt}$]
61. Two point charges each $+3 \mu\text{C}$ are placed along the diameter of a circle of radius 15 cm. Calculate the electric potential at the ends of perpendicular diameter
[Ans: $V = 2.52 \times 10^5 \text{ Volt}$]
62. An electric dipole of dipole moment $40 \times 10^{-6} \text{ C-m}$ is enclosed by a closed surface. What is the net flux coming out of the surface? **[Ans: zero]**

63. Does the charge given to a metallic sphere depend on whether it is solid or hollow .Give reason.

[Ans: Charge comes on the outer surface only, like charges repel and conductor allows flow of charge]

64. A and B are two conducting spheres of the same radius, A being solid and B hollow. Both have same field on their surface. What will be the relation between the charges on the two spheres? **[Ans: Same]**

65. How does the electric flux due to a point charge enclosed by a spherical gaussian surface is affected ,if radius is increased

[Ans: remains same as it does not depend upon shape and size of Gaussian surface]

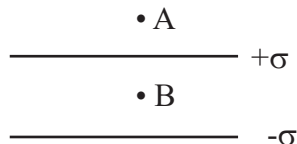
66. How does the Coulomb force between two point charges depend upon the dielectric constant of the intervening medium?

[Ans: It decreases with increasing dielectric constant of medium]

67. The distance of the field point, on the equatorial plane of a small electric dipole, is halved. By what factor will the electric field, due to the dipole, change? **[Ans: As $E \propto 1/r^3$, 8 times]**

68. Two plane sheets of charge densities $+\sigma$ and $-\sigma$ are kept in air as shown in figure.What are the electric field intensities at points A and B?

[Ans: zero, σ/ϵ_0]



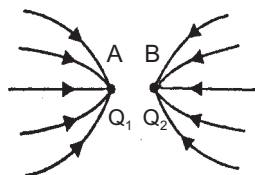
69. Why does the electric field inside a dielectric decrease when it is 'aced in an external electric field?

[Ans: Due to induced field is opposite direction]

70. A charge Q is uniformly distributed over a ring of radius a .Obtain an expression for electric field intensity at a point on the axis of ring. show that at far point ring behaves as a point charge.

71. Figure shows electric lines of force due to two point charges q_1 and q_2 placed at points A and B respectively. Write the nature of charge on them.

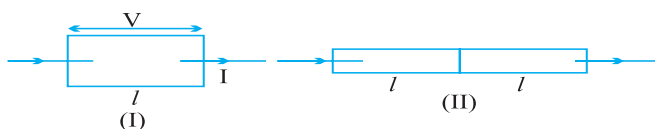
[Ans: $Q_1 < 0$, $Q_2 < 0$]



72. Two point charges q_1 and q_2 are placed close to each other. What is the nature of force between the charges when $q_1 < 0, q_2 > 0$, $q_1 < 0, q_2 < 0$

[Ans: Attractive, repulsive]

73. A metal rod of square cross-section area A having length l has current I flowing through it, when a potential difference of V volt is applied across its ends (figure I). Now the rod is cut parallel to its length in two identical pieces and joined as shown in (figure-II). What potential difference must be maintained across the length $2l$ so that the current in the rod is still remains I ?



Ans.

$$R_1 = \rho \frac{l}{A}$$

$$R_2 = \rho \frac{2l}{A/2} = 4R_1$$

$$I = \frac{V}{R_1} = \frac{V_2}{R_2}$$

$$\frac{V}{R_1} = \frac{V_2}{4R_1}$$

$$V_2 = 4V$$

74. (a) Define torque acting on a dipole moment \vec{p} Placed in a uniform electric field \vec{E} . Express it in the vector form and point out the direction along which it acts.
- (b) What happens if the electric field is non-uniform?
- (c) What would happen if the external field \vec{E} is increasing (i) Parallel to \vec{p} (ii) anti-parallel to \vec{p} ?
75. State the condition under which the terminal potential difference across a battery and its emf are equal.

Ans. When battery is in open circuit *i.e.* when no current is being drawn from the cell. $V_{\text{open}} = \text{emf of cell or battery}$

76. State the condition for maximum current to be drawn from a cell.

Ans. $I = \frac{E}{R + r}$ for I maximum $R = 0$ i.e., for maximum current the terminals of a cell must be short circuited.

SHORT ANSWER QUESTIONS (2 MARKS)

1. An oil drop of mass m carrying charge $-Q$ is to be held stationary in the gravitational field of the earth. What is the magnitude and direction of the electrostatic field required for this purpose ? **Ans.** $E = mg/Q$, downward
2. Draw E and V versus r on the same graph for a point charge.
3. Find position around dipole at which electric potential due to dipole is zero but has non zero electric field intensity.

Ans. Equatorial position, $V = 0$, $\vec{E} = \frac{-1}{4\pi\epsilon_0} \frac{\vec{p}}{r^3}$ ($a \ll r$)

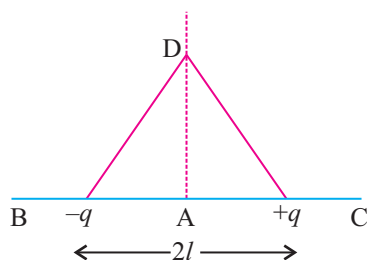
4. Derive an expression for the work done in rotating an electric dipole from its equilibrium position to an angle θ with the uniform electrostatic field.
5. A electrostatic field line can not be discontinuous. Why ?
6. A thin long conductor has linear charge density of $20 \mu\text{C/m}$. Calculate the electric field intensity at a point 5 cm from it. Draw a graph to show variation of electric field intensity with distance from the conductor.

Ans. $72 \times 10^5 \text{ N/C}$

7. What is the ratio of electric field intensity at a point on the equatorial line to the field at a point on axial line when the points are at the same distance from the centre of the dipole ? **Ans.** 1 : 2
8. Show that the electric field intensity at a point can be given as negative of potential gradient.
9. A charged metallic sphere A having charge q_A is brought in contact with an uncharged metallic sphere of same radius and then separated by a distance

d . What is the electrostatic force between them. **Ans.** $\frac{1}{16\pi\epsilon_0} \frac{q_A^2}{d^2}$

10. An electron and a proton travel through equal distances in the same uniform electric field E . Compare their time of travel. (Neglect gravity)
11. Two point charges $-q$ and $+q$ are placed $2l$ metre apart, as shown in Fig. Give the direction of electric field at points A, B, C and D, A is mid point between charges $-q$ and $+q$.



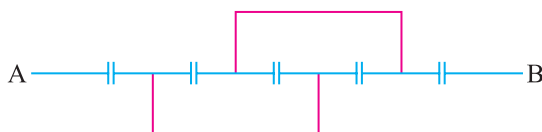
12. The electric potential V at any point in space is given $V = 20x^3$ volt, where x is in meter. Calculate the electric intensity at point $P(1, 0, 2)$.

Ans. 60 NC^{-1}

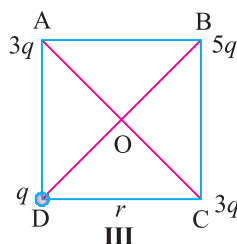
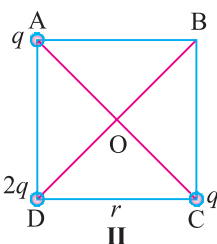
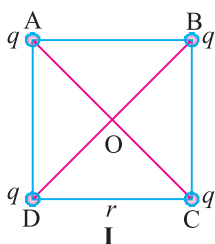
13. Justify why two equipotential surfaces cannot intersect.

14. Find equivalent capacitance between A and B in the combination given below : each capacitor is of $2 \mu\text{F}$.

Ans. $6/7 \mu\text{F}$



15. What is the electric field at O in Figures (i), (ii) and (iii), ABCD is a square of side r .



Ans. (i) Zero, (ii) $\frac{2q}{4\pi\epsilon_0 r^2}$ along OB (iii) $\frac{4q}{4\pi\epsilon_0 r^2}$ along OD

16. What should be the charge on a sphere of radius 4 cm, so that when it is brought in contact with another sphere of radius 2 cm carrying charge of $10 \mu\text{C}$, there is no transfer of charge from one sphere to other ?

Ans. $V_a = V_b$, $Q = 20 \mu\text{C}$.

17. For an isolated parallel plate capacitor of capacitance C and potential difference V , what will be change in (i) charge on the plates (ii) potential difference across the plates (iii) electric field between the plates (iv) energy stored in the capacitor, when the distance between the plates is increased ?

Ans. (i) No change (ii) increases (iii) No change (iv) increases.

- 18.** Does the maximum charge given to a metallic sphere of radius R depend on whether it is hollow or solid ? Give reason for your answer.

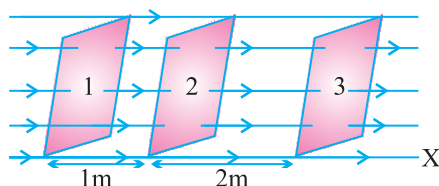
Ans. No, charge resides on the surface of conductor.

- 19.** Two charges Q_1 and Q_2 are separated by distance r . Under what conditions will the electric field be zero on the line joining them (i) between the charges (ii) outside the charge?

Ans. (i) Charge are alike (ii) Unlike charges of unequal magnitude.

- 20.** Obtain an expression for the electric field due to electric dipole at any point on the equatorial line.

- 21.** The electric field component in the figure are $\vec{E}_x = 2x \hat{i}$, $\vec{E}_y = \vec{E}_z = 0$. Calculate the electric flux through, (1, 2, 3) the square surfaces of side 5 m.



- 22.** Calculate the work required to separate two charges $5\mu\text{C}$ and $-2\mu\text{C}$ placed at $(-3\text{ cm}, 0, 0)$ and $(+3\text{ cm}, 0, 0)$ infinitely away from each other.

Ans. 1.5 J

- 23.** What is electric field between the plates with the separation of 2 cm and (i) with air (ii) dielectric medium of dielectric constant K . Electric potential of each plate is marked in the following figure.

_____ 150 V

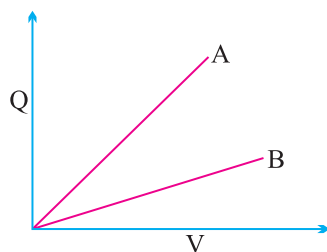
(i) _____ - 50 V

Ans. $E_0 = 10^4 \text{ NC}^{-1}$, $E = \frac{10^4}{k} \text{ NC}^{-1}$

- 24.** A RAM (Random access Memory) chip a storage device like parallel plate capacitor has a capacity of 55pF. If the capacitor is charged to 5.3V, how may excess electrons are on its negative plate ?

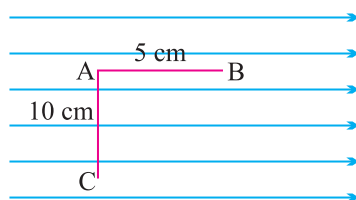
Ans. 1.8×10^9

- 25.** The figure shows the Q (charge) versus V (potential) graph for a combination of two capacitors. identify the graph representing the parallel combination.



Ans. A represents parallel combination

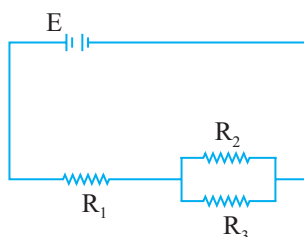
26. Calculate the work done in taking a charge of $1 \mu\text{C}$ in a uniform electric field of 10 N/C from B to C given $AB = 5 \text{ cm}$ along the field and $AC = 10 \text{ cm}$ perpendicular to electric field.



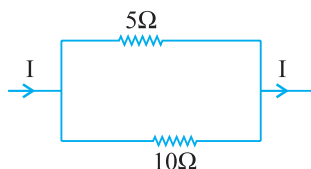
Ans. $W_{AB} = W_{BC} = 50 \times 10^{-8} \text{ J}$. $W_{AC} = 0 \text{ J}$

27. Two charges $-q$ and $+q$ are located at points A $(0, 0, -a)$ and B $(0, 0, +a)$ respectively. How much work is done in moving a test charge from point P $(7, 0, 0)$ to Q $(-3, 0, 0)$? (zero)
28. The potential at a point A is -500 V and that at another point B is $+500 \text{ V}$. What is the work done by external agent to take 2 units (S.I.) of negative charge from B to A. $W_{BA} = 2000 \text{ J}$
29. How does the (i) Potential energy of mutual interaction (ii) net electrostatic P.E. of two charges change when they are placed in an external electric field.
30. With the help of an example, show that Farad is a very large unit of capacitance.
31. What is meant by dielectric polarisation ? Why does the electric field inside a dielectric decreases when it is placed in an external field ?
32. In charging a capacitor of capacitance C by a source of emf V , energy supplied by the sources QV and the energy stored in the capacitor is $\frac{1}{2}QV$. Justify the difference.
33. An electric dipole of dipole moment p , is held perpendicular to an electric field. If the dipole is released does it have (a) only rotational motion

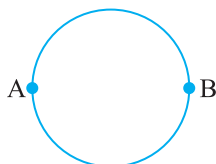
- (b) only translatory motion (c) both translatory and rotatory motion explain?
34. The net charge of a system is zero. Will the electric field intensity due to this system also be zero.
35. A point charge Q is kept at the intersection of (i) face diagonals (ii) diagonals of a cube of side a . What is the electric flux linked with the cube in (i) & (ii) ?
36. There are two large parallel metallic plates S_1 and S_2 carrying surface charge densities σ_1 and σ_2 respectively ($\sigma_1 > \sigma_2$) placed at a distance d apart in vacuum. Find the work done by the electric field in moving a point charge q a distance a ($a < d$) from S_1 and S_2 along a line making an angle $\pi/4$ with the normal to the plates.
37. Define mobility of electron in a conductor. How does electron mobility change when (i) temperature of conductor is decreased (ii) Applied potential difference is doubled at constant temperature ?
38. On what factor does potential gradient of a potentiometer wire depend ?
39. What are superconductors ? Give one of their applications.
40. Two copper wires with their lengths in the ratio 1 : 2 and resistances in the ratio 1 : 2 are connected (i) in series (ii) in parallel with a battery. What will be the ratio of drift velocities of free electrons in two wires in (i) and (ii) ? **Ans.** (1 : 1, 2 : 1)
41. The current through a wire depends on time as $i = i_0 + at$ where $i_0 = 4\text{A}$ and $a = 2\text{As}^{-1}$. Find the charge crossing a section of wire in 10 seconds.
42. Three identical resistors R_1 , R_2 and R_3 are connected to a battery as shown in the figure. What will be the ratio of voltages across R_1 and R_2 . Support your answer with calculations. (2 : 1)



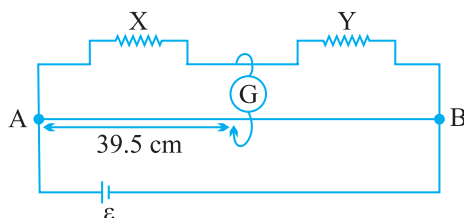
43. In the arrangement of resistors shown, what fraction of current I will pass through 5Ω resistor ? $\left(\frac{2I}{3}\right)$



44. A 100W and a 200 W domestic bulbs joined in series are connected to the mains. Which bulb will glow more brightly ? Justify. (100W)
45. A 100W and a 200 W domestic bulbs joined in parallel are connected to the mains. Which bulb will glow more brightly ? Justify. (200W)
46. A battery has an emf of 12V and an internal resistance of 2Ω . Calculate the potential difference between the terminal of cell if (a) current is drawn from the battery (b) battery is charged by an external source.
47. A uniform wire of resistance R ohm is bent into a circular loop as shown in the figure. Compute effective resistance between diametrically opposite points A and B. [Ans. $R/4$]



48. In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 63 cm. What is the emf of the second cell ? [Ans. 2.25V]
49. In a meter bridge, the balance point is found to be 39.5 cm from end A. The known resistance Y is 12.5Ω . Determine unknown resistance X . [Ans. 8.16Ω]



50. A meterbridge is in balance condition. Now if galvanometer and cell are interchanged, the galvanometer shows no deflection. Give reason. [Ans. Galvanometer will show no deflection. Proportionality of the arms are retained as the galvanometer and cell are interchanged.]

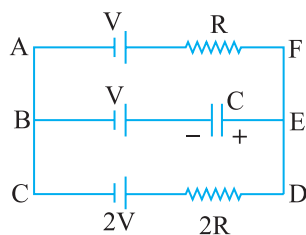
51. If the emf of the driving cell be decreased. What will be effect on the position of zero deflection in a potentiometer.
52. Why should the area of cross section of the meter bridge wire be uniform ? Explain.
53. Given any two limitations of Ohm's law.
54. Which one of the two, an ammeter or a milliammeter has a higher resistance and why ?
55. Name two factors on which the resistivity of a given material depends ? A carbon resistor has a value of $62\text{k}\Omega$ with a tolerance of 5%. Give the colour code for the resistor.
56. If the electron drift speed is so small ($\sim 10^{-3} \text{ m/s}$) and the electron's charge is very small, how can we still obtain a large amount of current in a conductor.
57. A battery of emf 2.0 volts and internal resistance 0.1Ω is being charged with a current of 5.0 A. What is the potential difference between the terminals of the battery ?



58. Why should the jockey be not rubbed against potentiometer wire ?
59. What is meant by the sensitivity of a potentiometer of any given length ?
60. Five identical cells, each of emf E and internal resistance r , are connected in series to form (a) an open (b) closed circuit. If an ideal voltmeter is connected across three cells, what will be its reading ?

[Ans. (a) $3E$; (b) zero]

61. An electron in a hydrogen atom is considered to be revolving around a proton with a velocity $\frac{e^2}{n}$ in a circular orbit of radius $\frac{n^2}{me^2}$. If I is the equivalent current, express it in terms of m , e , n .
62. In the given circuit, with steady current, calculate the potential drop across the capacitor in terms of V .



63. A cell of e.m.f. 'E' and internal resistance ' r ' is connected across a variable resistor 'R'. Plot a graph showing the variation of terminal potential 'V' with resistance 'R'. Predict from the graph the condition under which 'V' becomes equal to 'E'.

64. Winding of rheostat wire are quite close to each other why do not they get short circuited ?

Ans. The wire has a coating of insulating oxide over it which insulate the winding from each other.

65. Why is it necessary to obtain the balance point in the middle of bridge wire ? Explain.

66. What are the possible cause of one side deflection in Galvanometer while performing potentiometer experiment ?

Ans. (i) Either +ve terminals of all the cells are not connected to same end of potentiometer.

or

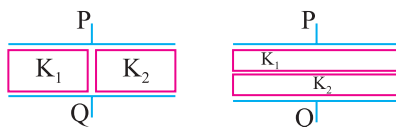
(ii) The total potential drop across wire is less than the emf to be measured.

SHORT ANSWER QUESTIONS (3 MARKS)

1. Define electrostatic potential and its unit. Obtain expression for electrostatic potential at a point P in the field due to a point charge.
2. Calculate the electrostatic potential energy for a system of three point charges placed at the corners of an equilateral triangle of side ' a '.
3. What is polarization of charge ? With the help of a diagram show why the electric field between the plates of capacitor reduces on introducing a dielectric slab. Define dielectric constant on the basis of these fields.
4. Using Gauss's theorem in electrostatics, deduce an expression for electric field intensity due to a charged spherical shell at a point (i) inside (ii) on

its surface (iii) outside it. Graphically show the variation of electric field intensity with distance from the centre of shell.

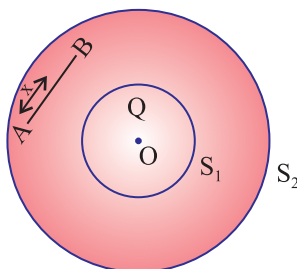
- Three capacitors are connected first in series and then in parallel. Find the equivalent capacitance for each type of combination.
- A charge Q is distributed over two concentric hollow sphere of radii r and R ($R > r$), such that their surface density of charges are equal. Find Potential at the common centre.
- Derive an expression for the energy density of a parallel plate capacitor.
- You are given an air filled parallel plate capacitor. Two slabs of dielectric constants K_1 and K_2 having been filled in between the two plates of the capacitor as shown in Fig. What will be the capacitance of the capacitor if initial area was A distance between plates d ?



Ans. $C_1 = (K_1 + K_2)C_0$

$$C_2 = \frac{K_1 K_2 C_0}{(K_1 + K_2)}$$

- In the figure shown, calculate the total flux of the electrostatic field through the sphere S_1 and S_2 . The wire AB shown of length l has a linear charge density λ given $\lambda = kx$ where x is the distance measured along the wire from end A.



Ans. Total charge on wire AB = $Q = \int_0^l \lambda dx = \int_0^l kx dx = \frac{1}{2}kl^2$

By Gauss's theorem.

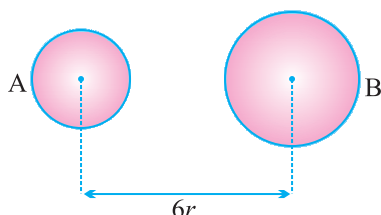
$$\text{Total flux through } S_1 = \frac{Q}{\epsilon_0}$$

$$\text{Total flux through } S_2 = \frac{Q + \frac{1}{2}kl^2}{\epsilon_0}$$

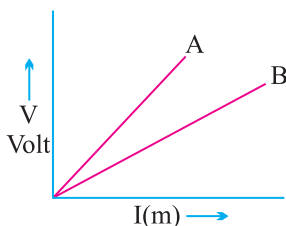
10. Explain why charge given to a hollow conductor is transferred immediately to outer surface of the conductor.
11. Derive an expression for total work done in rotating an electric dipole through an angle θ in an uniform electric field. Hence calculate the potential energy of the dipole.
12. Define electric flux. Write its SI unit. An electric flux of ϕ units passes normally through a spherical Gaussian surface of radius r , due to point charge placed at the centre.
 - (1) What is the charge enclosed by Gaussian surface ?
 - (2) If radius of Gaussian surface is doubled, what will be the flux through it ?
13. A conducting slab of thickness ' t ' is introduced between the plates of a parallel plate capacitor, separated by a distance d ($t < d$). Derive an expression for the capacitance of the capacitor. What will be its capacitance when $t = d$?
14. If a dielectric slab is introduced between the plates of a parallel plate capacitor after the battery is disconnected, then how do the following quantities change.
 - (i) Charge
 - (ii) Potential
 - (iii) Capacitance
 - (iv) Energy.
15. What is an equipotential surface ? Write three properties Sketch equipotential surfaces of
 - (i) Isolated point charge
 - (ii) Uniform electric field
 - (iii) Dipole
16. If charge Q is given to a parallel plate capacitor and E is the electric field between the plates of the capacitor the force on each plate is $1/2 QE$ and

if charge Q is placed between the plates experiences a force equal to QE .
Give reason to explain the above.

17. Two metal spheres A and B of radius r and $2r$ whose centres are separated by a distance of $6r$ are given charge Q , are at potential V_1 and V_2 . Find the ratio of V_1/V_2 . These spheres are connected to each other with the help of a connecting wire keeping the separation unchanged, what is the amount of charge that will flow through the wire ?

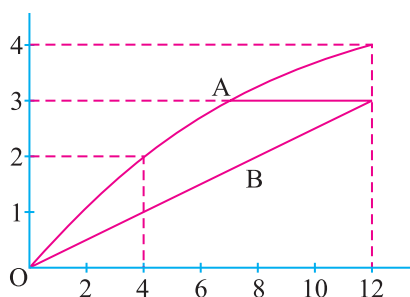


18. Define specific resistance. Write its SI unit. Derive an expression for resistivity of a wire in terms of its material's parameters, number density of free electrons and relaxation time.
19. A potential difference V is applied across a conductor of length L and diameter D . How are the electric field E and the resistance R of the conductor affected when (i) V is halved (ii) L is halved (iii) D is doubled. Justify your answer.
20. Define drift velocity. A conductor of length L is connected to a dc source of emf E . If the length of conductor is tripled by stretching it, keeping E constant, explain how do the following factors would vary in the conductor ?
(i) Drift speed of electrons (ii) Resistance and (iii) Resistivity
21. Define potential gradient. How can potential gradient of a potentiometers be determined experimentally. In the graph shown here, a plot of potential drop versus length of the potentiometer is made for two potentiometers. Which is more sensitive – A or B ?



22. Define conductivity of a substance. Give its SI units. How does it vary with temperature for (i) Copper (ii) Silicon ?
23. Two cells of emf E_1 and E_2 having internal resistance r_1 and r_2 are connected in parallel. Calculate E_{eq} and r_{eq} for the combination.
24. The graph A and B shows how the current varies with applied potential difference across a filament lamp and nichrome wire respectively. Using the graph, find the ratio of the values of the resistance of filament lamp to the nichrome wire

(i) when potential difference across them is 12 V.



- (ii) when potential difference across them is 4V. Give reason for the change in ratio of resistance in (i) and (ii).
25. Electron drift speed is estimated to be only a few mm/s for currents in the range of few amperes ? How then is current established almost the instant a circuit is closed.
26. Give three differences between e.m.f. and terminal potential difference of a cell.
27. Define the terms resistivity and conductivity and state their S. I. units. Draw a graph showing the variation of resistivity with temperature for a typical semiconductor.
28. The current flowing through a conductor is 2mA at 50V and 3mA at 60V. Is it an ohmic or non-ohmic conductor ? Give reason.
29. Nichrome and copper wires of same length and area of cross section are connected in series, current is passed through them why does the nichrome wire get heated first ?

30. Under what conditions is the heat produced in an electric circuit :

(i) directly proportional

(ii) inversely proportional to the resistance of the circuit.

LONG ANSWER QUESTIONS (5 MARKS)

1. Two charged capacitors are connected by a conducting wire. Calculate common potential of capacitors (ii) ratio of their charges at common potential. Show that energy is lost in this process.
2. Derive an expression for the strength of electric field intensity at a point on the axis of a uniformly charged circular coil of radius R carrying charge Q .
3. Derive an expression for potential at any point distant r from the centre O of dipole making an angle θ with the dipole.
4. Suppose that three points are set at equal distance $r = 90$ cm from the centre of a dipole, point A and B are on either side of the dipole on the axis (A closer to +ve charge and B closer to negative charge) point C which is on the perpendicular bisector through the line joining the charges. What would be the electric potential due to the dipole of dipole moment 3.6×10^{-19} Cm at points A , B and C ?
5. Derive an expression for capacitance of parallel plate capacitor with dielectric slab of thickness $t(t < d)$ between the plates separated by distance d . How would the following (i) energy (ii) charge, (iii) potential be affected (a) if dielectric slab is introduced with battery disconnected, (b) dielectric slab is introduced after the battery is connected.
6. Derive an expression for torque experienced by dipole placed in uniform electric field. Hence define electric dipole moment.
7. State Gauss's theorem. Derive an expression for the electric field due to a charged plane sheet. Find the potential difference between the plates of a parallel plate capacitor having surface density of charge 5×10^{-8} Cm⁻² with the separation between plates being 4 mm.
8. Define current density. Give its SI unit. Whether it is vector or scalar ? How does it vary when (i) potential difference across wire increases (ii) length of wire increases (iii) temperature of wire increases (iv) Area of cross-section of wire increases justify your answer.

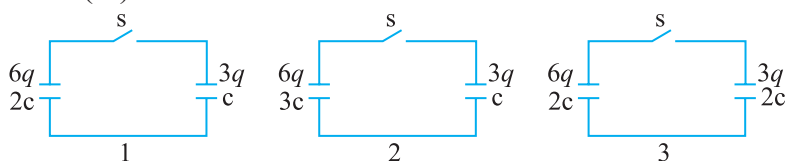
9. Using Gauss's theorem obtain an expression for electric field intensity due to a plane sheet of charge. Hence obtain expression for electric field intensity in a parallel plate capacitor.
10. Write any four important results regarding electro statics of conductors.
11. State Kirchhoffs's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance. How is it realized in actual practice in the laboratory ? Write the formula used.
12. Define emf and terminal potential difference of a cell. When is the terminal charging potential difference greater than emf ? Explain how emf and terminal potential difference can be compared using a potentiometer and hence determine internal resistance of the cell.
13. For three cells of emf E_1 , E_2 and E_3 with internal resistance r_1 , r_2 , r_3 respectively connected in parallel, obtain an expression for net internal resistance and effective current. What would be the maximum current possible if the emf of each cell is E and internal resistance is r each ?
14. Derive an expression for drift velocity of the electron in conductor. Hence deduce ohm's law.
15. State the principle of potentiometer. How can it be used to :
 - (i) Compare e.m.f. of two cells
 - (ii) Measure internal resistance of a cell ?
16. Explain how does the conductivity of a :
 - (i) Metallic conductor
 - (ii) Semi conductor and
 - (iii) Insulator varies with the rise of temperature.
17. Derive expression for equivalent e.m.f. and equivalent resistance of a :
 - (a) Series combination
 - (b) Parallel combination
 of three cells with e.m.f. E_1 , E_2 , E_3 & internal resistances r_1 , r_2 , r_3 respectively.

18. Deduce the condition for balance in a Wheatstone bridge. Using the principle of Wheatstone bridge, describe the method to determine the specific resistance of a wire in the laboratory. Draw the circuit diagram and write the formula used. Write any two important precautions you would observe while performing the experiment.

NUMERICALS

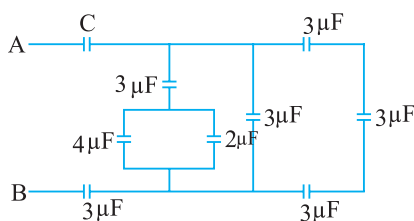
1. What should be the position of charge $q = 5\mu\text{C}$ for it to be in equilibrium on the line joining two charges $q_1 = -4\mu\text{C}$ and $q_2 = 16\mu\text{C}$ separated by 9 cm. Will the position change for any other value of charge q ? (9 cm from $-4\mu\text{C}$)
2. Two point charges $4e$ and e each, at a separation r in air, exert force of magnitude F . They are immersed in a medium of dielectric constant 16. What should be the separation between the charges so that the force between them remains unchanged. (1/4 the original separation)
3. Two capacitors of capacitance $10\mu\text{F}$ and $20\mu\text{F}$ are connected in series with a 6V battery. If E is the energy stored in $20\mu\text{F}$ capacitor what will be the total energy supplied by the battery in terms of E . (6E)
4. Two point charges $6\mu\text{C}$ and $2\mu\text{C}$ are separated by 3 cm in free space. Calculate the work done in separating them to infinity. (3.6 joule)
5. ABC is an equilateral triangle of side 10 cm. D is the mid point of BC charge $100\mu\text{C}$, $-100\mu\text{C}$ and $75\mu\text{C}$ are placed at B, C and D respectively. What is the force experienced by a $1\mu\text{C}$ positive charge placed at A?
($90\sqrt{2} \times 10^3 \text{ N}$)
6. A point charge of $2\mu\text{C}$ is kept fixed at the origin. Another point charge of $4\mu\text{C}$ is brought from a far point to a distance of 50 cm from origin. (a) Calculate the electrostatic potential energy of the two charge system. Another charge of $11\mu\text{C}$ is brought to a point 100 cm from each of the two charges. What is the work done? (a) $144 \times 10^{-3} \text{ J}$
7. A 5 MeV α particle is projected towards a stationary nucleus of atomic number 40. Calculate distance of closest approach. ($1.1 \times 10^{-4} \text{ m}$)

8. To what potential must a insulated sphere of radius 10 cm be charged so that the surface density of charge is equal to $1 \mu\text{C}/\text{m}^2$. ($1.13 \times 10^4 \text{V}$)
9. A slab of material of dielectric constant K has the same area as the plates of parallel plate capacitor but its thickness is $\frac{3d}{4}$, where d is separation between plates, How does the capacitance change when the slab is inserted between the plates ?
10. A point charge develops an electric field of 40 N/C and a potential difference of 10 J/C at a point. Calculate the magnitude of the charge and the distance from the point charge. ($2.9 \times 10^{-10} \text{ C}$, 25 cm)
11. Figure shows three circuits, each consisting of a switch and two capacitors initially charged as indicated. After the switch has been closed, in which circuit (if any) will the charges on the left hand capacitor (i) increase (ii) decrease (iii) remain same ?



(1 remains unchanged, 2 increases, 3 decreases).

12. For what value of C does the equivalent capacitance between A and B is $1 \mu\text{F}$ in the given circuit.



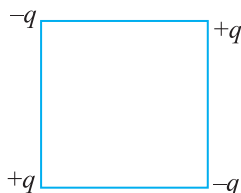
All capacitance given in micro farad

Ans. $2 \mu\text{F}$

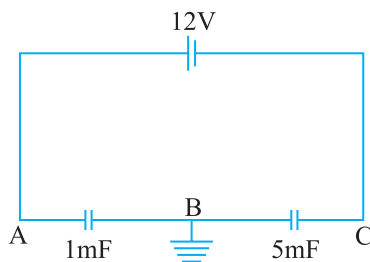
13. A pendulum bob of mass 80 mg and carrying charge of $3 \times 10^{-8} \text{ C}$ is placed in an horizontal electric field. It comes to equilibrium position at an angle of 37° with the vertical. Calculate the intensity of electric field. ($g = 10 \text{ m/s}^2$) ($2 \times 10^4 \text{ N/C}$)
14. Eight charged water droplets each of radius 1 mm and charge $10 \times 10^{-10} \text{ C}$ coalesce to form a single drop. Calculate the potential of the bigger drop. (3600 V)

15. What potential difference must be applied to produce an electric field that can accelerate an electron to $1/10$ of velocity of light. (2.6×10^3 V)
16. A $10 \mu\text{F}$ capacitor can withstand a maximum voltage of 100 V across it, whereas another $20 \mu\text{F}$ capacitor can withstand a maximum voltage of only 25 V. What is the maximum voltage that can be put across their series combination ?
17. Three concentric spherical metallic shells $A < B < C$ of radii a, b, c ($a < b < c$) have surface densities $\sigma, -\sigma$ and σ respectively. Find the potential of three shells A, B and C (ii). If shells A and C are at the same potential obtain relation between a, b, c .
18. Four point charges are placed at the corners of the square of edge a as shown in the figure. Find the work done in disassembling the system of charges.

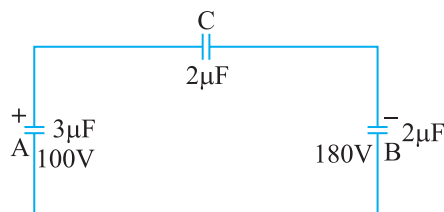
$$\left[\frac{kq^2}{a} (\sqrt{2} - 4) \right] \text{ J}$$



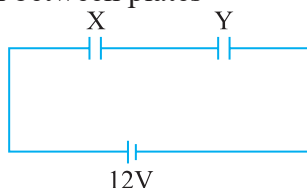
19. Find the potential at A and C in the following circuit :



20. Two capacitors A and B with capacitances $3 \mu\text{F}$ and $2 \mu\text{F}$ are charged 100 V and 180 V respectively. The capacitors are connected as shown in the diagram with the uncharged capacitor C. Calculate the (i) final charge on the three capacitors (ii) amount of electrostatic energy stored in the system before and after the completion of the circuit.



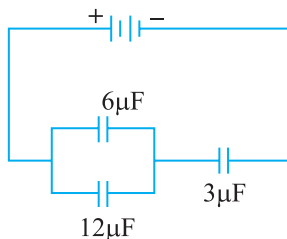
21. Fig. shows two parallel plate capacitors X and Y having same area of plates and same separation between them : X has air while Y has dielectric of constant 4 as medium between plates



- (a) calculate capacitance of each capacitor, if equivalent capacitance of combination is $4\mu\text{F}$ (b) calculate potential difference between plate X and Y (c) what is the ratio of electrostatic energy stored in X & Y.

Ans. (a) $5\mu\text{F}$, $20\mu\text{F}$, (b) 9.6V , 2.4V (c) 4

22.



In the following arrangement of capacitors, the energy stored in the $6\mu\text{F}$ capacitor is E.

Find :

- Energy stored in $12\mu\text{F}$ capacitors.
- Energy stored in $3\mu\text{F}$ capacitor.
- Total energy drawn from the battery.

Ans. (i) $E = \frac{1}{2} CV^2 = \frac{6}{2} \times 10^{-6} V^2 = 3 \times 10^{-6} V^2$

$$V^2 = \frac{E}{3 \times 10^{-6}}$$

$$\text{Energy stored in } 12\mu\text{F capacitor} = \frac{1}{2} CV^2$$

$$= \frac{1}{2} \times 12 \times 10^{-6} \times \frac{E}{3 \times 10^{-7}}$$

$$= 2E$$

(ii) Charge on $6\mu\text{F}$ capacitor

$$Q_1 = \sqrt{2EC}$$

$$= 2\sqrt{3} E \times 10^{-3} \text{ C}$$

$$\left[\because E = \frac{1}{2} \frac{Q^2}{C} \right]$$

Charge on $12\mu\text{F}$ capacitor

$$Q_2 = 2\sqrt{2CE}$$

$$= \sqrt{2 \times 12 \times 10^{-6} \times 2E}$$

$$= 4\sqrt{3} E \times 10^{-3} \text{ C}$$

Charge on $3\mu\text{F}$ capacitor $Q = Q_1 + Q_2$

$$= 6\sqrt{3} E \times 10^{-3}$$

Energy stored in $3\mu\text{F}$ capacitor

$$= \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} \times \frac{36 \times 3E \times 10^{-6}}{3 \times 10^{-6}}$$

$$= 18E$$

(ii) Capacitance of parallel combination = $18\mu\text{F}$

Charge on parallel combination $Q = CV$

$$= 18 \times 10^{-6} \text{ V}$$

Charge on $3\mu\text{F}$ = $Q = 3 \times 10^{-6} V_1$

$$18 \times 10^{-6} \text{ V} = 3 \times 10^{-6} V_1$$

$$V_1 = 6\text{V}$$

Energy stored in $3\mu\text{F}$ capacitor = $\frac{1}{2} CV_1^2$

$$= \frac{1}{2} \times 3 \times 10^{-6} \times \frac{E \times 36}{3 \times 10^{-6}}$$

$$= 18E$$

(iii) Total eEnergy drawn = $E + 2E + 18E = 21E$

- 23.** The charge passing through a conductor is a function of time and is given as $q = 2t^2 - 4t + 3$ milli coulomb. Calculate (i) current through the conductor (ii) potential difference across it at $t = 4$ second. Given resistance of conductor is 4 ohm.

Ans. $I = 12\text{A}$, $V = 48\text{V}$

24. The resistance of a platinum wire at a point 0°C is $5.00\ \Omega$ and its resistance at steam point is $5.40\ \Omega$. When the wire is immersed in a hot oil bath, the resistance becomes $5.80\ \Omega$. Calculate the temperature of the oil bath and temperature coefficient of resistance of platinum.

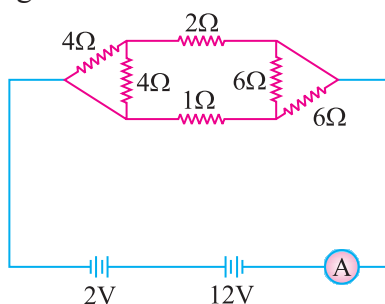
Ans. $\alpha = 0.004^{\circ}\text{C}$; $T = 200^{\circ}\text{C}$

25. Three identical cells, each of emf 2V and internal resistance $0.2\ \Omega$, are connected in series to an external resistor of $7.4\ \Omega$. Calculate the current in the circuit and the terminal potential difference across an equivalent.

Ans. $I = 0.75$; $V = 5.55\text{V}$

26. Calculate the equivalent resistance and current shown by the ammeter in the circuit diagram given.

Ans. $R = 2\ \Omega$; $I = 5\text{A}$



27. A storage battery of emf 12V and internal resistance of $1.5\ \Omega$ is being charged by a 12V supply. How much resistance is to be put in series for charging the battery safely, by maintaining a constant charging current of 6A .

Ans. $R = 16.5\ \Omega$

28. Three cells are connected in parallel, with their like poles connected together, with wires of negligible resistance. If the emf of the cell are 2V , 1V and 4V and if their internal resistance are $4\ \Omega$, $3\ \Omega$ and $2\ \Omega$ respectively, find the current through each cell. $\left[\text{Ans. } I_1 = \frac{-2}{13}\text{A}, I_2 = \frac{-7}{13}\text{A}, I_3 = \frac{9}{13}\text{A} \right]$

29. A $16\ \Omega$ resistance wire is bent to form a square. A source of emf 9V is connected across one of its sides. Calculate the potential difference across any one of its diagonals.

Ans. 1V

30. A length of uniform 'heating wire' made of nichrome has a resistance $72\ \Omega$. At what rate is the energy dissipated if a potential difference of 120V is applied across (a) full length of wire (b) half the length of wire (wire is cut into two). Why is it not advisable to use the half length of wire ?

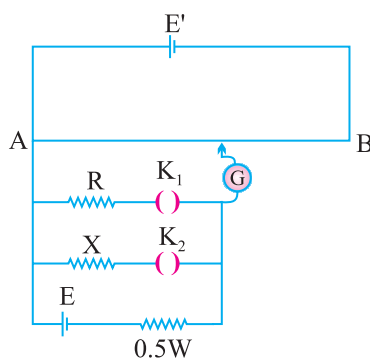
Ans. (a) 200W , (b) 400W , $400\text{W} \gg 200\text{W}$ but since current becomes large so it is not advisable to use half the length

31. With a certain unknown resistance X in the left gap and a resistance of $8\ \Omega$ in the right gap, null point is obtained on the metre bridge wire. On putting another $8\ \Omega$ in parallel with $8\ \Omega$ resistance in the right gap, the null point is found to shift by 15 cm . Find the value of X from these observations.

Ans. $8/3\ \Omega$

32. Figure show a potentiometer circuit for comparison of two resistances. The balance point with a standard resistance $R = 10\ \Omega$ is found to be 160 cm . While that with the unknown resistance X is 134.4 cm . Determine the value of X .

[Ans. $2\ \Omega$]



33. In a potentiometer, a standard cell of emf 5V of negligible internal resistance maintains a steady current through Potentiometer wire of length 5m . Two primary cells of emf E_1 and E_2 are joined in series with (i) same polarity (ii) opposite polarity. The balancing point are found at length 350 cm and 50 cm in two cases respectively.

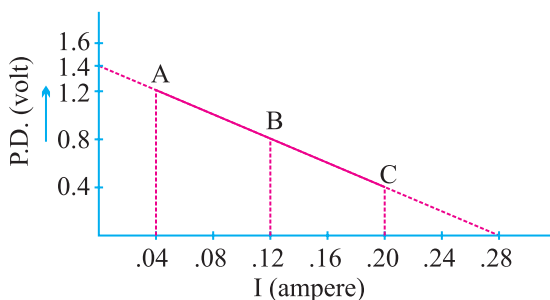
(i) Draw necessary circuit diagram

(ii) Find the value of emf E_1 and E_2 of the two cells (if $E_1 > E_2$)

Ans. $E_1 = 2\text{V}$, $E_2 = 1.5\text{V}$

34. Potential difference across terminals of a cell are measured (in volt) against different current (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph. Determine (i) the emf. (ii) The internal resistance of the cell.

Ans. $r = 5\Omega$ emf = 1.4V

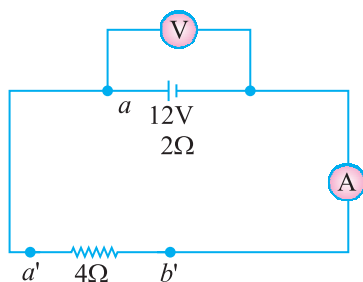


35. Four cells each of internal resistance 0.8Ω and emf 1.4V, d are connected (i) in series (ii) in parallel. The terminals of the battery are joined to the lamp of resistance 10Ω . Find the current through the lamp and each cell in both the cases.

Ans. $I_s = 0.424\text{A}$, $I_p = 0.137\text{A}$ current through each cell is 0.03A

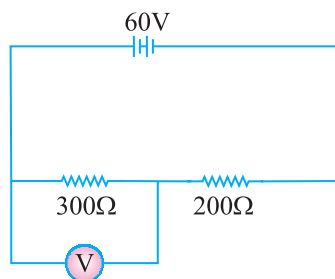
36. In the figure, an ammeter A and a resistor of resistance $R = 4\Omega$ have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω . Calculate voltmeter and ammeter reading.

Ans. Voltmeter reading : 8V, Ammeter reading = 2A

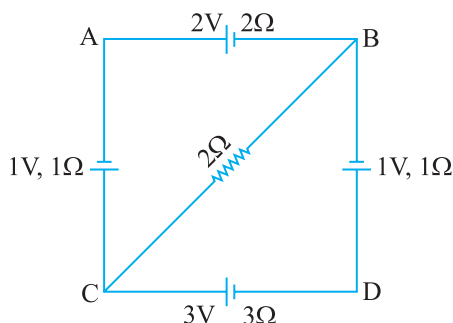


37. In the circuit shown, the reading of voltmeter is 20V. Calculate resistance of voltmeter. What will be the reading of voltmeter if this is put across 200Ω resistance ?

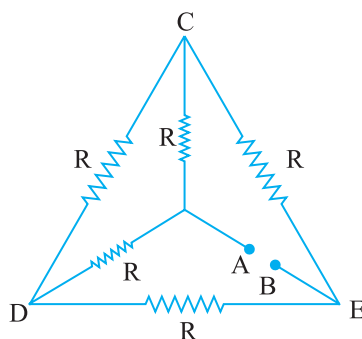
Ans. $R_v = 150\Omega$, $V = \frac{40}{3}\text{V}$



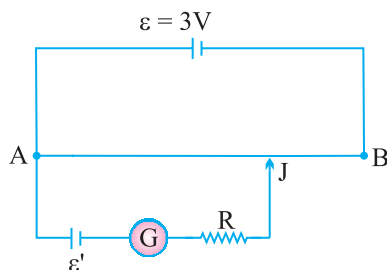
38. For the circuit given below, find the potential difference b/w points B and D. **Ans. 1.46 Volts**



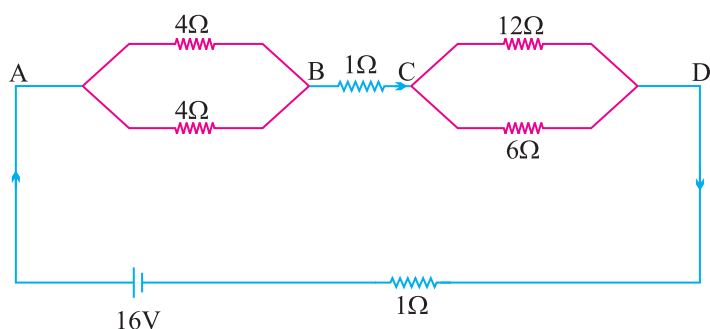
39. (i) Calculate Equivalent Resistance of the given electrical network *b/w* points A and B.
 (ii) Also calculate the current through CD & ACB if a 10V d.c. source is connected *b/w* points A and B and the value of $R = 2\Omega$.



40. A potentiometer wire AB of length 1m is connected to a driver cell of emf 3V as shown in figure. When a cell of emf 1.5V is used in the secondary circuit, the balance point is found to be 60 cm. On replacing this cell by a cell of unknown emf, the balance point shifts to 80 cm. :

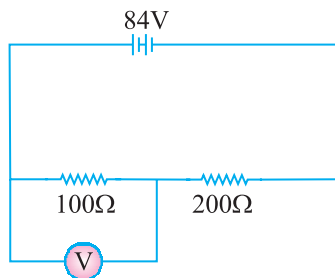


- (i) Calculate unknown emf of ε' the cell.
 - (ii) Explain with reason, whether the circuit works if the driver cell is replaced with another a cell of emf IV.
 - (iii) Does the high resistance R, used in the secondary circuit affect the balance point ? Justify your answer.
41. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?
42. A network of resistance is connected to a 16V battery with internal resistance of 1Ω as shown in Fig. on next page.
- (i) Compute the equivalent resistance of the network.
 - (ii) Obtain the current in each resistor.
 - (iii) Obtain the voltage drop V_{AB} , V_{BC} & V_{CD} .

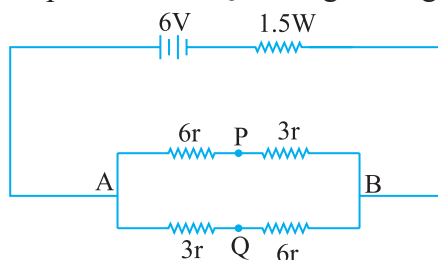


43. The number density of conduction electrons in a Copper Conductor estimated to be $8.5 \times 10^{28} \text{ m}^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end ? The area of cross section of the wire is $2.0 \times 10^{-6} \text{ m}^2$ and it is carrying a current of 3.0 A.

44. A voltmeter of resistance 400Ω is used to measure the potential difference across the 100Ω resistor in the circuit shown in figure. What will be the reading of voltmeter.



45. Find magnitude of current supplied by battery. Also find potential difference between points P and Q in the given fig. **Ans.** 1A, 1.5V

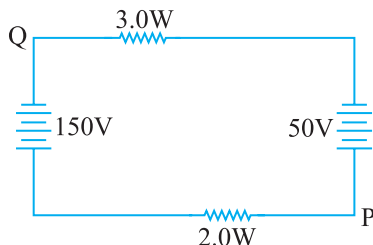


46. A copper wire of length 3 m and radius r is nickel plated till its radius becomes $2r$. What would be the effective resistance of the wire, if specific resistance of copper and nickel are ρ_c and ρ_n respectively.

[Hint : $P_c = P_e \frac{I}{\pi r^2}$; $R_n = \ln \frac{I}{\pi(2r)^2 - \pi r^2}$

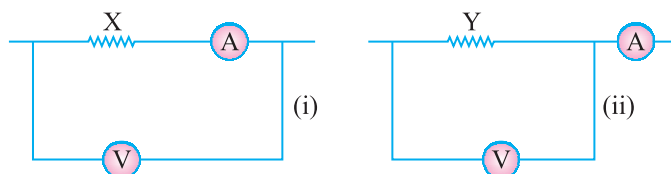
$$R = \frac{R_C R_n}{R_C + R_n} \quad \left[\text{Ans. } R = \frac{3\rho_n\rho_c}{\pi r^2 (3\rho_c + \rho_n)} \right]$$

47. In the figure, if the potential at point P is 100V, what is the potential at point Q?



Ans. $-10V$

48. Given two resistors X and Y whose resistances are to be determined using an ammeter of resistance 0.5Ω and a voltmeter of resistance $20\text{ k}\Omega$. It is known that X is in the range of a few ohms, while Y is in the range of several thousand ohm. In each case, which of the two connection shown should be chosen for resistance measurement ?

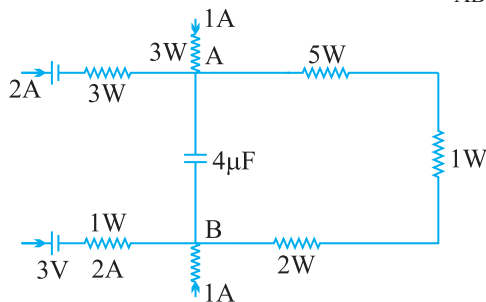


Ans. Small resistance : X will be preferred; large resistance : Y will be preferred

49. When resistance of 2Ω is connected across the terminals of a battery, the current is 0.5A . When the resistance across the terminal is 5Ω , the current is 0.25A . (i) Determine the emf of the battery (ii) What will be current drawn from the cell when it is short circuited.

Ans. $E = 1.5\text{ V}$, $I = 1.5\text{ A}$

50. A part of a circuit in steady state, along with the currents flowing in the branches and the resistances, is shown in the figure. Calculate energy stored in the capacitor of $4\mu\text{F}$ capacitance. **Ans.** $V_{AB} = 20\text{V}$, $U = 8 \times 10^{-4}\text{ J}$



51. With two resistance wires in two gaps of a meter bridge, balance point was found to be $1/3\text{m}$ from zero end, when a 6Ω coil is connected in series with smaller of two resistances the balance point shifted to $2/3\text{m}$ from the same end. Find resistances of two wires.

Ans. 2Ω , 4Ω

52. A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω . What will be the percentage error in the reading of the voltmeter.

Ans. 0.8%

HINTS FOR 2 MARKS QUESTIONS

$$\frac{t_e}{e_p} = \frac{\sqrt{\frac{2sm_e}{eE}}}{\sqrt{\frac{2sm_p}{eE}}} = \sqrt{\frac{m_e}{m_p}}$$



$$\frac{1}{C_s} = \frac{1}{2} + \frac{1}{6} + \frac{1}{2} = \frac{1}{6}$$

$$C_s = \frac{6}{7} \text{ ecf}$$

$$21. \quad \phi = \vec{E} \cdot d\vec{s} = 2x \hat{i} \cdot ds \hat{i} = 2x \cdot ds$$

$$\phi_1 = 0, \phi_2 = 50 \text{ Vm}, \phi_3 = 150 \text{ Vm}$$

$$28. \quad W_{BA} = 90 (V_B - V_A) = 2 \times 1000 = 2000 \text{ J}$$

$$40. \quad \frac{R_1}{R_2} = \frac{lI_1}{A_1} \times \frac{A_2}{lI_2} \Rightarrow \frac{I_1 A_2}{A_1 I_2} \Rightarrow \frac{1}{2}, \frac{I_1}{I_2} = \frac{1}{2} \therefore \frac{A_2}{A_1} = 1$$

$$(i) \text{ in series } neA, (V_d) = neA_2(V_d)_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = 1$$

$$(ii) i_1 R_1 = i_2 R_2 \Rightarrow \frac{(V_d)_1}{(V_d)_2} = \frac{2}{1}$$

$$43. \quad \text{Current through } 5\Omega = \left(\frac{10}{5+10} \right) I = \frac{2I}{3}$$

64. Sensitivity of Wheatstone Bridge is maximum when resistance of all its four arms are nearly of same order, so the accuracy of result of the experiment will be highest, if balance point is in the middle of wire.

32. In the capacitor the voltage increases from 0 to V, hence energy stored will correspond to average which will be $\frac{1}{2} QV$. While the source is at constant emf V. So energy supplied will be QV. The difference between the two goes as heat and emf radiations.

35. Construct a closed system such that charge is enclosed within it. For the charge on one face, we need to have two cubes place such that charge is

on the common face. According to Gauss's theorem total flux through the Gaussian surface (both cubes) is equal to $\frac{q}{2\epsilon_0}$. Therefore the flux through one cube will be equal to $\frac{q}{2\epsilon_0}$.

$$36. \text{ Work done} = fd \cos \theta = qEd \cos \theta = \frac{q(\sigma_1 - \sigma_2)}{\epsilon_0} \frac{a}{\sqrt{2}}$$

$$61. \quad I = \frac{\text{Charge circulating}}{\text{Time for one revolution}} = \frac{e}{2\pi r / v} \quad v \rightarrow \text{speed}$$

$$= \frac{ev}{2\pi r}$$

$$= \frac{ee^2 me^2}{n2\pi n^2} = \frac{me^5}{2\pi n^3}$$

62. In steady state the branch containing C can be omitted hence the current

$$I = \frac{2V - V}{R + 2R} = \frac{V}{3R}$$

For loop EBCDE

$$-V_C - V + 2V - 1(2R) = 0$$

$$\Rightarrow V_C = \frac{V}{3}$$

51. If e.m.f. decreases $\Rightarrow \frac{V}{l}$ decreases \Rightarrow position of zero deflection increases.

52. Otherwise resistance per unit length of Bridge wire be different over different length of meter Bridge.

54. Milliammeter. To produce large deflection due to small current we need a large number of turns we need a large number of turns in armature coil \Rightarrow Resistance increases.

55. Temperature, Material Blue, Red, Orange, Gold

56. The electron number density is of the order of 10^{29} m^{-3} , \Rightarrow the net current can be very high even if the drift spread is low.

$$57. \quad V = E + ir$$

$$= 2 + 0.15$$

$$= 2.15V$$

58. Affects the uniformity of the cross-section area of wire and hence changes the potential drop across wire.
59. A potentiometer is said to be sensitive if :
- It can measure very small potential differences.
 - For a small change in potential difference being measured it shows large change in balancing length.

HINTS FOR NUMERICALS

9.
$$V = E_o \left(\frac{d}{4} \right) + \frac{E_o}{K} \left(\frac{3d}{4} \right) = E_o d \left(\frac{K+3}{4K} \right)$$

$$V = V_o \left(\frac{K+3}{4K} \right)$$

$$C = \frac{Q_o}{V} = \frac{4K}{K+3} \frac{Q_o}{V_o} = \frac{4K}{K+3} C_o$$

14.

$$r = 1 \text{ mm}$$

$$\frac{4}{3} \pi R^3 = 8 \cdot \frac{4}{3} \pi r^3 \Rightarrow R = 2 \text{ mm}$$

$$Q = 8q = 8 \times 10 \times 10^{-10} \text{ C}$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{R}$$

$$= \frac{9 \times 10^9 \times 8 \times 10^{-9}}{2 \times 10^{-3}} = 36000 \text{ Volt}$$

21.

$$C_x = C, C_y = KC = 4C$$

$$\frac{C_x C_y}{C_x + C_y} = \frac{4}{5} C = 4 \Rightarrow C = 5\mu f$$

(a) $C_{eq} = C_x = 5\mu f$
 $C_y = 20\mu f$

(b) $V + \frac{V}{4} = 12 \text{ (} V_x = V, V_y = \frac{V}{4} \text{ as } q \text{ constant)}$
 $V = 9.6 \text{ Volt, } V_x = 9.6 \text{ Volt, } V_y = 2.4 \text{ Volt}$

$$(c) \quad \frac{U_x}{U_y} = \frac{\frac{1}{2} C_x V_x^2}{\frac{1}{2} C_y (V_y)^2} = 4$$

$$31. \quad \frac{X}{8} = \frac{l}{100 - l} \quad \dots(1)$$

$$\frac{1}{R_p} = \frac{1}{8} + \frac{1}{8} = \frac{1}{4} \Rightarrow R_p = 4,$$

$$\frac{X}{4} = \frac{1 + 15}{100 - (1 + 15)} \quad \dots(2)$$

\Rightarrow u sing (1) & (2)

$$l^2 - 85l + 1500 = 0$$

$$l = 25 \text{ cm or } l = 60 \text{ cm}$$

At $l = 60 \text{ cm}$ using (1) $X = \frac{8}{3} \Omega$

$$l = 60 \text{ cm using (1) } X = 12 \Omega.$$

$$32. \quad i_x = \frac{E}{x + 0.5}, i_R = \frac{E}{10 + 0.5} = \frac{E}{10.5}$$

$$\frac{V_R}{V_x} = \frac{160}{134.4} = \frac{i_R \cdot R}{i_x \cdot x} = \frac{10}{10.5} \frac{(x + 0.5)}{x} \Rightarrow x = 2 \Omega.$$

HINTS FOR 3 MARKS QUESTIONS

16. If E' be the electric field due to each plate (of large dimensions) then net electric field between them

$$E = E' + E' \Rightarrow E' = E/2$$

Force on charge Q at some point between the plates $F = QE$

Force on one plate of the capacitor due to another plate $F' = QE' = QE/2$

$$17. \quad V_1 = \frac{kq}{r} + \frac{kq}{6r} = \frac{7kq}{6r}$$

$$V_2 = \frac{kq}{2r} + \frac{kq}{6r} = \frac{3kq + kq}{6r} = \frac{4kq}{6r}$$

$$\frac{V_1}{V_2} = \frac{7}{4}$$

$$V_{\text{common}} = \frac{2q}{4\pi\epsilon_0(r + 2r)} = \frac{2q}{12\pi\epsilon_0 r} = V'$$

Charge transferred equal to

$$q' = C_1 V_1 - C_1 V' = \frac{r}{k} \cdot \frac{kq}{r} - \frac{r}{k} \cdot \frac{k_2 q}{3r}$$

$$= q - \frac{2q}{3} = \frac{q}{3}.$$

28. $R_1 = \frac{V_1}{I_1} = \frac{50}{2 \times 10^{-3}} = 25,000 \Omega$

$$R_2 = \frac{V_2}{I_2} = \frac{60}{3 \times 10^{-3}} = 20,000 \Omega.$$

As resistance changes with I, therefore conductor is non ohmic.

29. Rate of production of heat, $P = I^2 R$, for given I , $P \propto R$, $\therefore \rho_{\text{nichrome}} > \rho_{\text{cu}}$
 $\therefore R_{\text{Nichrome}} > R_{\text{cu}}$ of same length and area of cross section.

30. (i) If I in circuit is constant because $H = I^2 R t$

(ii) If V in circuit is constant because $H = \frac{V^2}{R} t$

NUMERICALS

17. $V_A = k \left[\frac{q_1}{a} + \frac{q_2}{b} + \frac{q_3}{c} \right]$

$$= k 4\pi a \sigma - k 4\pi b \sigma + k 4\pi c \sigma$$

$$= 4\pi a \sigma (a - b + c)$$

$$= \frac{\sigma}{\epsilon_0} (a - b + c)$$

$$V_B = k \left[\frac{q_1}{b} + \frac{q_2}{b} + \frac{q_3}{c} \right] = k \left[\frac{4\pi a^2 \sigma}{b} - 4\pi k b \sigma + 4\pi k c \sigma \right]$$

$$= \frac{\sigma}{\epsilon_0} \left(\frac{a^2}{b} - b^2 + c^2 \right)$$

$$V_C = \frac{\sigma}{\epsilon_0 c} (a^2 - b^2 + c^2)$$

When

$$V_A = V_C$$

$$\frac{\sigma}{\epsilon_0} (a - b + c) = \frac{\sigma}{\epsilon_0 c} (a^2 - b^2 + c^2)$$

$$ac - bc + c^2 = a^2 - b^2 + c^2$$

$$c(a-b) = (a-b)(a+b)$$

$$c = a + b$$

19.

$$Q = CV$$

Total charge

$Q = \text{Total capacitance in series} \times \text{voltage}$

$$= \left(\frac{5}{6} \times 10^{-3} \right) \times 12 = 10 \times 10^{-3} \text{ coulomb}$$

$$V_{AB} = \frac{Q}{c_1} = \frac{10 \times 10^{-3}}{1 \times 10^{-3}} = 10V$$

$$V_{BC} = \frac{Q}{c_2} = \frac{10 \times 10^{-3}}{5 \times 10^{-3}} = 2V.$$

When B is earthed $V_B = 0$, $V_A = 10V$ and $V_C = -2V$.

21. Before dielectric is introduced.

$$E_A = \frac{1}{2}CV^2; \quad E_B = \frac{1}{2}CV^2$$

$$E = E_A + E_B = CV^2$$

After disconnecting the battery and then introducing dielectric

$$E'_A = \frac{1}{2}(3C)V^2$$

$$E'_B = \frac{Q^2}{2C} = \frac{(CV)^2}{2 \times 3C}$$

$$= \frac{1}{3} \left(\frac{1}{2} CV^2 \right),$$

$$E' = E'_A + E'_B$$

$$\frac{E'}{E} = \frac{5}{3}.$$

33. Pot. gradient $k = \frac{5}{5} = 1Vm^{-1}$

$$l_1 = 350 \text{ cm} = 3.5 \text{ m}$$

$$E_1 + E_2 = kl_1 = 3.5$$

...(1)

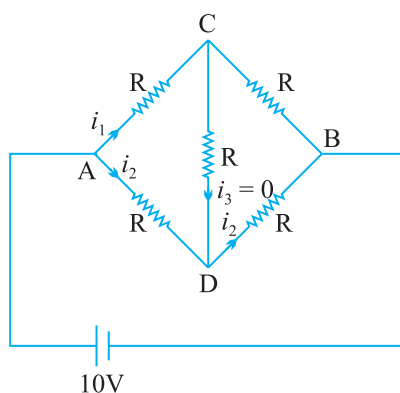
$$E_1 - E_2 = 0.5 \quad \dots(2)$$

$$E_1 = 2\text{V}, E_2 = 1.5\text{ Volt}$$

39.

$$R_{AB} = 2\Omega$$

$$I_{CD} = 0, I_{ACB} = \frac{V}{2R} = \frac{10}{2 \times 2} = 2.5\text{A}$$



$$40. \quad (i) \quad \frac{E_2}{E_1} = \frac{I_2}{I_1} \Rightarrow E_2 = \frac{I_2}{I_1} E_1 = \frac{80}{60} \times 1.5 = 2.0\text{V}$$

(ii) The circuit will not work if emf of driven cell is IV, /total Voltage across AB is 1 V, which cannot balance the voltage 1.5V.

(iii) No, since at balance point no current flows through galvanometer G. *i.e.*, cell remains in open circuit.

41.

$$E = I(R + r)$$

$$10 = 0.5(R + 3)$$

$$R = 17\Omega$$

$$V = E - Ir = 10 - 0.5 \times 3 = 8.5\text{V}$$

42.

$$R_{eq} = 7\Omega$$

$$I_{4\Omega} = 1\text{A}, I_{1\Omega} = 2\text{A}, I_{12\Omega} = \frac{2}{3}\text{A}, I_{6\Omega} = \frac{4}{3}\text{A},$$

$$V_{AB} = 4V, V_{BC} = 2V, V_{CD} = 8V$$

43.

$$I = enAV_d = \frac{l}{t}$$

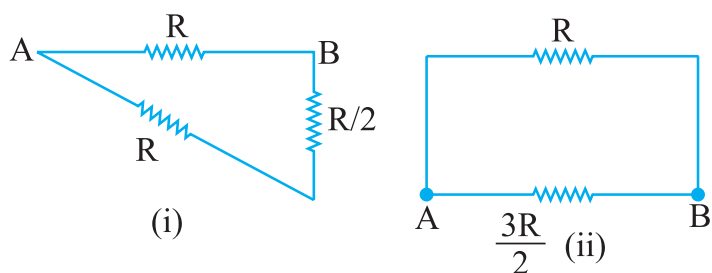
$$t = \frac{enAl}{I} = 2.7 \times 10^4 \text{ s}$$

44.

$$I = \frac{84}{\left(\frac{100 \times 400}{100 + 400}\right) + 200} = \frac{84}{280} = 0.3A$$

P.d. across voltmeter & 100Ω combination

$$= 0.3 \times \frac{100 \times 400}{100 + 400} = 24V.$$



When, $I \ll r$,

45.

$$R_{AB} = 4.5\Omega$$

$$i = \frac{E}{R_{AB} + 1.5} = \frac{6}{6} = 1A.$$

$$i_{AP} = i_{AQ} = 0.5A, V_{AP} = 3 \Rightarrow V_p = 3 \text{ Volt}$$

$$V_{AQ} = 1.5 \text{ V}_Q = 4.5 \text{ Volt}$$

$$V_Q - V_P = 1.5 \text{ Volt}$$

51. For two resistor P and Q

$$\frac{P}{Q} = \frac{I}{100 - I} = \frac{\frac{1}{3}}{1 - \frac{1}{3}} = \frac{1}{2} \quad \dots(i)$$

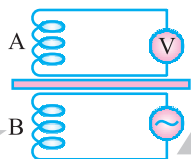
$$Q = 2P, P < Q$$

Now, $P' = P + 6$, $I' = 2/3$

$$\frac{P'}{Q} = \frac{I'}{(100 - I')} = \frac{\frac{2}{3}}{\frac{1}{3}} = \frac{2}{1}$$

$$\frac{P + 6}{Q} = \frac{2}{1} \quad \dots(ii)$$

On solving (i) & (ii), $P = 2\Omega$, $Q = 4\Omega$.



Unit III and IV

Section - 2

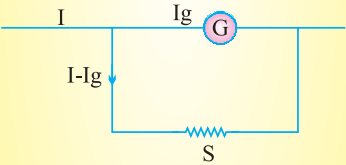

KEY POINTS

Physical Quantity	Formulae	SI Unit
Biot-Savart's Law	$d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{l} \times \vec{r}}{r^3}$ $ d\vec{B} = \frac{\mu_0}{4\pi} \frac{Idl \sin \theta}{r^2}$	Tesla (T); $10^4 \text{ Gauss} = 1\text{T}$
Magnetic field due to a straight current carrying conductor	$B = \frac{\mu_0 I}{2\pi R}$	T
Magnetic field at the centre of a circular loop	$B = \frac{\mu_0 I}{2a}$ $B = \frac{\mu_0 nI}{2a} \text{ (For } n \text{ loops)}$	T
Magnetic Field at a Point on the Axis of a current carrying loop	$B = \frac{\mu_0 I}{4\pi} \frac{2\pi a^2}{(a^2 + x^2)^{\frac{3}{2}}}$ <p>When, $x = 0$, $B = \frac{\mu_0 I}{2a}$</p> <p>For $a \ll x$, $B = \frac{\mu_0 Ia^2}{2x^3}$</p> <p>For n loops, $B = \frac{\mu_0 nIa}{2x^3}$</p>	T
Ampere's Circuital Law	$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$	T – m

Magnetic field due to a long straight solenoid	$B = \mu_0 n I$ At the end of solenoid, $B = \frac{1}{2} \mu_0 n I$ If solenoid is filled with material having magnetic permeability μ_r $B = \mu_0 \mu_r n I$	T
Magnetic field due to a toroidal solenoid	$B = \mu_0 n I$	T
Motion of a charged particle inside electric field	$y = \frac{qE}{2m} \left(\frac{x}{v_x} \right)^2$	m
Magnetic force on a moving charge	$\vec{F} = q(\vec{v} \times \vec{B})$ Or $F = qv B \sin \theta$	N
Lorentz Force (Electric and Magnetic)	$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$	N
The Cyclotron		
Radius of circular path	$r = \frac{mv}{Bq}$	
The period of circular motion	$T = \frac{2\pi m}{Bq}$	
The cyclotron frequency	$\nu = \frac{1}{T} = \frac{Bq}{2\pi m}$	
Maximum energy of the positive ions	$\frac{1}{2} m v_{\max}^2 = \frac{B^2 q^2 r^2}{2m} = qV = qV$	
The radius corresponding to maximum velocity	$r = \frac{1}{B} \left(\frac{2mV}{q} \right)^{\frac{1}{2}}$	

The maximum velocity	$V_{\max} = \frac{Bqr}{m}$	
The radius of helical path when \vec{v} and \vec{B} are inclined to each other by an angle θ	$r = \frac{mv \sin \theta}{qB}$	
Force on a current carrying conductor placed in a magnetic field	$\vec{F} = I(\vec{l} \times \vec{B})$	N
Force per unit length between two parallel current carrying conductors	$f = \frac{\mu_0}{4\pi} \frac{2I_1 I_2}{r}$	Nm^{-1}
Magnetic dipole moment	$\vec{M} = I \vec{A}$	Am^2 or JT^{-1}
Torque on a rectangular current carrying loop ABCD	$\vec{\tau} = \vec{M} \times \vec{B}$ $\Rightarrow \tau = MB \sin \alpha$ <p>If coil has n turns, $\tau = n B I A \sin \alpha$ $\alpha \rightarrow$ angle between normal drawn on the plane of loop and magnetic field</p>	
Period of oscillation of bar magnet if external magnetic field	$T = 2\pi \sqrt{\frac{I}{MB}}$	S
The potential energy associated with magnetic field	$U = - \vec{M} \cdot \vec{B} = - MB \cos \theta$	
Current through a galvanometer $\phi \rightarrow$ angle by which the coil rotates	$I = \frac{k}{nBA} \phi = G\phi;$ <p>$G \rightarrow$ galvanometer constant</p>	A

Sensitivity of a galvanometer or		
Current sensitivity	$I_s = \frac{\theta}{I} = \frac{nBA}{k} = \frac{1}{G}$	rad A ⁻¹
Voltage sensitivity	$V_s = \frac{\theta}{V} = \frac{nBA}{kR} = \frac{1}{GR}$	rad V ⁻¹
The current loop as a magnetic dipole on axis at very large distance from the centre	$B = \frac{\mu_0}{4\pi} \frac{2M}{x^3} \quad T$	
Gyromagnetic ratio	$\frac{\mu_e}{L} = \frac{e}{2m_e} = 8.8 \times 10^{10} \frac{C}{kg}$ → Angular momentum	C Kg ⁻¹
Bohr magneton	$(\mu_e)_{\min} = \frac{e}{4\pi m_e} h$ $= 9.27 \times 10^{-24}$	Am ²
Magnetic dipole moment	$\vec{M} = m \left(\vec{2l} \right)$	JT ⁻¹ or Am ²
Magnetic field on axial line of a bar magnet	$B_{\text{axial}} = \frac{\mu_0}{4\pi} \left[\frac{2Mr}{(r^2 - l^2)^2} \right]$ When, $l \ll r$, $B_{\text{eq}} = \frac{\mu_0}{4\pi} \frac{M}{r^3}$	T
Gauss's Law in magnetism	$\oint_S \vec{B} \cdot d\vec{S} = 0$	Tm ² or weber
Magnetic inclination (or Dip)	$\tan \delta = \frac{B_V}{B_H}, \quad \delta \rightarrow \text{angle of dip}$	
Magnetic intensity (or Magnetic field strength)	$H = \frac{B_0}{\mu_0} = nI$ n is the no. of	Am ⁻¹ terms/length
Intensity of magnetization	$I_m = \frac{M}{V}$	Am ⁻¹

Magnetic flux	$\phi = \vec{B} \cdot \Delta \vec{S}$	Weber or Tm^2
Magnetic induction (or Magnetic flux density or Magnetic field)	$B = B_0 + \mu_0 I_m$ $= \mu_0 (H + I_m)$	T
Magnetic susceptibility	$\chi_m = \frac{I_m}{H} \text{ ---}$	
Magnetic permeability	$\mu = \frac{B}{H} \text{ TmA}^{-1}$ (or NA^{-2})	
Relative permeability (μ)	$\frac{\mu}{\mu_0} = \mu_r = (1 + \chi_m)$	
Curie's Law	$\chi_m = \frac{C}{T}$, $C \rightarrow$ curie constant	
Conversion of a Galvanometer into Ammeter	 $I_g G = (I - I_g) S$ $I_g (G + S) = S I$ $I_g = \left(\frac{S}{G + S} \right) I$ <p>$S \rightarrow$ shunt resistance</p>	
Conversion of a Galvanometer into voltmeter	 $R = \frac{V}{I_g} - G$ <p>$G \rightarrow$ Galvanometer resistance</p>	

UNIT-III & UNIT-IV

MAGNETIC EFFECTS OF CURRENT AND MAGNETISM & E.M.I. AND ALTERNATING CURRENT

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

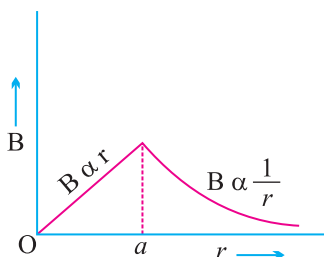
Ans. No, pole exists only when the source has some net magnetic moment. There is no pole in toroid. Magnetic field due to a toroid $B = \mu_0 nI$

2. How are the figure of merit and current sensitivity of galvanometer related with each other ?

Ans. Reciprocal.

3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section or radius ' a ' and carrying steady current as a function of distance r ($a > r$) from the axis of the conductor.

Ans.



4. The force per unit length between two parallel long current carrying conductor is F . If the current in each conductor is tripled, what would be the value of the force per unit length between them?

Ans. $F = \frac{\mu_w I_1 I_2}{2\pi r}$

$$F = \frac{\mu_0 (3I_1)(3I_2)}{2\pi r} = 9 \text{ times}$$

5. How does the angle of dip vary from equator to poles?

Ans. 0° to 90°

6. What is the effect on the current measuring range of a galvanometer when it is shunted?

Ans. Increased.

7. An electric current flows in a horizontal wire from East to West. What will be the direction of magnetic field due to current at a point (i) North of wire; (ii) above the wire.

Ans.



(i) Going into the plane of the paper.

(ii) Going out of the plane of paper.

8. Suggest a method to shield a certain region of space from magnetic fields.

Ans. By using a ferromagnetic case. Put an iron ring in the magnetic field inside the ring field will be zero.

9. Why the core of a moving coil galvanometer is made of soft iron?

Ans. To increase magnetic flux linked and sensitivity.

10. Where on the earth's surface is the vertical component of earth's magnetic field zero?

Ans. At equator.

11. If the current is increased by 1% in a moving coil galvanometer. What will be percentage increase in deflection?

Ans. 1%.

12. Write S.I. unit of (i) Pole strength and (ii) Magnetic dipole moment.

Ans. (i) Am

(ii) Am^2

13. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton (positive charge) ?

Ans. When velocity (\vec{v}) of positively charged particle is along x-axis and the magnetic field (\vec{B}) is along y-axis, so $\vec{v} \times \vec{B}$ is along the z-axis (Fleming's left hand rule).

Therefore,

(a) for electron Lorentz force will be along -z axis;

(b) for a positive charge (proton) the force is along +z axis.

14. If a toroid uses Bismuth at its core, will the field in the core be lesser or greater than when it is empty?

Ans. Bismuth is diamagnetic, hence, the overall magnetic field will be slightly less.

15. An electron beam projected along + x-axis, experiences a force due to a magnetic field along the + y-axis. What is the direction of the magnetic field?

Ans. + Z-axis

16. What do you understand by figure of merit ?

Ans. Figure of merit is defined as the current required per division of deflection derivation

$$K = \frac{I}{\theta}, \text{ SI unit A/div}$$

in observation for half deflection method

$$i_g = K\theta, i_g = \frac{E}{R+G}$$

$$k = \frac{1}{\theta} \left[\frac{E}{R+G} \right]$$

It enables us to find current required for full scale deflection.

17. What is the direction of magnetic dipole moment ?

Ans. S to N.

18. What is the angle of dip at a place where vertical and horizontal component of earth's field are equal ?

Ans. 45°

19. Does a charge Particle gain K.E. when passed through magnetic field region? Justify.

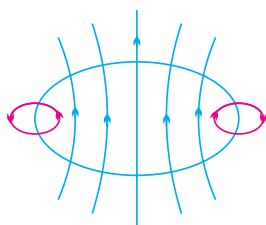
Ans. No, as the magnetic force acting on the charge particle is always perpendicular to the velocity, hence

$$\frac{d\omega}{dt} = \vec{f} \cdot \vec{v} = f v \cos 90^\circ = 0$$

\therefore there is no gain in KE of particle.

20. Sketch the magnetic field lines for a current carrying circular loop.

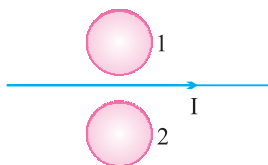
Ans.



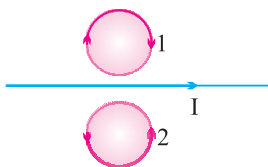
21. Why core of a transformer is laminated ?

Ans. To reduce loss due to eddy currents.

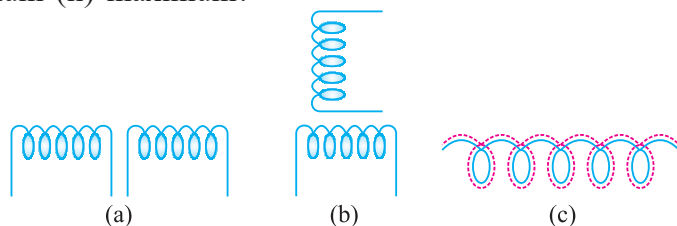
22. What is the direction of induced currents in metal rings 1 and 2 seen from the top when current I in the wire is increasing steadily ?



Ans.



23. In which of the following cases will the mutual inductance be (i) minimum (ii) maximum?



Ans. (i) b (ii) c

24. In a series L–C–R circuit, voltages across inductor, capacitor, and resistor are V_L , V_C and V_R respectively. What is the phase difference between (i) V_L and V_R (ii) V_L and V_C ?

Ans. (i) $\frac{\pi}{2}$ (ii) π

25. Why can't transformer be used to step up or step down dc voltage?

Ans. In steady current no induction phenomenon will take place.

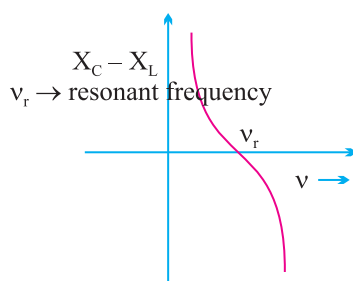
26. In an a.c. circuit, instantaneous voltage and current are $V = 200 \sin 300 t$ volt and $i = 8 \cos 300t$ ampere respectively. What is the average power dissipated in the circuit?

Ans. As the phase difference between current and voltage is $\frac{\pi}{2}$.

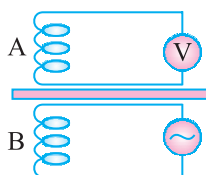
$$\therefore P_{av} = I_{vEv} \cos \frac{\pi}{2} = 0$$

27. Sketch a graph that shows change in reactance with frequency of a series LCR circuit. (x) (v)

Ans.



28. A coil A is connected to an A.C. ammeter and another coil B to A source of alternating e.m.f. How will the reading of ammeter change if a copper plate is introduced between the coils as shown.



Ans. Reading of ammeter will decrease due to eddy currents.

29. In a circuit instantaneously voltage and current are $V = 150 \sin 314t$ volt and $i = 12 \cos 314t$ ampere respectively. Is the nature of circuit is capacitive or inductive ?

Ans. $i = 12 \sin \left(314t + \frac{\pi}{2} \right)$

i.e. Current is ahead the voltage by a phase difference of $\frac{\pi}{2}$. Hence circuit is a capacitive circuit.

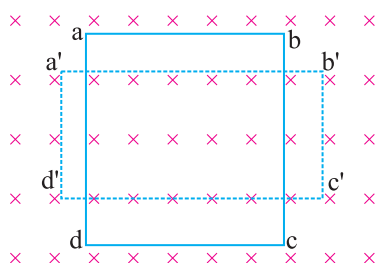
30. In a series L-C-R circuit $V_L = V_C \neq V_R$. What is the value of power factor?

Ans. At Resonance $\cos \phi = 1$.

31. In an inductor L, current passed I_0 and energy stored in it is U. If the current is now reduced to $I_0/2$, what will be the new energy stored in the inductor?

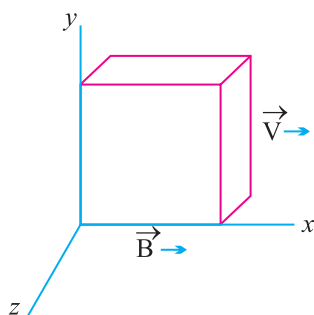
Ans. $U_L \propto I^2 \Rightarrow U' = \frac{U}{4}$

32. A square loop a, b, c, d of a conducting wire has been changed into a rectangular loop a', b', c', d' as shown in figure. What is the direction of induced current in the loop?



Ans. Clockwise.

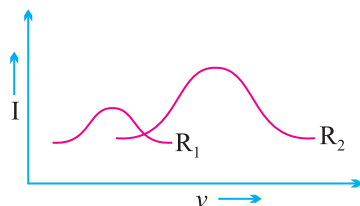
33. Twelve wires of equal lengths are connected in the form of a skeleton of a cube, which is moving with a velocity \vec{v} in the direction of magnetic field \vec{B} . Find the emf in each arm of the cube.



Ans. emf in each branch will be zero since V & B are parallel for all arms.

$$\therefore \vec{F} = q \left(\vec{V} \times \vec{B} \right) = 0$$

- 34.** Current versus frequency ($I - \nu$) graphs for two different series L-C-R circuits have been shown in adjoining diagram. R_1 and R_2 are resistances of the two circuits. Which one is greater— R_1 or R_2 ?



Ans. $R_1 > R_2$ as I is smaller in larger resistance.

- 35.** Why do we prefer carbon brushes than copper in an a.c. generator?

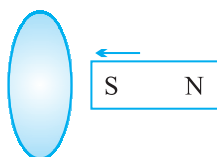
Ans. Corrosion free and small expansion on heating maintains proper contact.

- 36.** What are the values of capacitive and inductive reactance in a dc circuit?

Ans. $X_C = \infty$ for dc $\nu = 0$ $X_C = \frac{1}{\omega_c} = \frac{1}{2\pi\nu_c} = \infty$

$$X_L = 0 \quad \& \quad X_L = \omega L = 2\pi\nu L = 0$$

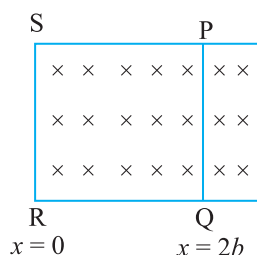
- 37.** Give the direction of the induced current in a coil mounted on an insulating stand when a bar magnet is quickly moved along the axis of the coil from one side to the other as shown in figure.



Ans. If observer is situated at the side from which bar magnet enters the loop. The direction of current is clockwise when magnet moves towards the loop and direction of current is anticlockwise when magnet moves away from the loop.

38. 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.

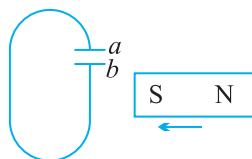


39. A wire moves with some speed perpendicular to a magnetic field. Why is emf induced across the rod?

Ans. Lorentz force acting on the free charge carrier of conducting wire hence polarity developed across it.

40. Predict the polarity of the capacitor in the situation described in the figure below.

Ans. Plate a will be positive with respect to ' b '. When the observer is looking from the side of moving bar magnet.



41. A circular coil rotates about its vertical diameter in a uniform horizontal magnetic field. What is the average emf induced in the coil?

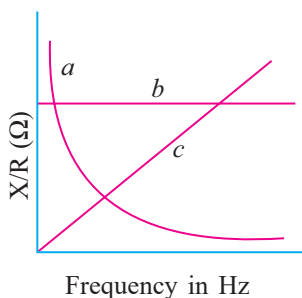
Ans. Zero

42. Define RMS Value of Current.

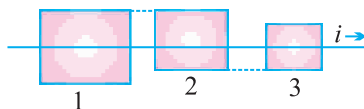
Ans. RMS value of ac is defined as that value of direct current which produces the same heating effect in a given resistor as is produced by the given alternating current when passed for the same time.

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

43. 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.



44. A long straight wire with current *i* passes (without touching) three square wire loops with edge lengths 2*L*, 1.5*L* and *L*. The loops are widely spaced (so as do not affect one another). Loops 1 and 3 are symmetric about the long wire. Rank the loops according to the size of the current induced in them if current *i* is (a) constant and (b) increasing.



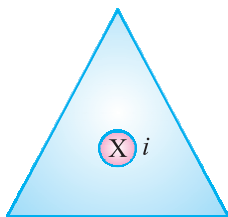
Ans. (a) No induced current

(b) Current will be induced only in loop 2.

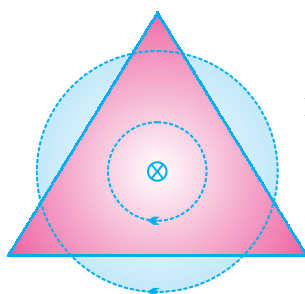
45. In an L-C circuit, current is oscillating with frequency 4×10^6 Hz. What is the frequency with which magnetic energy is oscillating?

Ans. $\nu_m = 2\nu = 8 \times 10^6$ Hz.

46. 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.



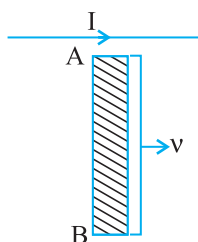
Ans. Magnetic field lines are tangential to the triangular plane $\theta = 90^\circ$ so $\phi = 0$



Induced emf = 0

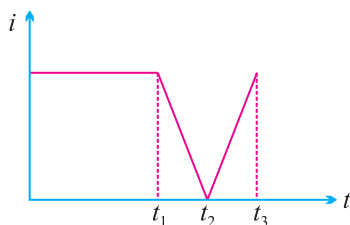
\therefore Induced current = 0

47. Wire carrying a steady current and rod AB are in the same plane the rod moves parallel to wire with velocity v then which end of the rod is at higher potential.



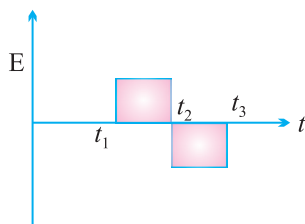
Ans. End A will be at higher potential.

48. The current i in an induction coil varies with time t according to the graph



Draw the graph of induced e.m.f. with time.

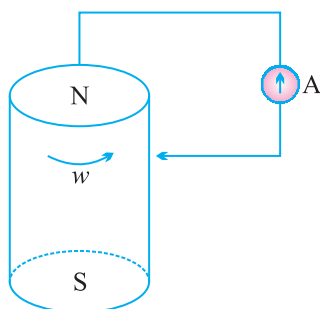
Ans.



49. Can a capacitor of suitable capacitance replace an inductor in an AC circuit?

Ans. Yes, because average power consumed in both is least while controlling an AC.

50. In the given figure,

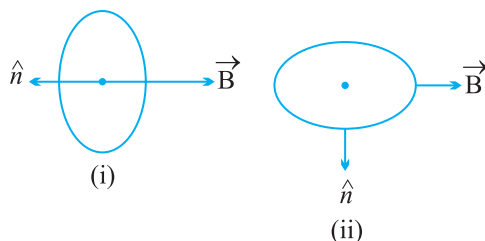


a cylindrical bar magnet is rotated about its axis. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then, current in the Ammeter is.....

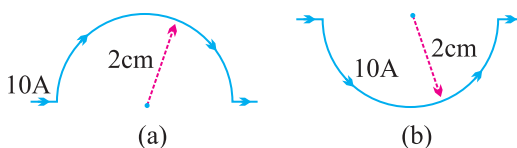
Ans. When cylindrical bar magnet is rotated about its axis, no change in magnetic flux linked with the circuit take place hence no e.m.f. is induced hence no current flows through the ammeter (A)

SHORT ANSWERS QUESTIONS (2 MARKS)

1. Write the four measures that can be taken to increase the sensitivity of galvanometer.
2. A galvanometer of resistance 120Ω gives full scale deflection for a current of 5mA . How can it be converted into an ammeter of range 0 to 5A ? Also determine the net resistance of the ammeter.
3. A current loop is placed in a uniform magnetic field in the following orientations (1) and (2). Calculate the magnetic moment in each case.



4. A current of 10A flows through a semicircular wire of radius 2 cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b) ?



5. A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

6. Why does the susceptibility of diamagnetic substance independent of temperature ?

Ans. As there is no permanent dipoles in diamagnetic substance, so, there is no meaning of randomness of dipoles on increasing temp.

7. Mention two properties of soft iron due to which it is preferred for making electromagnet.

Ans. Low retentivity, low coercivity

8. A magnetic dipole of magnetic moment M is kept in a magnetic field B . What is the minimum and maximum potential energy? Also give the most stable position and most unstable position of magnetic dipole.

9. What will be (i) Pole strength, (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces :

(a) normal to its length?

(b) along its length?

10. A steady current I flows along an infinitely long straight wire with circular cross-section of radius R . What will be the magnetic field outside and inside the wire at a point r distance far from the axis of wire?

11. A circular coil of n turns and radius R carries a current I . It is unwound and rewound to make another square coil of side ' a ' keeping number of turns and current same. Calculate the ratio of magnetic moment of the new coil and the original coil.

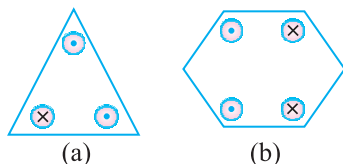
12. A coil of N turns and radius R carries a current I . It is unwound and rewound to make another coil of radius $R/2$, current remaining the same. Calculate the ratio of the magnetic moment of the new coil and original coil.

13. At a place horizontal component of the earth's magnetic field is B and angle of dip at the place is 60° . What is the value of horizontal component of the earth's magnetic field.

(i) at Equator; (ii) at a place where dip angle is 30°

14. A galvanometer coil has a resistance G . 1% of the total current goes through the coil and rest through the shunt. What is the resistance of the shunt in terms of G ?

15. Prove that magnetic moment of a hydrogen atom in its ground state is $eh/4\pi m$. Symbols have their usual meaning.
16. Each of conductors shown in figure carries 2A of current into or out of page. Two paths are indicated for the line integral $\oint \vec{B} \cdot d\vec{l}$. What is the value of the integral for the path (a) and (b).



17. What is the radius of the path of an electron (mass 9×10^{-31} kg and charge 1.6×10^{-19} C) moving at a speed of 3×10^7 m/s in a magnetic field of 6×10^{-4} T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = 1.6×10^{-19} J).

Ans. Radius, $r = mv/(qB)$

$$= 9.1 \times 10^{-31} \text{ kg} \times 3 \times 10^7 \text{ ms}^{-1} / (1.6 \times 10^{-19} \text{ C} \times 6 \times 10^{-4} \text{ T}) = 20 \text{ cm}$$

$$\nu = v/(2\pi r) = 1.7 \times 10^7 \text{ Hz}$$

$$E = (1/2)mv^2 = (1/2) 9 \times 10^{-31} \text{ kg} \times 9 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$= 40.5 \times 10^{-17} \text{ J} = 4 \times 10^{-16} \text{ J} = 2.5 \text{ keV.}$$

18. Why is it necessary for voltmeter to have a higher resistance?

Ans. Since voltmeter is to be connected across two points in parallel, if it has low resistance, a part of current will pass through it which will decrease actual potential difference to be measured.

19. Can d.c. ammeter use for measurement of alternating current?

Ans. No, it is based on the principle of torque. When ac is passing through it (of freq. 50 Hz). It will not respond to frequent change in direction due to inertia hence would show zero deflection.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed ' v ', around an orbit of radius ' r ' in hydrogen atom.

Ans. The product of the current in the loop to the area of the loop is the magnetic dipole moment of a current loop.

The magnetic moment of electron

$$\vec{\mu} = -\frac{e}{2} \left(\vec{r} \times \vec{v} \right) = -\frac{e}{2m_e} \left(\vec{r} \times \vec{p} \right) = -\frac{e}{2m_e} \vec{L}$$

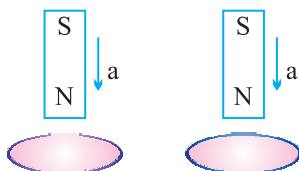
21. An ac source of rms voltage V is put across a series combination of an inductor L , capacitor C and a resistor R . If V_L , V_C and V_R are the rms voltage across L , C and R respectively then why is $V \neq V_L + V_C + V_R$? Write correct relation among V_L , V_C and V_R .

Ans. Hint :

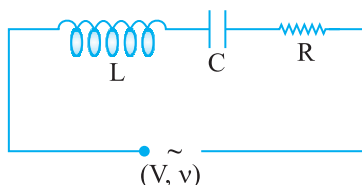
V_L , V_C and V_R are not in the same phase

$$V_L + V_C + V_R > V$$

22. A bar magnet is falling with some acceleration ' a ' along the vertical axis of a coil as shown in fig. What will be the acceleration of the magnet (whether $a > g$ or $a < g$ or $a = g$) if (a) coil ends are not connected to each other? (b) coil ends are connected to each other?

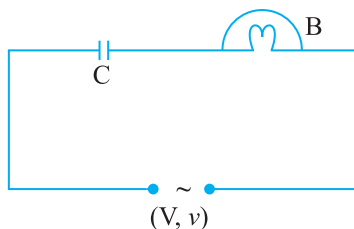


23. The series L - C - R circuit shown in fig. is in resonance state. What is the voltage across the inductor?

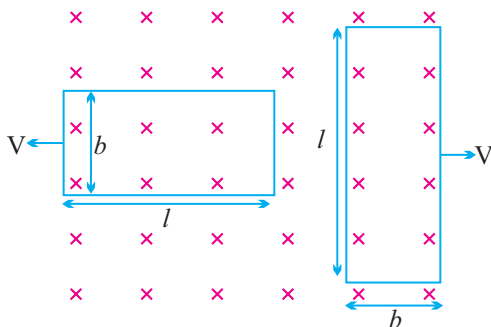


Ans. [Hint $V_L = I X_L$ where $I = \frac{V}{R}$]

24. The division marked on the scale of an a.c. ammeter are not equally spaced. Why?
25. Circuit shown here uses an air filled parallel plate capacitor. A mica sheet is now introduced between the plates of capacitor. Explain with reason the effect on brightness of the bulb B.



26. In the figure shown, coils P and Q are identical and moving apart with same velocity V . Induced currents in the coils are I_1 and I_2 . Find I_1/I_2 .



27. An electron moving through magnetic field does not experience magnetic force, under what conditions is this possible ?
 Ans. when electron moving parallel to magnetic field.
28. A $1.5 \mu\text{F}$ capacitor is charged to 57V . The charging battery is then disconnected, and a 12 mH coil is connected in series with the capacitor so that LC Oscillations occur. What is the maximum current in the coil? Assume that the circuit has no resistance.
29. The self inductance of the motor of an electric fan is 10H . What should be the capacitance of the capacitor to which it should be connected in order to impart maximum power at 50Hz ?
30. A galvanometer needs 50mV for full scale deflection of 50 Divisions. Find its voltage sensitivity. What must be its resistance if its current sensitivity is 1 Div/A .

Ans. $V_s = \frac{\theta}{V} = \frac{50\text{Div}}{50\text{mv}} = 10^3 \text{ div/v}$ $I_s \rightarrow \text{Current sensitivity}$

$R_g = \frac{I_s}{V_s} = 10^{-3}\Omega$ $V_s \rightarrow \text{Voltage sensitivity}$

31. How does an inductor behave in an AC circuit at very high frequency? Justify.
32. An electric bulb is connected in series with an inductor and an AC source. When switch is closed. After sometime an iron rod is inserted into the interior of inductor. How will the brightness of bulb be affected? Justify your answer.

Ans. Decreases, due to increase in inductive reactance.

- 33.** Show that in the free oscillation of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant with time.

Ans. Hint : $U = \frac{1}{2} LI^2 + \frac{1}{2} \frac{q^2}{c}$

- 34.** Show that the potential difference across the LC combination is zero at the resonating frequency in series LCR circuit

Ans. Hint : P.d. across L is $= IX_L$

P.D. across C is $= IX_C$

$$\Rightarrow V = IX_L - IX_C$$

at resonance $X_L = X_C$

$$\Rightarrow V = 0.$$

- 34.** When a large amount of current is passing through solenoid, it contract, explain why ?

Ans. Current in two consecutive turns being in same direction make them to form unlike poles together hence, they attract each other.

- 35.** for circuits used for transmitting electric power, a low power factor implies large power loss in transmission. Explain.

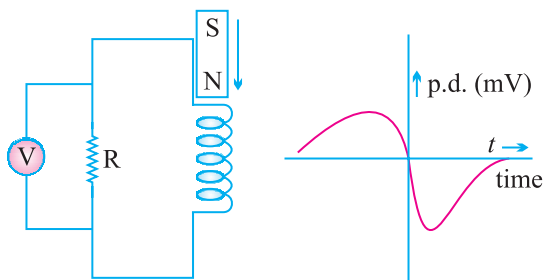
$$\therefore P = VI \cos \theta$$

$$I = \frac{P}{V \cos \theta}$$

If $\cos \phi$ is low I will be high \Rightarrow Large power loss.

- 36.** An applied voltage signal consists of a superposition of DC Voltage and an AC Voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the DC signal will appear across C where as AC signal will appear across L.

- 37.** 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 figure.



- (i) Explain the shape of the graph.
- (ii) Why is the negative peak longer than the positive peak ?

Ans. (i) When the bar magnet moves towards the coil magnetic flux passing through the coil increases as velocity of magnet increases in downward direction, e.m.f. induced also increases, due to formation of similar pole repulsive force decreases the rate of increase of flux.

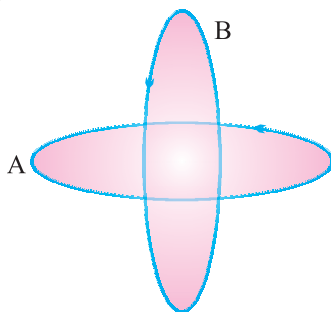
- (ii) once the magnet has passed through the coil, flux decreases in downward direction but $\frac{d\phi}{dt}$ increases as self induced e.m.f. in the coil maintains its flux in the same direction. Thus due to the addition of self induced e.m.f. in same direction according to Lenz's law.

38. What is the significance of Q-factor in a series LCR resonant circuit ?

39. How does mutual inductance of a pair of coils kept coaxially at a distance in air change when

- (i) the distance between the coils is increased?
- (ii) an iron rod is kept between them?

40. Two circular conductors are perpendicular to each other as shown in figure. If the current is changed in conductor B, will a current be induced in the conductor A,



41. What is a radial magnetic field? Why is it required in a galvanometer ?

Ans. Using concave shaped pole of magnet and placing soft iron cylindrical core, A magnetic field, having field lines along radii is called as radial magnetic field.

To make Torque independent of ' θ ' (constant) radial magnetic field is required $\tau = NIAB \sin \theta$

for radial Magnetic Field $\theta = 90^\circ$

$\tau = NIAB$. (independent of θ)

42. The hysteresis loop of material depends not only on the nature of material but also on the history of its magnetization cycles. Suggest a use of this property of material.

Ans. The value of magnetization is record/memory of its cycles of magnetisation. If information bits can be made correspond to these cycles, the system displaying such hysteresis loop can act as a device for storing information's.

43. A wire in the form of a tightly wound Solenoid is connected to a DC source, and carries a current. If the coil is stretched so that there are gaps between successive elements of the spiral coil, will the current increase or decrease ? Explain ?

Ans. When the coil is stretched so that there are gaps between successive elements of the spiral coil *i.e.* the wires are pulled apart which lead to the flux leak through the gaps. According to Lenz's law, the e.m.f. produced must oppose this decrease, which can be done by an increase in current. So, the current will increase.

44. Show that the induced charge does not depend upon rate of change of flux.

Ans.

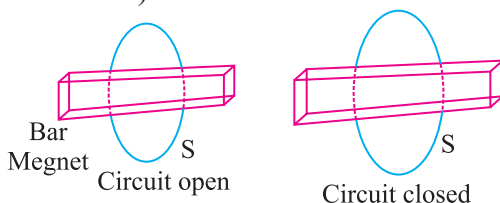
$$|E| = N \frac{d\phi}{dt}$$

$$i = \frac{E}{R} = \frac{N}{R} \frac{d\phi}{dt}$$

$$\frac{dq}{dt} = \frac{N}{R} \frac{d\phi}{dt}$$

$$\therefore dq = \frac{N}{R} d\phi$$

45. Consider a magnet surrounded by a wire with an on/off switch S (figure). If the switch is thrown from the 'off' position (open circuit) to the 'on' position (Closed circuit) will a current flow in the circuit ? Explain.



Ans. $\phi = BA \cos \theta$ so flux linked will change only when either B or A or the angle between B and A change.

When switch is thrown from off position to the on position, then neither B nor A nor the angle between A and B change. Thus there is no change in magnetic flux linked with the coil, hence no electromotive force (e.m.f.) is produced and consequently no current will flow in the circuit.

Short answers Questions (3 marks)

1. Derive the expression for force between two infinitely long parallel straight wires carrying current in the same direction. Hence define 'ampere' on the basis of above derivation.
2. Define (i) Hysteresis (ii) Retentivity (iii) Coercivity
3. Distinguish between diamagnetic, paramagnetic and ferromagnetic substances in terms of susceptibility and relative permeability.
4. Name all the three elements of earth magnetic field and define them with the help of relevant diagram.
5. Describe the path of a charged particle moving in a uniform magnetic field with initial velocity
 - (i) parallel to (or along) the field.
 - (ii) perpendicular to the field.
 - (iii) at an arbitrary angle θ ($0^\circ < \theta < 90^\circ$).
6. Obtain an expression for the magnetic moment of an electron moving with a speed ' v ' in a circular orbit of radius ' r '. How does the magnetic moment change when :
 - (i) the frequency of revolution is doubled?
 - (ii) the orbital radius is halved?
7. State Ampere, circuital law. Use the law to obtain an expression for the magnetic field due to a toroid.
8. Obtain an expression for magnetic field due to a long solenoid at a point inside the solenoid and on the axis of solenoid.
9. Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.
10. Derive an expression for magnetic field intensity due to a bar magnet (magnetic dipole) at any point (i) Along its axis (ii) Perpendicular to the axis.
11. Derive an expression for the torque acting on a loop of N turns of area A of each turn carrying current I, when held in a uniform magnetic field B.
12. How can a moving coil galvanometer be converted into a voltmeter of a given range. Write the necessary mathematical steps to obtain the value of resistance required for this purpose.

13. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having n turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

Ans. When there is only one turn, the magnetic field at the centre,

$$B = \frac{\mu_0 I}{2a}$$

$$2\pi a' \times n = 2\pi a \Rightarrow a' = a/n$$

$$\text{The magnetic field at its centre, } B_1 = \frac{\mu_0 n I}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B$$

The ratio is, $B_1/B = n^2$

14. Obtain an expression for the self inductance of a straight solenoid of length l and radius r ($l \gg r$).
15. Distinguish between : (i) resistance and reactance (ii) reactance and impedance.
16. In a series L–C–R circuit X_L , X_C and R are the inductive reactance, capacitive reactance and resistance respectively at a certain frequency f . If the frequency of a.c. is doubled, what will be the values of reactances and resistance of the circuit?

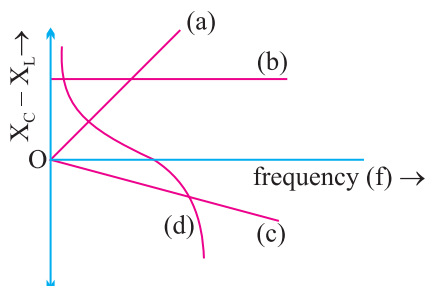
Ans. [Hint : $X_L = \omega L$, $X_C = \frac{1}{\omega C}$, R independent]

17. What are eddy currents? Write their any four applications.
18. In a series L–R circuit, $X_L = R$ and power factor of the circuit is P_1 . When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2 . Find P_1/P_2 .

Ans. [Hint $P = \cos \theta = \frac{R}{Z}$]

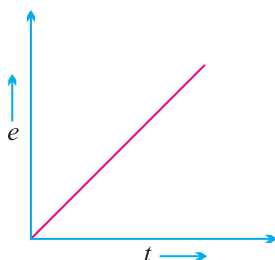
19. Instantaneous value of a.c. voltage through an inductor of inductance L is $e = e_0 \cos \omega t$. Obtain an expression for instantaneous current through the inductor. Also draw the phasor diagram.
20. In an inductor of inductance L , current passing is I_0 . Derive an expression for energy stored in it. In what forms is this energy stored?

21. Which of the following curves may represent the reactance of a series LC combination.



22. A sinusoidal e.m.f. device operates at amplitude E_0 and frequency ν across a purely (1) resistive (2) capacitive (3) inductive circuit. If the frequency of driving source is increased. How would (a) amplitude E_0 and (b) amplitude I_0 increase, decrease or remain same in each case?
23. 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.

Ans. Hint : $e = B/v$ and $v = gt$



24. In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T then :
- at what time is the energy stored completely electrical
 - at what time is the energy stored completely magnetic
 - at what time is the total energy shared equally between the inductor and capacitor.

Ans. (i) $t = 0, T/2, 3T/2, \dots$

(ii) $t = T/4, 3T/4, 5T/4, \dots$

(iii) $t = \frac{T}{8}, \frac{3T}{8}, \frac{5T}{8}, \dots$

25. An alternating voltage of frequency f is applied across a series LCR circuit. Let f_r be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when (i) $f > f_r$ (ii) $f < f_r$ (iii) $f = f_r$? Explain your answer in each case.

Ans. (i) Current will lag because.

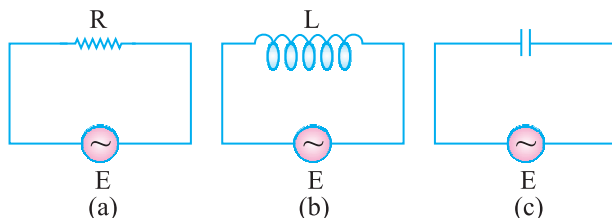
$$V_L < V_C \text{ Hence } V_L - V_C > 0$$

(ii) Current will lead, because.

$$V_L > V_C \text{ Hence } V_L - V_C < 0$$

(iii) In phase

26. Figure (a), (b), (c) show three alternating circuits with equal currents. If the frequency of alternating emf be increased, what will be the effect on current in the three cases? Explain.

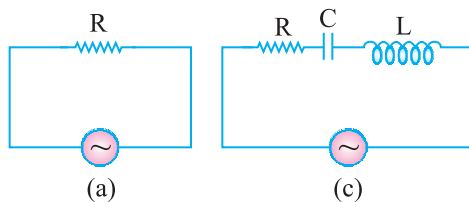


Ans. (i) No effect, R is not affected by frequency.

(ii) Current will decrease as X_L increase.

(iii) Current will increase as X_C decrease.

27. Study the circuit (a) and (b) shown in the figure and answer the following questions.



(a) Under which condition the rms current in the two circuits to be the same?

(b) Can the r.m.s. current in circuit (b) larger than that of in (a) ?

Ans.
$$I_{\text{rms(a)}} = \frac{V_{\text{rms}}}{R} = \frac{V}{R} \quad I_{\text{rms(b)}} = \frac{V_{\text{rms}}}{Z} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$(a) \quad I_{\text{rms(a)}} = I_{\text{rms(b)}}$$

when $X_L = X_C$ (resonance condition)

$$\frac{I_{\text{rms(a)}}}{I_{\text{rms(b)}}} = \frac{Z}{R} = 1$$

(b) As $z \geq R$

$$I_{\text{rms(a)}} \geq I_{\text{rms(b)}}$$

No, the rms current in circuit (b), cannot be larger than that in (a).

28. Can the instantaneous power output of an AC source ever be negative ?

Can average power output be negative ? Justify your answer.

Ans. Yes, Instantaneous power output of an AC source can be negative.

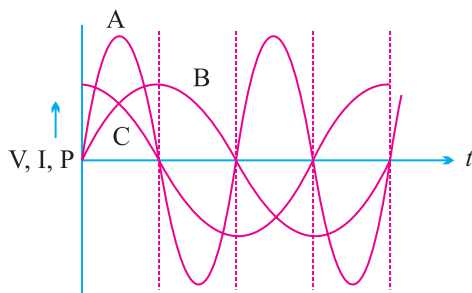
$$\text{Instantaneous power output } P = EI = \frac{E.I.}{2} [\cos \phi - \cos (2\omega t + \phi)]$$

$$\text{No, } P_{\text{avc}} = V_{\text{rms}} I_{\text{rms}} \cos \phi$$

$$P_{\text{avc}} > 0$$

$$\cos \phi = \frac{R}{Z} > 0$$

29. A device 'X' is connected to an AC source. The variation of voltage, current and power in one complete cycle is shown in fig.



(a) Which curves shows power consumption over a full cycle?

(b) What is the average power consumption over a cycle?

(c) Identify the device X if curve B shows voltage.

Ans. (a) A (a curve of power have a max. Amplitude of V and I)

(b) Zero.

(c) as average power is zero the device is a capacitor.

LONG ANSWER QUESTIONS (5 MARKS)

1. How will a diamagnetic, paramagnetic and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide suitability for making.
(i) Permanent magnet (ii) Electromagnet.
2. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance d from the centre of a circular coil of radius ' a ' and carrying current I . Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of d is $\sqrt{3}a$.
3. Write an expression for the force experienced by a charged particle moving in a uniform magnetic field B . With the help of diagram, explain the principle and working of a cyclotron. Show that cyclotron frequency does not depend on the speed of the particle.
- *4. Write the principle, working of a moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phosphor bronze used in the construction of moving coil galvanometer?
5. Draw a labelled diagram to explain the principle and working of an a.c. generator. Deduce the expression for emf generated. Why cannot the current produced by an a.c. generator be measured with a moving coil ammeter?
6. Explain, with the help of a neat and labelled diagram, the principle, construction and working of a transformer.
7. An L-C circuit contains inductor of inductance L and capacitor of capacitance C with an initial charge q_0 . The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.
 - (i) What is the total energy stored initially?
 - (ii) What is the maximum current through inductor?
 - (iii) What is the frequency at which charge on the capacitor will oscillate?
 - (iv) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

8. An a.c. $i = i_0 \sin \omega t$ is passed through a series combination of an inductor (L), a capacitor (C) and a resistor (R). Use the phasor diagram to obtain expressions for the (a) impedance of the circuit and phase angle between voltage across the combination and current passed in it. Hence show that the current
- (i) leads the voltage when $\omega < \frac{1}{\sqrt{LC}}$
- (ii) is in phase with voltage when $\omega = \frac{1}{\sqrt{LC}}$.
9. Write two differences in each of resistance, reactance and impedance for an ac circuit. Derive an expression for power dissipated in series LCR circuit.

NUMERICALS

- An electron travels on a circular path of radius 10 m in a magnetic field of 2×10^{-3} T. Calculate the speed of electron. What is the potential difference through which it must be accelerated to acquire this speed?
[Ans. Speed = 3.56×10^9 m/s; V = 3.56×10^7 volts]
- A charge particle of mass m and charge q entered into magnetic field B normally after accelerating by potential difference V. Calculate radius of its circular path.
[Ans. $r = \frac{1}{B} \sqrt{\frac{2mv}{q}}$]
- Calculate the magnetic field due to a circular coil of 500 turns and of mean diameter 0.1m, carrying a current of 14A (i) at a point on the axis distance 0.12 m from the centre of the coil (ii) at the centre of the coil.
[Ans. (i) 5.0×10^{-3} Tesla; (ii) 8.8×10^{-2} Tesla]
- An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli tesla. Calculate the time period of rotation of the electron in the magnetic field.
[Ans. 4.467×10^{-8} s.]
- If the current sensitivity of a moving coil galvanometer is increased by 20% and its resistance also increased by 50% then how will the voltage sensitivity of the galvanometer be affected? [Ans. 25% decrease]

6. A uniform wire is bent into one turn circular loop and same wire is again bent in two circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres.

[Ans. Increased 4 times]

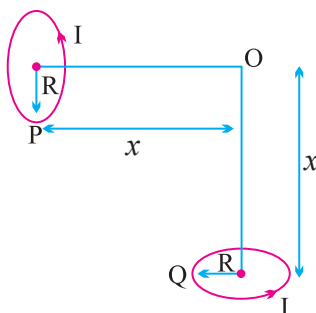
7. A horizontal electrical power line carries a current of 90A from east to west direction. What is the magnitude and direction of magnetic field produced by the power line at a point 1.5 m below it?

[Ans. 1.2×10^{-5} T South ward]

8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 25mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be converted?

[Ans. 1910Ω in series]

9. Two identical circular loops P and Q carrying equal currents are placed such that their geometrical axis are perpendicular to each other as shown in figure. And the direction of current appear's anticlockwise as seen from point O which is equidistant from loop P and Q. Find the magnitude and direction of the net magnetic field produced at the point O.



$$\tan \theta = \frac{B_2}{B_1} = 1, \theta = \pi/4.$$

[Ans. $\frac{\mu_0 I R^2 \sqrt{2}}{2(R^2 + x^2)^{3/2}}$]

10. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons, if the radius of its dees is 60 cm ? What is the kinetic energy of the proton beam produced by the accelerator? Given $e = 1.6 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg. Express your answer in units of MeV [$1\text{MeV} = 1.6 \times 10^{-13}$ J].

[Ans. $B = 0.656\text{T}$, $E_{\text{max}} = 7.421 \text{ MeV}$]

11. The coil of a galvanometer is $0.02 \times 0.08 \text{ m}^2$. It consists of 200 turns of fine wire and is in a magnetic field of 0.2 tesla. The restoring torque

constant of the suspension fibre is 10^{-6} Nm per degree. Assuming the magnetic field to be radial.

- (i) What is the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection?
- (ii) What is the smallest, current that can be detected if the minimum observable deflection is 0.1° ?

[Ans. (i) 4.69×10^{-4} A; (ii) 1.56×10^{-6} A]

12. A voltmeter reads 5V at full scale deflection and is graded according to its resistance per volt at full scale deflection as $5000\Omega V^{-1}$. How will you convert it into a voltmeter that reads 20V at full scale deflection? Will it still be graded as $5000\Omega V^{-1}$? Will you prefer this voltmeter to one that is graded as $2000\Omega V^{-1}$?

[Ans. $7.5 \times 10^4\Omega$]

13. A short bar magnet placed with its axis at 30° with an external field 1000G experiences a torque of 0.02 Nm. (i) What is the magnetic moment of the magnet. (ii) What is the work done in turning it from its most stable equilibrium to most unstable equilibrium position?

[Ans. (i) 0.4 Am^2 ; (ii) 0.08 J]

14. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 4 cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is a 0.5Am^2 .

[Ans. $B_E = 7.8125 \times 10^{-7}\text{ T}$; $B_A = 15.625 \times 10^{-7}\text{ T}$]

15. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of 30° with the direction of a uniform magnetic field of 0.15T?

16. Two moving coil galvanometers, M_1 and M_2 have the following specifications.

$$R_1 = 10\Omega, N_1 = 30, A_1 = 3.6 \times 10^{-3}\text{m}^2, B_1 = 0.25\text{T}$$

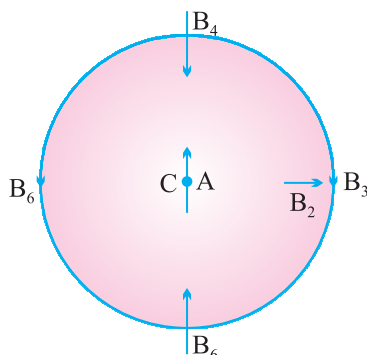
$$R_2 = 14\Omega, N_2 = 42, A_2 = 1.8 \times 10^{-3}\text{m}^2, B_2 = 0.50\text{T}$$

Given that the spring constants are the same for the two galvanometers, determine the ratio of (a) current sensitivity (b) voltage sensitivity of M_1 & M_2 .

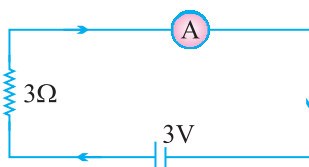
[Ans. (a) 5/7 (b) 1:1]

17. In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows

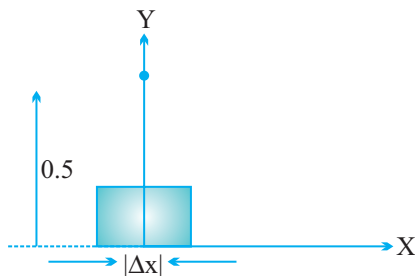
shown different positions and orientations of the magnetic moment of another identical magnetic needs B.



- In which configuration is the systems not in equilibrium?
 - In which configuration is the system.
 - stable and (ii) unstable equilibrium?
 - Which configuration corresponds to the lowest potential energy among all the configurations shown?
18. In the circuit, the current is to be measured. What is the value of the current if the ammeter shown :



- is a galvanometer with a resistance $R_G = 60 \Omega$,
 - is a galvanometer described in (i) but converted to an ammeter by a shunt resistance $r_s = 0.02\Omega$
 - is an ideal ammeter with zero resistance?
19. An element $\Delta l = \Delta x \cdot \hat{i}$ 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 0.5 m. $\Delta x = 1 \text{ cm}$.



20. A straight wire of mass 200 g and length 1.5 m 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?
21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop ?

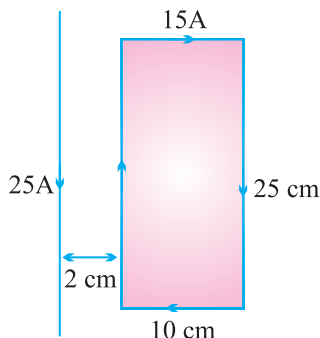
[Ans. 7.82×10^{-4} N towards the conductor]

Hint :

$$F_1 = \frac{\mu_0}{4\pi} \frac{2I_1 I_2}{r_1} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.02} = 9.38 \times 10^{-4} \text{ N attractive}$$

$$F_2 = \frac{\mu_0}{4\pi} \frac{2I_1 I_2}{r_2} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.12} = 1.56 \times 10^{-4} \text{ N repulsive}$$

$$\text{Net } F = F_1 - F_2 = 7.82 \times 10^{-4} \text{ N}$$



22. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6 \text{ ms}^{-1}$ normal to the field. Explain why the path of electron is a circle.
- (a) Determine the radius of the circular orbit ($e = 1.6 \times 10^{-19} \text{ C}$, $m_e = 9.1 \times 10^{-31} \text{ kg}$)
- (b) Obtain the frequency of revolution of the electron in its circular orbit.

Hint : (a) $r = \frac{m_e v}{eB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2 \text{ cm}$

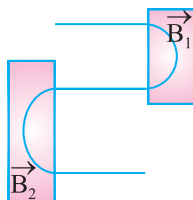
(b) frequency $\nu = \frac{1}{T} = \frac{eB}{2\pi m_e} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18 \text{ MHz}$

23. The horizontal and vertical components of earth's magnetic field at a place are 0.22G and 0.38G respectively. Calculate the angle of dip and resultant intensity of earth's field.

Hint : $\tan \delta = \frac{B_v}{B_H} = \frac{0.38}{0.22} = 1.73 = 60^\circ$, $B = \sqrt{B_H^2 + B_v^2} = 0.44 \text{ G}$

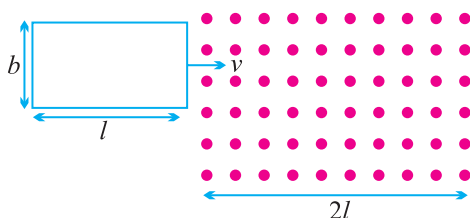
24. Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude B_1 and B_2 . Its path in each region is a half circle. (a) which field is stronger? (b) What are the directions of two fields? (c) Is the time spent by the electron in the \vec{B}_1 region greater than, less than, or the same as the time spent in \vec{B}_2 region?

[Ans. (a) $B_1 > B_2$; (b) B_1 inward; B_2 outward (c) Time spent in $B_1 <$ Time spent in B_2]



25. In a series C–R circuit, applied voltage is $V = 110 \sin 314t$ volt. What is the (i) The peak voltage (ii) Average voltage over half cycle ?
26. Magnetic flux linked with each turn of a 25 turns coil is 6 milliweber. The flux is reduced to 1 mWb in 0.5s. Find induced emf in the coil.
27. The current through an inductive circuit of inductance 4mH is $i = 12 \cos 300t$ ampere. Calculate :
- Reactance of the circuit.
 - Peak voltage across the inductor.
28. A power transmission line feeds input power at 2400 V to a step down ideal transformer having 4000 turns in its primary. What should be number of turns in its secondary to get power output at 240V?
29. The magnetic flux linked with a closed circuit of resistance 8Ω varies with time according to the expression $\phi = (5t^2 - 4t + 2)$ where ϕ is in milliweber and t in second. Calculate the value of induce current at $t = 15 \text{ s}$.

30. A capacitor, a resistor and 4 henry inductor are connected in series to an a.c. source of 50 Hz. Calculate capacitance of capacitor if the current is in phase with voltage.
31. A series C–R circuit consists of a capacitance 16 mF and resistance 8Ω . If the input a.c. voltage is (200 V, 50 Hz), Calculate (i) voltage across capacitor and resistor. (ii) Phase by which voltage lags/leads current.
32. A rectangular conducting loop of length l and breadth b enters a uniform magnetic field B as shown below.



The loop is moving at constant speed v and at $t = 0$ it just enters the field B . Sketch the following graphs for the time interval $t = 0$ to

$$t = \frac{3l}{v}.$$

- (i) Magnetic flux versus time
- (ii) Induced emf versus times
- (iii) Power versus time

Resistance of the loop is R .

33. A charged 8mF capacitor having charge 5mC is connected to a 5mH inductor. What is :
- (i) the frequency of current oscillations?
 - (ii) the frequency of electrical energy oscillations in the capacitor?
 - (iii) the maximum current in the inductor?
 - (iv) the magnetic energy in the inductor at the instant when charge on capacitor is 4mC?
34. A 31.4Ω resistor and 0.1H inductor are connected in series to a 200V, 50Hz ac source. Calculate
- (i) the current in the circuit
 - (ii) the voltage (rms) across the inductor and the resistor.
 - (iii) is the algebraic sum of voltages across inductor and resistor more than the source voltage ? If yes, resolve the paradox.

35. A square loop of side 12 cm with its sides parallel to X and Y-axis is moved with a velocity of 8 cm/s in positive x-direction. Magnetic field exists in z-directions.

- Determine the direction and magnitude of induced emf if the field changes with 10^{-3} Tesla/cm along negative z-direction.
- Determine the direction and magnitude of induced emf if field changes with 10^{-3} Tesla/s along +z direction.

Ans. (i) Rate of change of flux = induced emf

$$= (0.12)^2 \times 10^{-3} \times 8$$

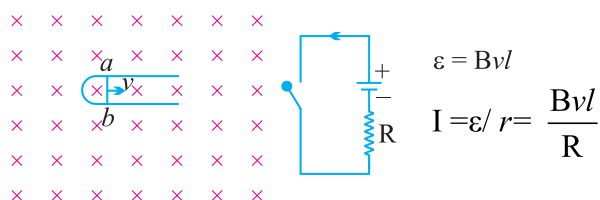
$$= 11.52 \times 10^{-5} \text{ Wb/s in } +z \text{ direction.}$$

(ii) Rate of change of flux = induced emf

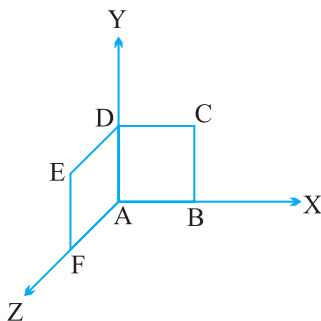
$$= (0.12)^2 \times 10^{-3} \times 8$$

$$= 11.52 \times 10^{-5} \text{ Wb/s in } -z \text{ direction.}$$

36. Figure shows a wire ab of length l which can slide on a U-shaped rail of negligible resistance. The resistance of the wire is R . The wire is pulled to the right with a constant speed v . Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire.



37. 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 $B = B_0 (\hat{i} + \hat{k})$ T is present in the region. Find the flux passing through the loop ABCDEFA?



Ans. Loop ABCDA lie in x - y plane whose area vector $A_1 = L^2 \hat{k}$ where ADEFA lie in y - z plane where are vector $A_2 = L^2 \hat{i}$

$$\phi = \mathbf{B} \cdot \mathbf{A}, \quad \mathbf{A} = \mathbf{A}_1 + \mathbf{A}_2 = (L^2 \hat{k} + L^2 \hat{i})$$

$$\mathbf{B} = B_0 (\hat{i} + \hat{k})(L^2 \hat{k} + L^2 \hat{i}) = 2 B_0 L^2 \text{ Wb.}$$

- 38.** A coil of 0.01 H inductance and 1Ω resistance is connected to 200V, 50 Hz AC supply. Find the impedance and time lag between maximum alternating voltage and current.

Ans. $Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi fL)^2} = 3.3\Omega$

$$\tan \phi = \frac{\omega L}{R} = \frac{2\pi fL}{R} = 3.14$$

$$\phi \cong 72^\circ$$

$$\text{Phase diff. } \phi = \frac{72 \times \pi}{180} \text{ rad.}$$

$$\omega = \frac{\Delta\phi}{\Delta t}, \text{ time lag } \Delta t = \frac{\phi}{\omega}$$

$$= \frac{72\pi}{180 \times 2\pi \times 50} = \frac{1}{250} \text{ s}$$

- 39.** An electrical device draws 2 KW power from AC mains (Voltage = 223V,

$$V_{\text{rms}} = \sqrt{50000\text{V}}). \text{ The current differ (lags) in phase by } \phi \left(\tan \phi = \frac{-3}{4} \right)$$

as compared to voltage. Find

- (a) R
- (b) $X_C - X_L$
- (c) I_m

Ans. $P = 2\text{KW} = 2000\text{W}$; $\tan \phi = \frac{-3}{4}$; $I_m = I_0$? $R = ?$ $X_C - X_L = ?$

$$V_{\text{rms}} = V = 223\text{V}$$

$$Z = \frac{V^2}{P} = 25\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$625 = R^2 + (X_L - X_C)^2$$

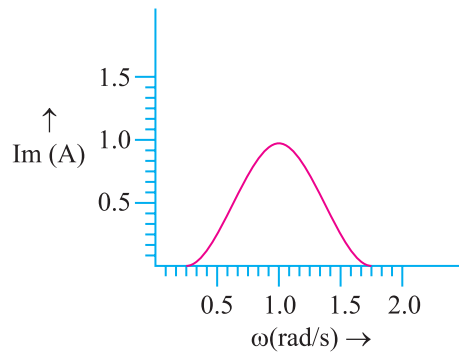
Again $\tan \phi = \frac{X_L - X_C}{R} = \frac{3}{4}$

$$X_L - X_C = \frac{3R}{4}$$

using this $R = 20\Omega$; $X_L - X_C = 15\Omega$, $I = \frac{V}{Z} = \frac{223}{25} = 8.92 \text{ A}$,

$$I_m = \sqrt{2} I = 12.6 \text{ A}$$

40. In a LCR circuit, the plot of I_{\max} versus ω is shown in figure. Find the bandwidth ?



Ans. $I_{\text{rms}} = \frac{I_{\max}}{\sqrt{2}} = \frac{1}{\sqrt{2}} = 0.7 \text{ A}$

from diagram $\omega_1 = 0.8 \text{ rad/s}$

$$\omega_2 = 1.2 \text{ rad/s}$$

$$\Delta\omega = 1.2 - 0.8 = 0.4 \text{ rad/s}$$

41. An inductor of unknown value, a capacitor of $100\mu\text{F}$ and a resistor of 10Ω are connected in series to a 200V , 50Hz ac source. It is found that the power factor of the circuit is unity. Calculate the inductance of the inductor and the current amplitude.

Ans. $L = 0.10 \text{ H}$, $I_0 = 28.3 \text{ A}$

42. A 100 turn coil of area 0.1 m^2 rotates at half a revolution per second.

It is placed in a magnetic field of 0.01 T perpendicular to the axis of rotation of the coil. Calculate max. e.m.f. generated in the coil.

Ans. $\varepsilon_0 = 0.314 \text{ Volt}$.

43. The magnetic flux linked with a large circular coil of radius R is $0.5 \times 10^{-3} \text{ Wb}$, when current of 0.5 A flows through a small neighbouring coil of radius r . Calculate the coefficient of mutual inductance for the given pair of coils.

If the current through the small coil suddenly falls to zero, what would be the effect in the larger coil.

Ans. $M = 1 \text{ mH}$.

If the current through small coil suddenly falls to zero, [as, $e_2 = -M$

$\frac{di_1}{dt}$] so initially large current is induced in larger coil, which soon becomes zero.

2 MARKS QUESTIONS

$$2. S = \frac{I_g}{(I - I_g)} G = \frac{5 \times 10^{-3}}{5 - 5 \times 10^{-3}} \times 120 = 0.12 \Omega.$$

3. (i) $-mB$ (ii) zero

$$4. (i) B = \frac{10^{-7} \times \pi \times 10}{2 \times 10^{-2}} = 5\pi \times 10^{-5} \text{ T (inwards).}$$

(ii) $B = 5\pi \times 10^{-5} \text{ T (inwards).}$

$$5. r_p = \frac{mv}{qB} \text{ and } r_\alpha = \frac{4mv}{(2q)B} = 2r_\alpha \Rightarrow \frac{r_p}{r_\alpha} = \frac{1}{2}.$$

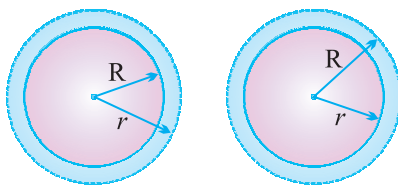
7. Low Retentivity and high permeability.

8. Minimum potential = $-MB$ when $\theta = 0$ (most stable position)

Maximum potential = MB when $\theta = 180^\circ$ (most unstable position).

9. (a) Pole strength same; magnetic moment half.

(b) Pole strength half; magnetic moment half.



$$10. \quad B (2\pi r) = \mu_0 \left[\frac{I}{\pi R^2} (\pi r^2) \right]$$

$$B = \left(\frac{\mu_0 I}{2\pi R^2} \right) r \quad (R \geq r)$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

$$\therefore \quad B = \frac{\mu_0 I}{2\pi r} \quad (r \geq R)$$

$$11. \quad M_1 = NI\pi R^2; M_2 = NIa^2 \quad \therefore \quad \frac{M_2}{M_1} = \frac{a^2}{R^2}$$

$$2\pi rN = 4aN \Rightarrow a = \frac{\pi R}{2}$$

$$\frac{M_2}{M_1} = \pi/4$$

$$12. \quad \frac{m_{new}}{m_{original}} = \frac{2I \times \pi \left(\frac{r}{2} \right)^2}{I \times \pi R^2} = \frac{1}{2} \quad (\text{As } N_2 = 2N_1)$$

$$13. \quad 2B, B\sqrt{3}.$$

$$16. (a) \oint \vec{B} \cdot d\vec{l} = \mu_0 I = 2\mu_0 Tm$$

(b) zero

22. (i) $a = g$ because the induced emf set up in the coil does not produce any current and hence no opposition to the falling bar magnet.

(ii) $a < g$ because of the opposite effect caused by induced current.

$$23. \quad \text{Current at resonance } I = \frac{V}{R}.$$

$$\therefore \text{Voltage across inductor } V_L = I.X_L = I\omega L = \frac{V}{R} (2\pi\nu) L.$$

24. A.C. ammeter works on the principle of heating effect $H \propto I^2$.

25. Brightness of bulb depends on current. $P \propto I^2$ and

$$I = \frac{V}{Z} \text{ where } Z = \sqrt{X_c^2 + R^2} \text{ and}$$

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

$X_C \propto \frac{1}{C}$, when mica sheet is introduced capacitance C increases

$$\left(C = \frac{K \epsilon_0 A}{d} \right),$$

X_C decreases, current increases and therefore brightness increases.

26. Current $I = \mathcal{E}/R$

$$\text{In coil P, } I_1 = \mathcal{E}_1/R = \frac{Bvb}{R}$$

$$\text{In coil Q, } I_2 = \mathcal{E}_2/R = \frac{Bvl}{R} \qquad I_1/I_2 = \frac{b}{l}.$$

27. Electro magnetic energy is conserved.

$$\mu_E(\text{max}) = \mu_B(\text{max})$$

$$\frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} LI^2$$

$$I = 637 \text{ mA}$$

28. 10^{-6} F .

40. No current is induced in coil A since angle is 90° .

ANSWER FOR NUMERICALS

15. Force experienced by current carrying conductor in magnetic field.

$$F = \vec{IL} \times \vec{B} = IBL \sin \theta$$

Hence, force per unit length, $f = \frac{F}{L} IB \sin 30^\circ$

$$= 8 \times 0.15 \times 1/2 = 0.6 \text{ Nm}^{-1}$$

16. (a) Current sensitivity, $\frac{\phi}{I} = \frac{NBA}{K}$

Ratio of current Sensitivity = $\left(\frac{N_1 B_1 A_1}{K} \right) / \left(\frac{N_2 B_2 A_2}{K} \right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = 5/7$$

(b) Voltage sensitivity, $\frac{\phi}{V} = \frac{NBA}{kR}$

Ratio of voltage sensitivity = $\left(\frac{N_1 B_1 A_1}{kR_1} \right) / \left(\frac{N_2 B_2 A_2}{kR_2} \right)$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1$$

17. (a) For equilibrium, the dipole moment should be parallel or anti parallel to B. Hence, AB_1 and AB_2 are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : AB_5 and AB_6 (ii) for unstable equilibrium, the dipole moment should be anti parallel examples : AB_3 and AB_4 .

(c) Potential energy is minimum when angle between M and B is 0° , i.e., $U = -MB$ Example : AB_6 .

18. (a) Total resistance, $R_G + 3 = 63\Omega$.

Hence, $I = \frac{3V}{63\Omega} = 0.048A$

(b) Resistance of the galvanometer as ammeter is

$$\frac{R_G r_s}{R_G + r_s} = \frac{60\Omega \times 0.02\Omega}{(60 + 0.02)} = 0.02\Omega$$

Total resistance $R = 0.02\Omega + 3\Omega = 3.02\Omega$

$$\text{Hence, } I = \frac{3}{302} = 0.99\text{A.}$$

- (c) For the ideal ammeter, resistance is zero, the current,
 $I = 3/3 = 1.00\text{A.}$

19. From Biot-Savart's Law, $\left| \overrightarrow{dB} \right| = Id\ell \sin \theta / r^2$

$$dI = \Delta x = 1 \text{ cm} = 10^{-2} \text{ m, } I = 10\text{A, } r = y = 0.5 \text{ m}$$

$$\mu_0/4\pi = 10^{-7} \text{ Tm/A, } \theta = 90^\circ \text{ so } \sin \theta = 1$$

$$\left| \overrightarrow{dB} \right| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8} \text{ T along } +z \text{ axis}$$

20. Force experienced by wire $F_m = BIl$ (due to map field)
 The force due to gravity, $F_g = mg$

$$mg = BIl \Rightarrow B = mg/Il = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657 \text{ T}$$

[Earth's mag. field $4 \times 10^{-5} \text{ T}$ is negligible]

25. (i) $V_0 = 110 \text{ volt}$

$$(ii) V_{av1/2} = \frac{2V_0}{\pi} = \frac{2 \times 110 \times 7}{22} = 70 \text{ volt.}$$

26. Induced emf $\varepsilon = -N \frac{d\phi}{dt} = -25 \frac{(1-6) \times 10^{-3}}{.5} = 0.25 \text{ volt.}$

27. (i) Reactance $X_L = \omega L = 300 \times 4 \times 10^{-3} = 1.2 \Omega$.

$$(ii) \text{ Peak Voltage } V_0 = i_0 X_L = 12 \times 1.2 = 14.4 \text{ volt.}$$

28. In ideal transformer $P_{in} = P_0$

$$V_P I_P = V_S I_S$$

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \quad N_S = \left(\frac{V_S}{V_P} \right) N_P = \frac{240}{2400} \times 4000 = 400$$

29. Induced current $I = \varepsilon/R$

$$\text{where } \varepsilon = \frac{-d\phi}{dt} = -10t + 4$$

$$\varepsilon = -10(15) + 4 = -146 \text{ mV}$$

where $\phi = 5t^2 - 4t + 2$ and $R = 8\Omega$

$$\therefore I = -\frac{.146}{8} \text{ A} = -.018 \text{ A}$$

30. When V and I in phase

$$X_L = X_C, \quad v = \frac{1}{2\pi\sqrt{LC}}$$

$$C = \frac{1}{4\pi^2 v^2 L} = \frac{1}{4\pi^2 \times 50 \times 50 \times \frac{4}{\pi^2}}$$

$$= 2.5 \times 10^{-5} = 25 \mu\text{F}.$$

31. Current in the circuit $I = \frac{V}{Z}$

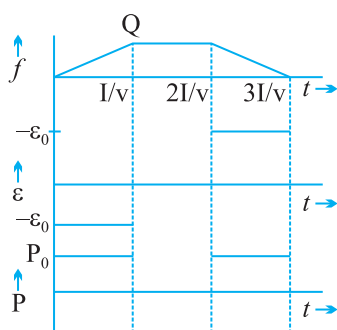
$$\text{When } Z = \sqrt{X_C^2 + R^2}, \quad X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$$

Then total voltage across capacitor and resistor.

$$V_C = iX_C, \quad V_R = IR.$$

$$(ii) \quad \tan \phi = \frac{X_C}{R} \quad [V \text{ lags current}]$$

32.



$$(i) \quad \phi = Blb$$

$$(ii) \quad \varepsilon_0 = Bvb$$

$$(iii) \quad P_0 = \frac{\varepsilon_0^2}{R}$$

$$= \frac{B^2 v^2 b^2}{R}$$

33. (i) Frequency of current oscillations

$$v = \frac{1}{2\pi\sqrt{LC}}$$

(ii) Frequency of electrical energy oscillation $\nu_c = 2\nu$

(iii) Maximum current in the circuit $I_0 = \frac{q_0}{\sqrt{LC}}$

(iv) Magnetic energy in the inductor when charge on capacitor is $4mC$.

$$U_L = U - U_C = \frac{1}{2} \frac{q_0^2}{C} - \frac{1}{2} \frac{q^2}{C} = \frac{q_0^2 - q^2}{2C}$$

Here $q_0 = 5mC$; $q = 4mC$

34. Current in the circuit :

(i) $I = \frac{V}{Z}$, where $Z = \sqrt{X_L^2 + R^2}$

(ii) RMS voltage across L and R

$$V_L = I \cdot X_L;$$

$$V_R = IR$$

(iii) $(V_L + V_R) > V$ because V_L and V_R are not in same phase.



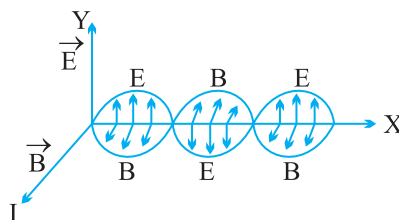


Unit V & VI

ELECTROMAGNETIC WAVES AND OPTICS

KEY POINTS

1. EM waves are produced by accelerated (only by the change in speed) charged particles.
2. \vec{E} and \vec{B} vectors oscillate with the frequency of oscillating charged particles.
3. Propagation of wave along x -direction.



4. Properties of em waves :
 - (i) Transverse nature
 - (ii) Can travel though vacuum.
 - (iii) $\frac{E_0}{B_0} = \frac{E}{B} = \lambda\nu = C$ $C \rightarrow$ Speed of EM waves.
 - (iv) Speed of em wave $C = 3 \times 10^8$ m/s in vacuum and

$$C = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \text{ m/sec (in vacuum)}$$

(v) In any medium $V = \frac{1}{\sqrt{\mu\epsilon}}$

Where $\mu = \mu_r \mu_0$ $\epsilon = \epsilon_r \epsilon_0$

$\sqrt{\epsilon_r} = n$ refractive index of medium

Also $V = \frac{c}{n}$

(vi) A material medium is not required for the propagation of e.m. waves.

(vii) Wave intensity equals average of Pointing vector $I = |\vec{S}|_{av} \frac{B_0 E_0}{2\mu_0}$.

(viii) Average electric and average magnetic energy densities are equal.

$$U_E = \frac{1}{2} \epsilon_0 E^2 \text{ and } U_B = \frac{1}{2} \frac{B^2}{\mu_0}$$

(ix) The electric vector is responsible for optical effects due to electromagnetic wave. For this reason, electric vector is called light vector.

➤ In an em spectrum, different waves have different frequency and wavelengths.

➤ Penetration power of em waves depends on frequency. Higher, the frequency larger the penetration power.

➤ Wavelength λ and frequency ν are related with each other $v = \nu\lambda$. Here V is the wave velocity.

➤ A wave travelling along $+x$ axis is represented by

$$E_y = E_0 \cos(\omega t - kx)$$

$$B_z = B_0 \cos(\omega t - kx)$$

$$\omega = \frac{2\pi}{T} = 2\pi\nu$$

$$\frac{\omega}{k} = \lambda\nu = V = C \text{ wave speed}$$

$$k = \frac{2\pi}{\lambda} = 2\pi\bar{\nu}$$

$\nu \rightarrow$ frequency

$\bar{\nu} = \frac{1}{\lambda}$ wave number.

Electromagnetic Spectrum

Name	Wavelength range	Production	Uses
Gamma Rays	$< 10^{-12}$ m	Gamma rays produced in radio active decay of nucleus	in treatment of cancer and to carry out nuclear reactions.
x-rays	10^{-9} m to 10^{-12} m	x-ray tubes or inner shell electrons	used as diagnostic tool in medical to find out fractures in bones. to find crack, flaws in metal part of machine
UV rays	4×10^{-7} to 10^{-9} m	by very hot bodies like sun and by UV lamps	in water purifier in detection of forged documents, in food preservation.
Visible light	7×10^{-7} m to 4×10^{-7} m	by accelerated tiny (electrons) charge particles	to see every thing around us
IR rays	10^{-3} m to 7×10^{-7} m	due to vibration of atoms	in green houses to keep plant warm to reveal secret writings on walls in photography during fog and smoke
Microwaves	10^{-1} m to 10^{-3} m	produced in klystron Valve and magnetron Valve	in RADAR in microwave ovens
Radio waves	> 0.1 m	by accelerated charged particles excited electrical circuits excited	in radio telecommunication system in radio astrology

Displacement Current—Current produced due to time varying electric field or electric flux.

$$I_D = \epsilon_0 \frac{d\phi_e}{dt}, \text{ , } \phi_e \text{ is electric flux}$$

Modified Ampere's Circuital law by Maxwell

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(I_C + \epsilon_0 \frac{d\phi_e}{dt} \right)$$

$I_c \rightarrow$ Conduction current

$$I_C = I_D$$

OPTICS

RAY OPTICS

GIST

1. REFLECTION BY CONVEX AND CONCAVE MIRRORS

- a. Mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ where u is the object distance, v is the image distance and f is the focal length.
- b. Magnification $m = -\frac{v}{u} = \frac{f-v}{f} = \frac{f}{f-u}$ m is $-ve$ for real images and $+ve$ for virtual images.
- c. Focal length of a mirror depends up only on the curvature of the mirror $\left(f = \frac{R}{2}\right)$. It does not depend on the material of the mirror or on wave length of light.

2. REFRACTION

- d. Ray of light bends when it enters from one medium to the other, having different optical densities.
When light wave travels from one medium to another, the wave length and velocity changes but frequency of light wave remains the same.
- e. Sun can be seen before actual sunrise and after actual sun set due to Atmospheric refraction.
- f. An object under water (any medium) appears to be raised due to refraction when observed obliquely.

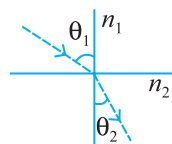
$$n = \frac{\text{Real depth}}{\text{apparent depth}} \quad n = \text{refractive index}$$

and normal shift in the position (apparent) of object is

$$x = t \left\{ 1 - \frac{1}{n} \right\} \quad \text{where } t \text{ is the actual depth of the medium.}$$

- g. Snell's law states that for a given colour of light, the ratio of sine of the angle of incidence to sine of angle of refraction is a constant, when light travels from one medium to another.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$



- h. Absolute refractive index is the ratio between the velocities of light in vacuum to velocity of light in medium. For air refractive index is 1.003 for practical uses taken to be 1

$$n = \frac{c}{v}$$

3. T.I.R.

- i. When a ray of light travels from denser to rarer medium and if the angle of incidence is greater than critical angle, the ray of light is reflected back to the denser medium. This phenomenon is called total internal reflection. (T.I.R.)

$$\sin C = \frac{n_R}{n_D}$$

Essential conditions for T.I.R.

1. Light should travel from denser to rarer medium.
 2. Angle of incidence must be greater than critical angle ($i > i_c$)
- j. Diamond has a high refractive index, resulting with a low critical angle ($C = 24.4^\circ$). This promotes a multiple total internal reflection causing its brilliance and luster. Working of an optical fibre and formation of mirage are the examples of T.I.R.
4. When light falls on a convex refracting surface, the relation among, u , v and R is given by $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$.
5. Lens maker formula for thin lens formula is given by

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1} \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

For Convex Lens $R_1 +ve$; $R_2 -ve$ and Concave lens $R_1 -ve$; $R_2 +ve$. The way in which a lens behaves as converging or diverging depends upon the values of n_2 and n_1 .

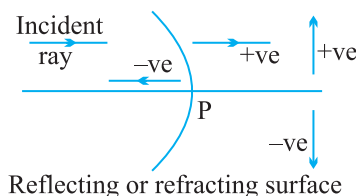
6. When two lenses are kept in contact the equivalent focal length is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \text{ and Power } P = P_1 + P_2$$

Magnification $m = m_1 \times m_2$

7. The lens formula is given by $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

Sign convention for mirrors and lenses → Distances in the direction of incident ray are taken as positive. All the measurement is done from pole (P).

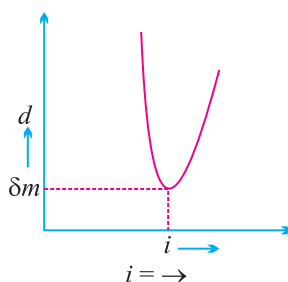


8. When ray of light passes through a glass prism it undergoes refraction, then $A + \delta = i + e$ and, the expression of refractive index of glass prism

$$n = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

As the angle of incidence increases, the angle of deviation decreases, reaches a minimum value and then increases. This minimum value of angle of deviation is called angle of minimum deviation “ δ_m ”.

9.



Where d is minimum, $i = e$, refracted ray lies parallel to the base. For a small angled prism $d_{\min} = (n - 1)A$.

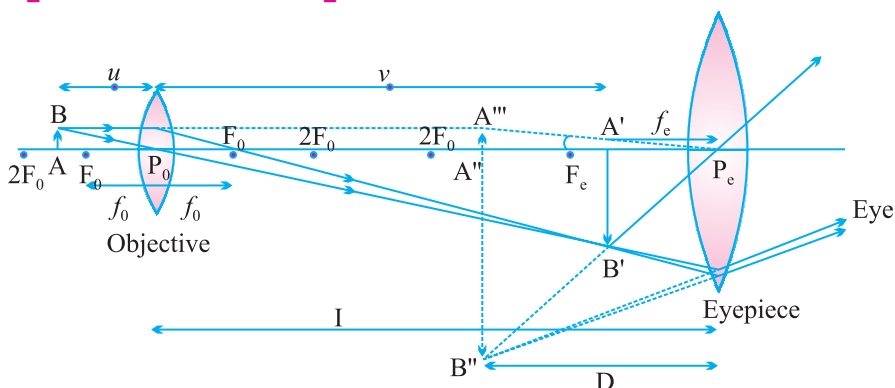
10. When white light is passed through a glass prism, it splits up into its constituent colours (Monochromatic). This phenomenon is called Dispersion.
11. Scattering of light takes place when size of the particle is very small as compared to the wavelength of light.

Intensity of scattered light is $I \propto \frac{1}{\lambda^4}$

The following properties or phenomena can be explained by scattering.

- (i) Sky is blue.
- (ii) Sun looks reddish at the time of sunrise and sunset.
- (iii) Red light used in danger mark.
- (iv) Clouds are white.

Compound Microscope :



Objective : The converging lens nearer to the object.

Eyepiece : The converging lens through which the final image is seen.

Both are of short length. Focal length of eyepiece is slightly greater than that of the objective.

4. Angular Magnification or Magnifying Power (M) :

$$M = M_e \times M_o$$

(a) When final image is formed at least distance of distinct vision.

$$M = \frac{v_o}{-u_o} \left(1 + \frac{D}{f_e} \right)$$

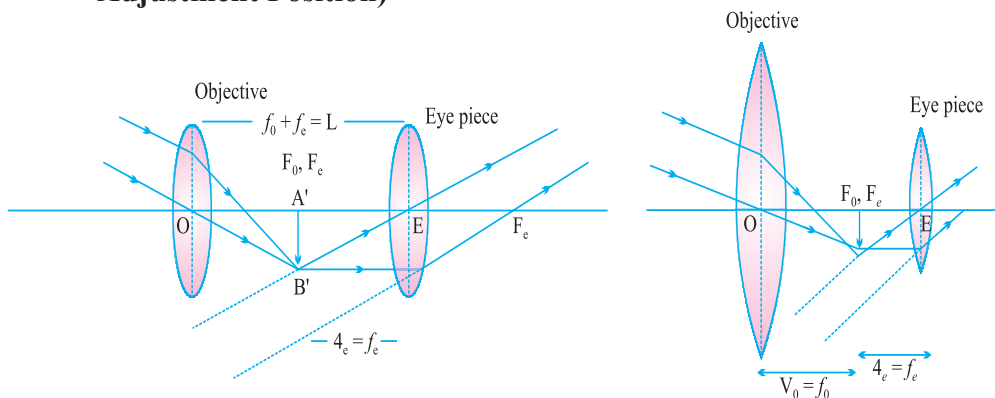
$$M = \frac{-L}{f_o} \left(1 + \frac{D}{f_e} \right)$$

(b) When final image is formed at infinity $M = \frac{-L}{f_o} \frac{D}{f_e}$

(Normal adjustment *i.e.* image at infinity) Length of tube

$$L = |v_o| + |u_e|$$

5. Formation of Image by Astronomical Telescope : at infinity Normal Adjustment Position)



Focal length of the objective is much greater than that of the eyepiece. A perture of the objective is also large to allow more light to pass through it.

6. Angular magnification or Magnifying power of a telescope.

(a) When final image is formed at infinity (Normal adjustment)

$$M = \frac{\beta}{\alpha}$$

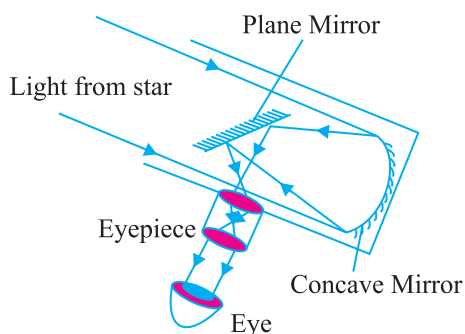
$$M = \frac{-f_o}{f_e}$$

($f_o + f_e = L$ is called the length of the telescope in normal adjustment).

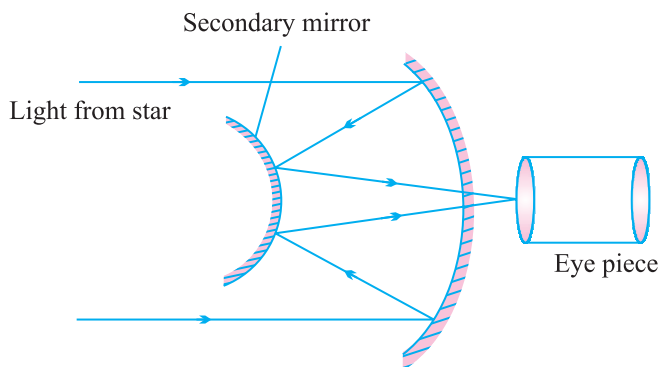
(b) When final image is formed at least distance of distinct vision.

$$m = \frac{-f_o}{f_e} \left(1 + \frac{f_e}{D} \right) \text{ and } L = f_o + |u_e|$$

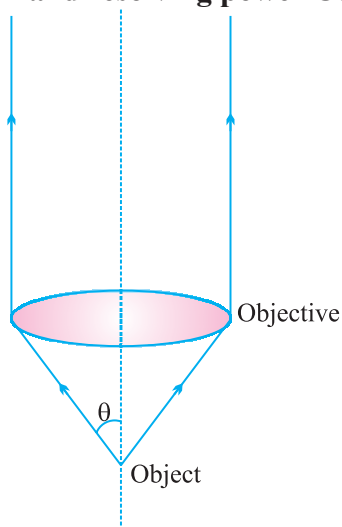
7. Newtonian Telescope : (Reflecting Type)



8. Cassegrain telescope refer



Limit of resolution and resolving power Compound Microscope



$$\text{Limit of resolution } \Delta d = \frac{\lambda}{2\mu \sin \theta}$$

$$\text{Resolving Power} = \frac{1}{\Delta d} = \frac{2\mu \sin \theta}{\lambda}$$

Resolving power depends on (i) wavelength λ , (ii) refractive Index of the medium between the object and the objective and (iii) half angle of the cone of light from one of the objects θ .

$$\text{Telescope : Limit of resolution } d\theta = \frac{1.22\lambda}{D}$$

$$\text{Resolving Power} = \frac{1}{d\theta} = \frac{D}{1.22\lambda}$$

$D \rightarrow$ diameter of objective.

Resolving power depends on (i) wavelength λ , (ii) diameter of the objective D .

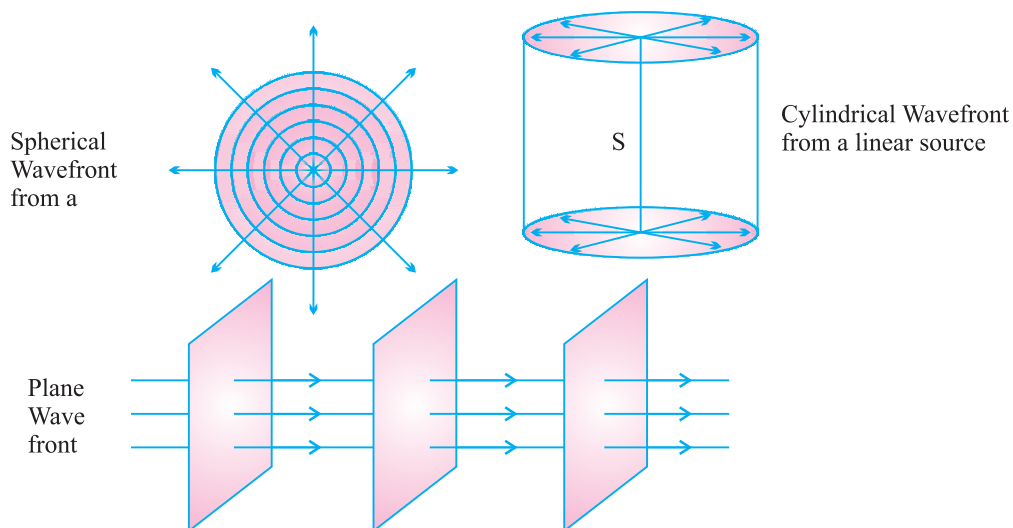
WAVE OPTICS

Wave front :

A wavelet is the point of disturbance due to propagation of light.

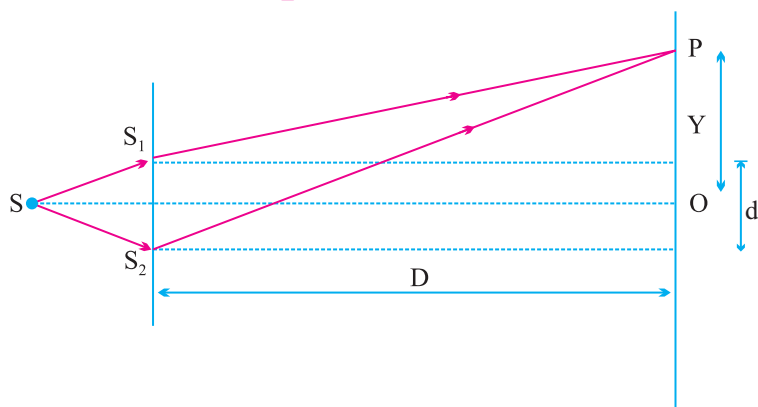
A wavefront is the locus of points (wavelets) having the same phase of oscillations.

A perpendicular to a wavefront in forward direction is called a ray.



INTERFERENCE OF WAVES

Young's Double Slit Experiment



The waves from S_1 and S_2 reach the point P with some phase difference and hence path difference

$$\Delta = S_2P - S_1P$$

$$S_2P^2 - S_1P^2 = \left[D^2 + \left\{ y + \left(\frac{d}{2} \right) \right\}^2 \right] - \left[D^2 + \left\{ y - \left(\frac{d}{2} \right) \right\}^2 \right]$$

$$(S_2P - S_1P)(S_2P + S_1P) = 2yd \quad S_2P \approx S_1P \approx D$$

$$\Delta (2D) = 2yd$$

$$\Delta = \frac{yd}{D}$$

Interference phenomenon

1. Resultant intensity at a point on screen

$$I_R = R (a_1^2 + a_2^2 + 2a_1a_2 \cos \phi)$$

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

$$\begin{aligned} \text{Where } I_1 &= ka_1^2 \\ I_2 &= ka_2^2 \end{aligned}$$

$$\text{If } I_1 = I_2 = I_0, \text{ then } I_R = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

$$2. \quad I_{\max} = (\sqrt{I_1} + \sqrt{I_2})^2 \quad \text{If } I_1 = I_2 = I_0, I_{\max} = 4I_0$$

$$I_{\min} = (\sqrt{I_1} - \sqrt{I_2})^2 \quad \text{If } I_1 = I_2 = I_0, I_{\min} = 0$$

$$3. \quad \frac{I_{\max}}{I_{\min}} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2}$$

$$4. \quad \frac{I_{\max}}{I_{\min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

$$5. \quad \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{w_1}{w_2}, \quad w_1 \text{ and } w_2 \text{ are widths of two slits}$$

6. Constructive interference

$$\text{Phase difference, } \phi = 2n\pi$$

$$\text{Path difference, } x = n\lambda$$

Destructive interference

$$\text{Phase difference } \phi = (2n + 1)\pi$$

$$\text{Path difference } x = (2n + 1)\frac{\lambda}{2}$$

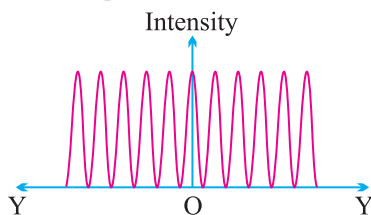
Where

$$n = 0, 1, 2, 3, \dots$$

$$7. \quad \text{Fringe width (dark or bright) } \beta = \frac{\lambda D}{d}$$

$$\text{Angular width of fringe } \Delta\theta = \frac{\beta}{D} = \frac{\lambda}{d}$$

Distribution of Intensity :



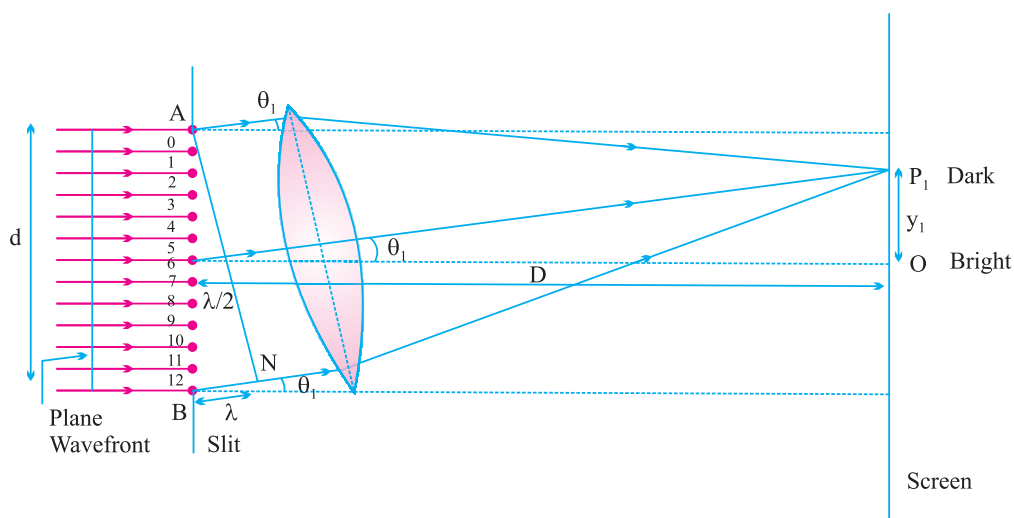
Conditions for Sustained Interference :

1. The two sources must be coherent.
2. The two interfering wave trains must have the same plane of polarisation.
3. The two sources must be very close to each other and the pattern must be observed at a large distance to have sufficient width of the fringe

$$b = \frac{\lambda D}{d}$$
 Angular width $a = \lambda/d$
4. The sources must be monochromatic. Otherwise, the fringes of different colours will overlap.
5. The two waves must be having same amplitude for better contrast between bright and dark fringes.

DIFFRACTION OF LIGHT AT A SINGLE SLIT :

Width of Central Maximum :



$$y_1 = \frac{D\lambda}{d}$$

Since the Central Maximum is spread on either side of O, the width is

$$\beta_0 = \frac{2D\lambda}{d}$$

Fresnel's Distance :

$$y_1 = \frac{D\lambda}{d}$$

At Fresnel's distance, $y_1 = d$ and $D = D_F$

$$\text{So, } \frac{D_F \lambda}{d} = d \text{ or } D_F = \frac{d^2}{\lambda}$$

POLARISATION OF LIGHT WAVES :

Malus' Law : When a beam of plane polarised light is incident on an analyser, the intensity I of light transmitted from the analyser varies directly as the square of the cosine of the angle θ between the planes of transmission of analyser and polariser.

Intensity of transmitted light from the analyser is

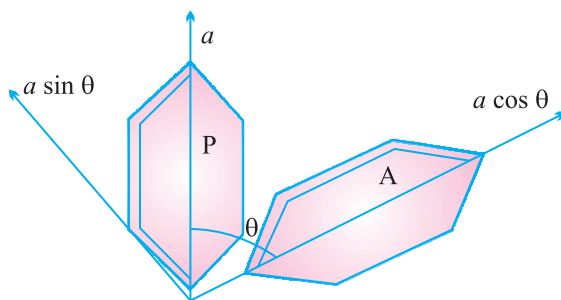
$$I \propto \cos^2 \theta$$

$$I = k (a \cos \theta)^2$$

or

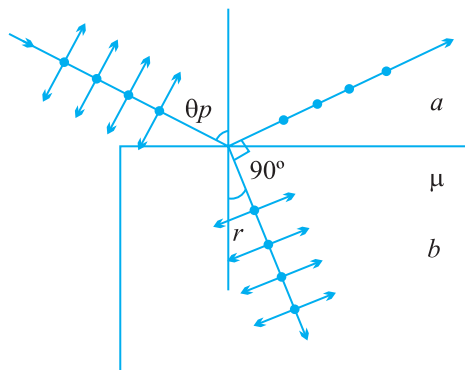
$$I = k a^2 \cos^2 \theta$$

$$I = I_0 \cos^2 \theta$$



(where $I_0 = ka^2$ is the intensity of light transmitted from the polariser)

Polarisation by Reflection and Brewster's Law :



$$\theta_p + r = 90^\circ \text{ or } r = 90^\circ - \theta_p$$

$${}_a\mu_b = \frac{\sin \theta_p}{\sin r}$$

$${}_a\mu_b = \frac{\sin \theta_p}{\sin 90^\circ - \theta_p}$$

$$\boxed{{}_a\mu_b = \tan \theta_p}$$

QUESTIONS

VERY SHORT ANSWER QUESTIONS (I Mark)

1. Every EM wave has certain frequency. Name two parameters of an em wave that oscillate with this frequency.

Ans. Electric field vector and Magnetic field vector.

2. What is the phase difference between electric and magnetic field vectors in an em wave?

Ans. $\frac{\pi}{2}$

3. Name em radiations used for detecting fake currency notes.

Ans. U.V. Radiation.

4. Give any two uses of microwaves.

Ans. Radar, Microwave ovens

5. Name the phenomenon which justifies the transverse nature of em waves.

Ans. Polarization.

6. Arrange the following em waves in descending order of wavelengths :
 γ ray, microwaves UV radiations.

Ans. Microwave, U V radiation, γ -rays

7. Which component \vec{E} or \vec{B} of an em wave is responsible for visible effect?

Ans. \vec{E}

8. Write expression for speed of em waves in a medium of electrical permittivity ϵ and magnetic permeability μ .

Ans.
$$V = \frac{1}{\sqrt{\mu \epsilon}}$$

9. Which of the following has longest penetration power?
 UV radiation, X-ray, Microwaves.

Ans. X-rays

10. Which of the following has least frequency ?
 IR radiations, visible radiation, radio waves.

Ans. Radiowaves.

11. Which physical quantity is the same for microwaves of wavelength 1 mm and UV radiations of 1600 \AA in vacuum?

Ans. Speed.

12. Name two physical quantities which are imparted by an em wave to a surface on which it falls.

Ans. Energy and pressure.

13. Name the physical quantity with unit same as that of

$$\left| \epsilon_0 \frac{d\phi_e}{dt} \right| \text{ where } \phi_e \rightarrow \text{electric flux.}$$

Ans. Current.

14. What is the source of energy associated with propagating em waves?

Ans. Oscillating/accelerated charge.

15. A plane mirror is turned through 15° . Through what angle will the reflected ray be turned ?

Ans. 30°

16. Name the device used for producing microwaves.

Ans. Klystron valve and magnetron valve

17. Relative electric permittivity of a medium is 9 and relative permeability close to unity. What is the speed of em waves in the medium.

Ans.
$$V = \frac{1}{\sqrt{\mu \epsilon}} = \frac{1}{\sqrt{(\mu_0 \mu_r)(\epsilon_0 \epsilon_r)}} = \frac{1}{\sqrt{(\mu_0 \epsilon_r)(\mu_r \epsilon_0)}}$$

$$V = \frac{C}{\sqrt{9}} = \frac{C}{3}$$

18. Identify the part of the electromagnetic spectrum to which the following wavelengths belong :

(i) 10^{-1} m

(ii) 10^{-12} m

Ans. Microwave, γ -ray

19. Name the part of the electromagnetic spectrum of wavelength 10^{-2} m and mention its one application.

Ans. Microwave \rightarrow microwave oven.

20. Which of the following act as a source of electromagnetic waves?

(i) A charge moving with a constant velocity.

(ii) A charge moving in a circular orbit with time varying speed.

(iii) A charge at rest.

Ans. A charge moving in a circular orbit

21. Mention the pair of space and time varying E and B fields which would generate a plane em wave travelling in Z-direction.

Ans. E_x and B_y

22. The charging current for a capacitor is 0.2A. What is the displacement current?

Ans. Remain same $I_C = I_D$

23. Give the ratio of velocities of light waves of wavelengths 4000\AA and 8000\AA in Vacuum.

24. Which physical quantity has the same value for waves belonging to the different parts of the electromagnetic spectrum?

Ans. Speed

25. Write the value of angle of reflection for a ray of light falling normally on a mirror.

Ans. Zero.

26. How does the dispersive power of glass prism change when it is dipped in water?

Ans. Decreases.

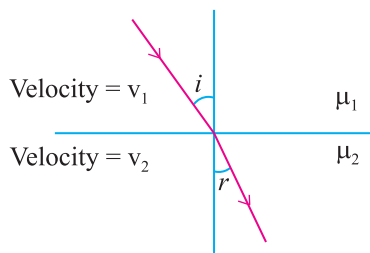
27. Light travels from glass to air. Find the angle of incidence for which the angle of refraction is 90° if refractive index of glass is $\sqrt{2}$.

Ans. 45°

28. Name the phenomenon due to which one cannot see through fog.

Ans. Scattering of light.

29. What is the ratio of $\sin i$ and $\sin r$ in terms of velocities in the given figure.

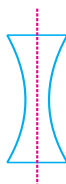


Ans. v_1/v_2

30. What is the shape of fringes in Young's double slit experiment?

Ans. Hyperbolic.

31. A equiconcave lens of focal length 15 cm is cut into two equal halves along dotted lines as shown in figure. What will be new focal length of each half.



Ans. 30 cm.

32. For the same angle of the incidence the angle of refraction in three media A, B and C are 15° , 25° and 35° respectively. In which medium would the velocity of light be minimum?

Ans. A

33. What is the phase difference between two points on a cylindrical wave front?

Ans. Zero.

34. What is the 'power' of plane glass plate?

Ans. Zero.

35. How does focal length of lens change when red light incident on it is replaced by violet light?

Ans. Decreases,

36. Lower half of the concave mirror is painted black. What effect will this have on the image of an object placed in front of the mirror?
- Ans.** The intensity of the image will be reduced (in this case half) but no change in size of the image.
37. An air bubble is formed inside water. Does it act as converging lens or a diverging lens?
- Ans.** Diverging lens
38. A water tank is 4 meter deep. A candle flame is kept 6 meter above the level μ for water is $4/3$. Where will the image of the candle be formed?
- Ans.** 6 m. below the water level.
39. What is the ratio of contribution made by the electric field and magnetic field components to the intensity of an EM wave is ?
- Ans.** 1 : 1.
40. An EM wave of intensity 'I' falls on a surface kept in vacuum. What is the radiation pressure if wave is totally reflected?
- Ans.** $\frac{2I}{c}$, $c \rightarrow$ Speed of light
41. In a single slit diffraction pattern, how does the angular width of central maxima change when (i) slit width is decreased (ii) distance between slit & screen is increased and (iii) light of smaller visible wavelength is used ? Justify your answer.
- Ans.** Angular width of central maxima $\theta = \frac{\beta_0}{D} = \frac{2\lambda}{d}$
- (i) If $d \rightarrow$ decreases Angular width increases.
(ii) Angular width remain same on increasing D
(iii) If λ decreases, angular width decreases.

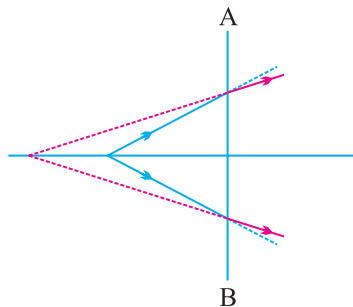
SHORT ANSWER QUESTIONS (1 Marks)

1. If the angle between the pass axis of polarizer and analyser is 45° , write the ratio of intensities of original light and the transmitted light after passing through analyser
[**Ans.** $\rightarrow 2$]
2. Light of wavelength 600nm is incident normally on a slit of width 3mm. Calculate the angular width of central maximum on a screen kept 3m away from the slit.
[**Ans.** 4×10^{-4} rad]
3. If the polarising angle for air glass interface is 56.3° , what is the angle of refraction in glass?
[**Ans.** 33.7°]

4. How does magnifying power changes with change in length of tube for a given telescope? [Ans Decreases with increase in length]
5. The magnifying power of an artronomical telescope in normal adjustment is 100 and distance between objective and eye lens in 101cm. Find the focal lenth of objective and eye piece.
[Ans $f_o = 100$ cm, $f_e = 1$ cm.]

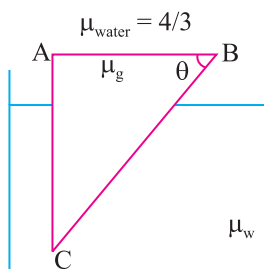
SHORT ANSWER QUESTIONS (2 Marks)

1. Give one use of each of the following
(i) UV ray (ii) γ -ray.
2. Represent EM waves propagating along the x-axis in which electric and magnetic fields are along y-axis and z-axis respectively.
3. State the principles of production of EM waves. An EM wave of wavelength λ goes from vacuum to a medium of refractive index n . What will be the frequency of wave in the medium?
4. An EM wave has amplitude of electric field E_0 and amplitude of magnetic field is B_0 . The electric field at some instant become $\frac{3}{4}E_0$. What will be magnetic field at this instant? (Wave is travelling in vacuum).
5. State two applications of infrared radiations.
6. State two applications of radio waves.
7. State two applications of x-rays.
8. Show that the average energy density of the electric field \vec{E} equals the average energy density of the magnetics fields \vec{B} ?
9. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave.

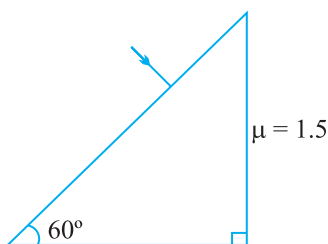


10. Use mirror equation to deduce that an object placed between the pole and focus of a concave mirror produces a virtual and enlarged image.
11. Calculate the value of θ , for which light incident normally on face AB grazes along the face BC.

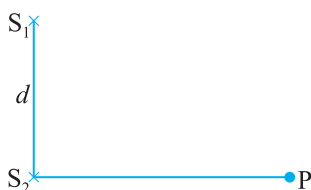
$$\mu_{\text{glass}} = 3/2 \quad \text{and} \quad \mu_{\text{water}} = 4/3$$



12. Name any two characteristics of light which do not change on polarisation.
13. Complete the path of light with correct value of angle of emergence.

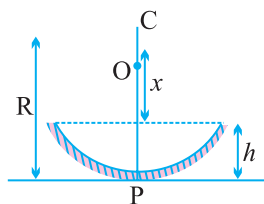


14. Define diffraction. What should be the order of the size of the aperture to observe diffraction.
15. Show that maximum intensity in interference pattern is four times the intensity due to each slit if amplitude of light emerging from slits is same.
16. Two poles-one 4 m high and the other is 4.5 m high are situated at distance 40 m and 50 m respectively from an eye. Which pole will appear taller?
17. S_1 and S_2 are two sources of light separated by a distance d . A detector can move along S_2P perpendicular to S_1S_2 . What should be the minimum and maximum path difference at the detector?

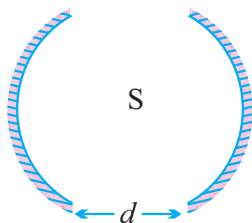


18. If a jogger runs with constant speed towards a vehicle, how fast does the image of the jogger appear to move in the rear view mirror when
 (i) the vehicle is stationary
 (ii) the vehicle is moving with constant speed towards jogger.
- Ans.** The speed of the image of the jogger appears to increase substantially though jogger is moving with constant speed.
 Similar phenomenon is observed when vehicle is in motion.
19. Define Brewster's angle. Show that the Brewster's angle i_B for a given pair of media is related to critical angle i_c through the relation
- $$i_c = \sin^{-1}(\cot i_B)$$
20. If angle between the pass axes of polariser & analyser is 45° . Write the ratio of the intensities of original light and transmitted light after passing through the analyser.
21. When does (i) a plane mirror and (ii) a convex mirror produce real image of objects.
- Ans.** Plane and convex mirror produce real image when the object is virtual that is rays converging to a point behind the mirror are reflected to a point on a screen.
22. A virtual image cannot be caught on a screen. Then how do we see it?
- Ans.** The image is virtual when reflected or refracted rays divergent, these are converged on to the retina by convex lens of eye, as the virtual image serves as the object.
23. Draw a diagram to show the advance sunrise and delayed sunset due to atmospheric refraction.
24. Define critical angle for total internal reflection. Obtain an expression for refractive index of the medium in terms of critical angle.
25. The image of a small bulb fixed on the wall of a room is to be obtained on the opposite wall 's' m away by means of a large convex lens. What is the maximum possible focal length of the lens required.
- Ans.** For fixed distance 's' between object and screen, for the lens equation to give real solution for $u = v = 2f$, ' f ' should not be greater than $4f = s$.
- $$\therefore f = s/4$$
26. The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass. In what sense then does magnifying glass produce angular magnification?
- Ans.** The absolute image size is bigger than object size, the magnifier helps in bringing the object closer to the eye and hence it has larger angular size than the same object at 25 cm, thus angular magnification is achieved.

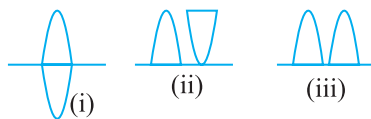
27. Obtain relation between focal length and radius of curvature, of (i) concave mirror (ii) convex mirror using proper ray diagram.
28. Two independent light sources cannot act as coherent sources. Why?
29. How is a wave front different from a ray? Draw the geometrical shape of the wavefronts when.
- light diverges from a point source,
 - light emerges out of convex lens when a point source is placed at its focus.
30. What two main changes in diffraction pattern of single slit will you observe when the monochromatic source of light is replaced by a source of white light.
31. You are provided with four convex lenses of focal length 1cm, 3cm, 10 cm and 100 cm. Which two would you prefer for a microscope and which two for a telescope.
32. Give reasons for the following
- Sun looks reddish at sunset
 - clouds are generally white
33. Using Huygens Principle draw ray diagram for the following :
- Refraction of a plane wave front incident on a rarer medium
 - Refraction of a plane wave front incident on a denser medium.
34. Water (refractive index μ) is poured into a concave mirror of radius of curvature 'R' up to a height h as shown in figure. What should be the value of x so that the image of object 'O' is formed on itself?



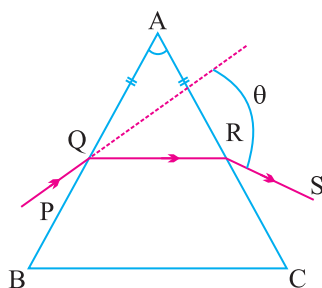
35. A point source S is placed midway between two concave mirrors having equal focal length f as shown in Figure. Find the value of d for which only one image is formed.



36. A thin double convex lens of focal length f is broken into two equal halves at the axis. The two halves are combined as shown in figure. What is the focal length of combination in (ii) and (iii).



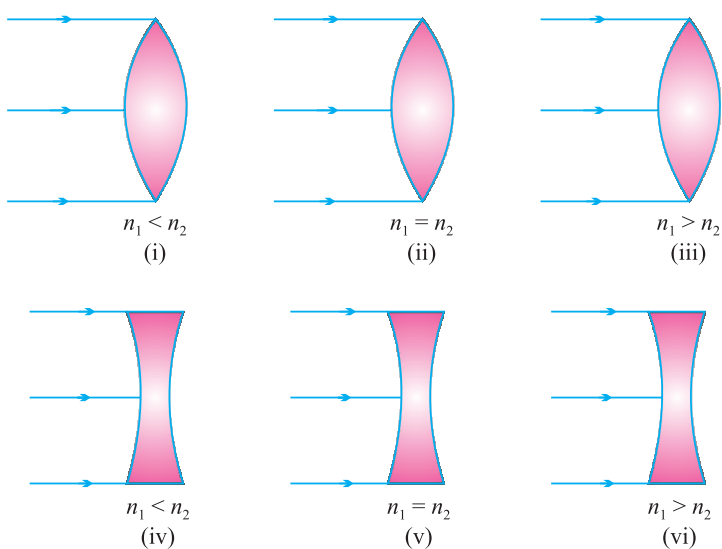
37. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container. ($\mu_w = 4/3$.)
38. A ray PQ incident on the refracting face BA is refracted in the prism BAC as shown in figure and emerges from the other refracting face AC as RS such that $AQ = AR$. If the angle, of prism $A = 60^\circ$ and μ of material of prism is $\sqrt{3}$ then find angle θ .



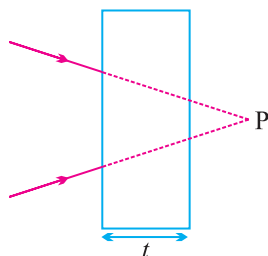
SHORT ANSWER QUESTIONS (3 Marks)

- Name EM radiations used
 - in the treatment of cancer.
 - For detecting flow in pipes carrying oil.
 - In sterilizing surgical instruments.
- How would you experimentally show that EM waves are transverse in nature?
- List any three properties of EM waves.
- Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. Give its two applications.
- Using mirror formula show that virtual image produced by a convex mirror is always smaller in size and is located between the focus and the pole.
- Obtain the formula for combined focal length of two thin lenses in contact, taking one divergent and the other convergent.

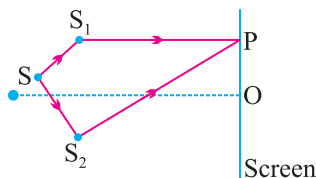
7. Derive Snell's law on the basis of Huygen's wave theory.
8. A microscope is focussed on a dot at the bottom of the beaker. Some oil is poured into the beaker to a height of ' b ' cm and it is found that microscope has to raise through vertical distance of ' a ' cm to bring the dot again into focus. Express refractive index of oil in terms of a and b .
9. Define total internal reflection. State its two conditions. With a ray diagram show how does optical fibres transmit light.
10. A plane wave front is incident on (i) a prism (ii) A convex lens (iii) a concave mirror. Draw the emergent wavefront in each case.
11. Explain with reason, how the resolving power of a compound microscope will change when (i) frequency of the incident light on the objective lens is increased, (ii) focal length of the objective lens is increased, (iii) aperture of objective lens is increased.
12. Derive Mirror formula for a concave mirror forming real Image.
13. Two narrow slits are illuminated by a single monochromatic sources.
 - (a) Draw the intensity pattern and name the phenomenon
 - (b) One of the slits is now completely covered. Draw the intensity pattern now obtained.
14. Explain (i) sparkling of diamond (ii) use of optical fibre in communication.
15. Using appropriate ray diagram obtain relation for refractive index of water in terms of real and apparent depth.
16. Complete the ray diagram in the following figure where, n_1 is refractive index of medium and n_2 is refractive index of material of lens.



17. A converging beam of light is intercepted by a slab of thickness t and refractive index μ . By what distance will the convergence point be shifted? Illustrate the answer.



18. In double slit experiment SS_2 is greater than SS_1 by 0.25λ . Calculate the path difference between two interfering beam from S_1 and S_2 for minima and maxima on the point P as shown in figure.



LONG ANSWER QUESTIONS (5 MARKS)

- With the help of ray diagram explain the phenomenon of total internal reflection. Obtain the relation between critical angle and refractive indices of two media. Draw ray diagram to show how right angled isosceles prism can be used to :
 - Deviate the ray through 180° .
 - Deviate the ray through 90° .
 - Invert the ray.
- Draw a labelled ray diagram of a compound microscope and explain its working. Derive an expression for its magnifying power if final image is formed at least distance of distant vision.
- Diagrammatically show the phenomenon of refraction through a prism. Define angle of deviation in this case. Hence for a small angle of incidence derive the relation $\delta = (\mu - 1) A$.
- Explain the following :
 - Sometimes distant radio stations can be heard while nearby stations are not heard.
 - If one of the slits in Youngs Double Slit Experiment is covered, what change would occur in the intensity of light at the centre of the screen?

5. Define diffraction. Deduce an expression for fringe width of the central maxima of the diffraction pattern, produced by single slit illuminated with monochromatic light source.
6. What is polarisation? How can we detect polarised light? State Brewster's Law and deduce the expression for polarising angle.
7. Derive lens maker formula for a thin converging lens.
8. Derive lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ for
 - (a) a convex lens, (b) a concave lens.
9. Describe an astronomical telescope and derive an expression for its magnifying power using a labelled ray diagram. When final image is formed at least distance of distinct vision.
10. Draw a graph to show the angle of deviation with the angle of incidence i for a monochromatic ray of light passing through a prism of refracting angle A . Deduce the relation

$$\mu = \frac{\sin(A + \delta_m)/2}{\sin A/2}$$

11. State the condition under which the phenomenon of diffraction of light takes place. Also draw the intensity pattern with angular position.
12. How will the interference pattern in Young's double slit experiment change, when
 - (i) distance between the slits S_1 and S_2 are reduced and
 - (ii) the entire set up is immersed in water ?
 Justify your answer in each case.

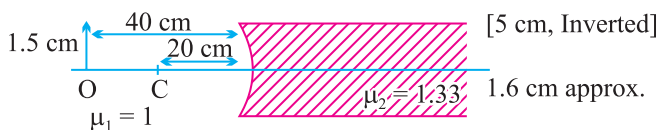
Ans. Fringe width $\beta = \frac{\lambda D}{d}$

- (i) If d decreases, fringe width $\beta \propto \frac{1}{d}$ increases
- (ii) When apparatus is immersed in water, wavelength reduces to $\frac{\lambda}{\mu_w}$. Therefore, fringe width $\beta \propto \lambda$ decreases.

NUMERICALS

1. The refractive index of medium is 1.5. A beam of light of wavelength 6000 \AA enters in the medium from air. Find wavelength and frequency of light in the medium.
2. An EM wave is travelling in vacuum. Amplitude of the electric field vector is $5 \times 10^4 \text{ V/m}$. Calculate amplitude of magnetic field vector.
3. Suppose the electric field amplitude of an em wave is $E_0 = 120 \text{ NC}^{-1}$ and that its frequency is $\nu = 50.0 \text{ MHz}$.
 - (a) Determine B_0 , ω , κ and λ ,
 - (b) Find expressions for E and B .
4. A radio can tune into any station of frequency band 7.5 MHz to 10 MHz . Find the corresponding wave length range.
5. The amplitude of the magnetic field vector of an electromagnetic wave travelling in vacuum is 2.4 mT . Frequency of the wave is 16 MHz . Find :
 - (i) Amplitude of electric field vector and
 - (ii) Wavelength of the wave.
6. An EM wave travelling through a medium has electric field vector.
 $E_y = 4 \times 10^5 \cos (3.14 \times 10^8 t - 1.57 x) \text{ N/C}$. Here x is in m and t in s . Then find :
 - (i) Wavelength
 - (ii) Frequency
 - (iii) Direction of propagation
 - (iv) Speed of wave
 - (v) Refractive index of medium
 - (vi) Amplitude of magnetic field vector.
7. An object of length 2.5 cm is placed at a distance of $1.5 f$ from a concave mirror where f is the focal length of the mirror. The length of object is perpendicular to principal axis. Find the size of image. Is the image erect or inverted?
[5 cm, Inverted]

8. Find the size of image formed in the situation shown in figure.



[1.2 cm, approx.]

9. A ray of light passes through an equilateral prism in such a manner that the angle of incidence is equal to angle of emergence and each of these angles is equal to $3/4$ of angle of prism. Find angle of deviation.

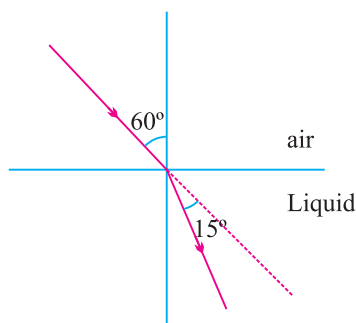
[Ans. : 30°]

10. Critical angle for a certain wavelength of light in glass is 30° . Calculate the polarising angle and the angle of refraction in glass corresponding to this.

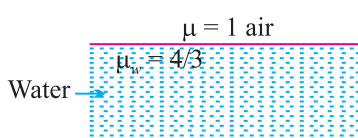
[$i_p = \tan^{-1} 2$]

11. A light ray passes from air into a liquid as shown in figure. Find refractive index of liquid.

[${}^{\text{air}}\mu_{\text{Liquid}} = \sqrt{3/2}$]



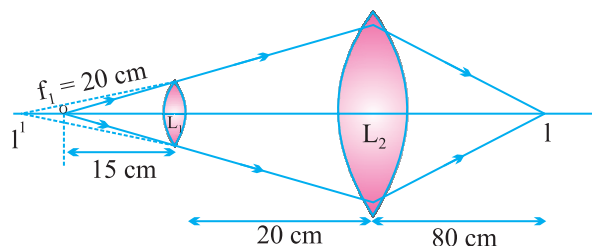
12. At what angle with the water surface does fish in figure see the setting sun ?



[$C = \sin^{-1} (0.7518)$]

[At critical angle, fish will see the sun.]

13. In the following diagram, find the focal length of lens L_2 . [40 cm]



14. Three immiscible liquids of densities $d_1 > d_2 > d_3$ and refractive indices

$\mu_1 > \mu_2 > \mu_3$ are put in a beaker. The height of each liquid is $\frac{h}{3}$. A

dot is made at the bottom of the beaker. For near normal vision, find the apparent depth of the dot.

Ans. (Hint : the image formed by first medium act as an object for second medium) Let the apparent depth be O_1 for the object seen from

$O_1 = \frac{\mu_2}{\mu_1} \cdot \frac{h}{3}$ image formed by medium 1, O acts as an object for medium

2. It is seen from M_3 , the apparent depth is O_2 .

Similarly, the image found by medium 2, O_2 act as an object for medium 3

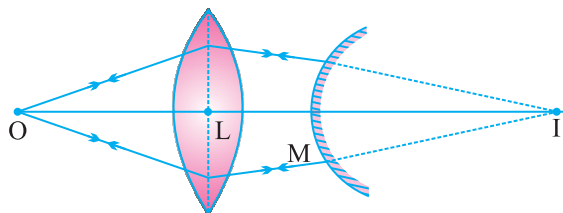
$$O_2 = \frac{\mu_3}{\mu_2} \left(\frac{h}{3} + O_1 \right)$$

$$O_3 = \mu_3 \left(\frac{h}{3} + O_2 \right) \quad \text{putting value of } O_2 \text{ and } O_1$$

$$O_3 = \frac{h}{3} \left(\frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3} \right)$$

15. 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 right side at 50 cm from the lens, the image of object O formed by lens-mirror combination coincides with object itself. Calculate focal length of mirror.

Ans. Image formed by combination coincides with the object itself. It implies that I is the centre of curvature of convex mirror.



For lens

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{25} = \frac{1}{v} + \frac{1}{30}$$

$$v = 150 \text{ cm}$$

$$MI = LI - LM = 150 - 50 = 100 \text{ cm}$$

$$f_m = \frac{MI}{2} = \frac{100}{2} = 50 \text{ cm}$$

16. Using the data given below, state which two of the given lenses will be preferred to construct a (i) telescope (ii) Microscope. Also indicate which is to be used as objective and as eyepiece in each case.

Lenses	Power (p)	Apetune (A)
L_1	6 D	1 cm
L_2	3 D	8 cm
L_3	10 D	1 cm

Ans. For telescope, lens L_2 is chosen as objective as it aperture is largest, L_3 is chosen as eyepiece as its focal length is smaller.

For microscope lens L_3 is chosen as objective because of its small focal length and lens L_1 , serve as eye piece because its focal length is not larges.

17. Two thin converging lens of focal lengths 15 cm and 30 cm respectively are held in contact with each other. Calculate power and focal length of the combination.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$= \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

$$F = 10 \text{ cm}$$

$$P = 10D$$

18. An object is placed in front of a concave mirror of focal length 20 cm. The image is formed three times the size of the object. Calculate two possible distances of the object from the mirror.

Ans. $m = \pm 3$

$$m = \frac{-v}{u} = + 3 \text{ for virtual image}$$

$$v = - 3u$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{-34} + \frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{40}{3} \text{ cm}$$

$$m = \frac{-v}{u} = -3 \text{ for real image}$$

$$v = 3u$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{3u} + \frac{1}{u} = -\frac{1}{20}$$

$$u = -\frac{80}{3} \text{ cm.}$$

1 MARKS QUESTIONS

- Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.
- How is the equation for Ampere's circuital law modified in the presence of displacement current?
- How are electromagnetic waves produced by oscillating charges? What is the source of the energy associated with the em waves?
- Name the radiation of the electromagnetic spectrum which is used for the following:
 - (i) Radar
 - (ii) Eye surgery
 - To photograph internal parts of human body
 - For taking photographs of the sky during night and foggy conditions

Give the frequency range in each case.
- Two polaroids A and B are kept in crossed position. How should a third polaroid C be placed between them so that the intensity of polarised light transmitted by polaroid B reduces to $1/8^{\text{th}}$ of the intensity of unpolarised light incident on A. [Hint $I = I_0 \cos^2 \theta$]

Ans. 45° .

6. 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 the intensity of light at a point where path difference is $\frac{\lambda}{3}$.

$$\text{Phase diff.} = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3} = 120^\circ$$

and

$$I = I_0 \cos^2 \frac{\phi}{2} = \frac{K}{4}$$

$$\left[\text{Hint } I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi \right]$$

7. Two nicole polaroids are so oriented that the maximum amount of light is transmitted. To what fraction of its maximum value is the intensity of transmitted light reduced when the analyser is rotated through (i) 30° (ii) 60° ?

Ans. (i) 75% of max. intensity (ii) 25% of max. intensity

8. In young's double slit experiment, a light of wavelength 630 nm produces an interference pattern where bright fringes are separated by 8.1 mm. Another light produces the interference pattern. Where the bright fringes are separated by 72 mm. Calculate the wavelength of second light.

$$\left[\text{Hint } \beta = \frac{\lambda D}{d} \right]$$

Ans. 560 nm

9. A beam of light consisting of two wavelength 800 nm and 600 nm is used to obtain the interference pattern in young's double slit experiment on a screen placed 1.4 m away. If the separation between two slits is 0.28 mm. Calculate the least distance from the central bright maximum, where the bright fringes of two wavelength coincide.

$$\text{Ans. } x = n\lambda_1 \frac{D}{d} = (n+1)\lambda_2 \frac{D}{d}$$

$$\therefore n \times 800 = (n+1)\lambda_2 \frac{D}{d}$$

$$\therefore n = 3$$

$$\therefore x = n\lambda_1 \frac{D}{d} = 3 \times 800 \times \frac{10^{-9} \times 1.4}{0.28 \times 10^{-3}} = 12 \text{ mm}$$

Numericals

1. The focal lengths of objective and eye piece of a microscope are 1.25 cm and 5 cm respectively find the position of the object relative to the objective in order to obtain an angular magnification of 30 in normal adjustment.

Ans. In normal adjustment

$$m_e = \frac{d}{f_e} = \frac{25}{5} = 5$$

$$m = m_o m_e$$

$$\therefore m_o = \frac{m}{m_e} = \frac{30}{5} = 6$$

$$\text{and } m_o = \frac{V_o}{u_o} = -6$$

$$\therefore V_o = -6u_o$$

$$\therefore \frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\frac{1}{-6u_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\text{here } f_o = 1.25 \text{ cm}$$

$$u_o = -1.46 \text{ cm}$$

2. A small telescope has an objective lens of focal length 150 cm and an eye piece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away find the height of the final image when it is formed 25 cm away from the eye pieces.

Ans.

$$\tan \alpha = \frac{100}{3000} = \frac{1}{30} \text{ radian}$$

again

$$\tan \alpha = \frac{h}{f_0}$$

\therefore

$$\frac{1}{30} = \frac{h}{150}$$

$$h = 5 \text{ cm}$$

h height of image of tower

\therefore

$$m_e = \left(1 + \frac{\alpha}{f_e}\right) = \left(1 + \frac{25}{5}\right) = 6$$

and

$$m_e = \frac{h'}{h}$$

\therefore

$$h' = 5 \times 6 = 30 \text{ cm}$$

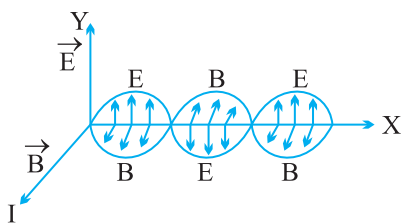
h' height of final image.

ANSWER OF 2 MARKS QUESTIONS

1. UV ray – In water purifier.

γ ray – In treatment of cancer

2.



3. An accelerated charge produces oscillating electric field in space, which produces an oscillating magnetic field, which in turn, is a source of oscillating electric field and so on. The oscillating electric & magnetic fields produces each other & give rise to e.m. waves.

4. In vacuum

$$C = \frac{E_0}{B_0}$$

If electric field become $\frac{3}{4}E_0$, magnetic field will be $\frac{3}{4}B_0$.

5. (i) In green houses to keep plants warm.
(ii) In reading secret writings on ancient walls.
6. (i) In radio & tele communication systems.
(ii) In radio astronomy.
7. (i) In medical to diagnose fractures in bones.
(ii) In engineering for detecting cracks, flaws & holes in metal parts of a machine.

$$8. \quad \mu_E = \frac{1}{2}\epsilon_0 E^2 \quad \& \quad u_B = \frac{1}{2} \frac{B^2}{\mu_0}$$

$$\mu_E = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\epsilon_0 (CB)^2 \quad \text{As } c = \frac{E}{B}$$

$$= \frac{1}{2}\epsilon_0 \frac{B^2}{\mu_0 \epsilon_0} \quad c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$$= \frac{B^2}{2\mu_0}$$

$$= \mu_B$$

10. For concave mirror

$$f < 0 \quad \text{and} \quad u < 0$$

$$f < u < 0$$

$$\frac{1}{f} > \frac{1}{u} \quad \text{or} \quad \frac{1}{f} - \frac{1}{u} > 0$$

$$\text{or} \quad \frac{1}{v} > 0$$

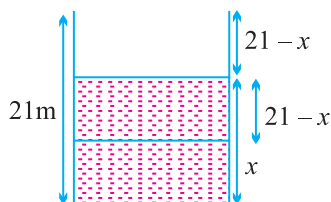
Virtual image is formed.

$$\text{Also} \quad \frac{1}{v} < \frac{1}{|u|} \quad \text{or} \quad v > |u|$$

$$m = \frac{v}{|u|} > 1$$

magnified image.

11. $\theta = \sin^{-1} (8/9)$
12. Speed and frequency
13. $\sin^{-1} (3/4)$
16. 4 m pole
17. Minimum path difference is zero (when p is at infinity).
Maximum path difference = d .
29. A wavefront is a surface obtained by joining all points vibrating in the same phase.
A ray is a line drawn perpendicular to the wavefront in the direction of propagation of light.
- (i) Spherical
(ii) Plane
30. (i) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light. As fringe width $\propto \lambda$, \therefore red fringe with higher wavelength is wider than violet fringe with smaller wavelength.
(ii) In higher order spectra, the dispersion is more and it cause overlapping of different colours.
31. $f_0 = 1$ cm and $f_e = 3$ cm for Microscope and
 $f_0 = 100$ cm and $f_e = 1$ cm for a Telescope
33. N.C.E.R.T. Fig. 10.5; Fig. 10.4.
34. Distance of object from p should be equal to radius of curvature.
- $$R = \mu x + h \Rightarrow x = \frac{R - h}{\mu}$$
35. Distance between mirror will be $2f$ or $4f$.
36. (i) Focal length of combination is infinite,
(ii) $f/2$
- 37.



$$\frac{\text{Real depth}}{\text{Apparent depth}} = \mu$$

$$\frac{x}{21-x} = \frac{4}{3} \Rightarrow x = 12 \text{ cm}$$

38. This is a case of min. deviation $\theta = 60^\circ$.

ANSWERS OF 3 MARKS QUESTIONS

11. R.P. of a compound Microscope

$$= \frac{2\mu \sin \theta}{\lambda} = 2\mu \sin \theta \frac{v}{c}$$

- (i) When frequency v increases, R.P. increases
 - (ii) R.P. does not change with change in focal length of objective lens.
 - (iii) When aperture increases, θ increases
- \therefore R.P. increases.

17. $x = \left(1 - \frac{1}{\mu}\right)t$

18. Path difference :

$$\begin{aligned} (SS_2 + S_2P) - (SS_1 + S_1P) &= (SS_2 - SS_1) + (SS_2P - S_1P) \\ &= (0.25\lambda + S_2P - S_1P) \end{aligned}$$

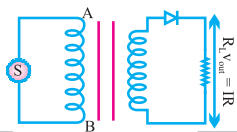
For maxima, path difference $= n\lambda$

So, $S_2P - S_1P = n\lambda - 0.25\lambda = (n - 0.25)\lambda$

For minima, path difference $= (2n+1)\frac{\lambda}{2}$

So, $S_2P - S_1P = (2n + 0.5) \lambda/2$.





Unit VII

Dual Nature of Matter And Radiation

Unit VII

DUAL NATURE OF MATTER AND RADIATION

KEY POINTS

- Light consists of individual photons whose energies are proportional to their frequencies.
- A photon is a quantum of electromagnetic energy :
Energy of photon

$$E = h\nu = \frac{hc}{\lambda}$$

Momentum of a photon

$$= \frac{h\nu}{c} = \frac{h}{\lambda}$$

Dynamic mass of photon

$$= \frac{h\nu}{c^2} = \frac{h}{c\lambda}$$

Rest mass of a photon is zero.

- **Photoelectric effect** : Photon of incident light energy interacts with a single electron and if energy of photon is equal to or greater than work function, the electron is emitted.
- Max. kinetic energy of emitted electron = $h(\nu - \nu_0)$ Here ν_0 is the frequency below which no photoelectron is emitted and is called threshold frequency.
- If 'V' is the stopping potential of photoelectron emission, then max. kinetic energy of photo electron $E_K = qV$

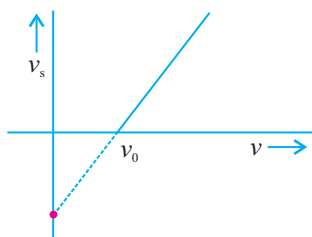
- Wavelength associated with the charge particle accelerated through a potential of g volt.

$$\lambda = \frac{h}{\sqrt{2mqv}}$$

- Wavelength associated with electron accelerated through a potential difference

$$\lambda_e = \frac{12.27}{\sqrt{V}} \text{Å}$$

- Stopping potential versus frequency graph



$v_0 \rightarrow$ threshold frequency

slope of the curve gives $\frac{h}{e}$

The intercept on v_s axis gives $\frac{\phi}{e}$ i.e. $\frac{\text{Work function}}{e}$

- A moving body behaves in a certain way as though it has a wave nature having wavelength,

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2m E_k}}$$

where E_k is kinetic energy of moving particle

- Einstein's Photoelectric equation

$$\frac{1}{2}mv_{\max}^2 = h\nu - h\nu_0$$

or
$$eV_0 = h\nu - h\nu_0$$

Unit VIII

ATOMS AND NUCLEI

KEY POINTS

- ❑ Gieger-Marsden α -scattering experiment established the existence of nucleus in an atom.

Bohr's atomic model

- (i) Electrons revolve round the nucleus in certain fixed orbits called stationary orbits.
- (ii) In stationary orbits, the angular momentum of electron is integral multiple of $h/2\pi$.
- (iii) While revolving in stationary orbits, electrons do not radiate energy. The energy is emitted (or absorbed) when electrons jump from higher to lower energy orbits, (or lower to higher energy orbits). The frequency of the emitted radiation is given by $h\nu = E_f - E_i$. An atom can absorb radiations of only those frequencies that it is capable of emitting.

- ❑ As a result of the quantisation condition of angular momentum, the electron orbits the nucleus in circular paths of specific radii. For a hydrogen atom it is given by

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\epsilon_0}{e^2} = \frac{n^2 h^2 \epsilon_0}{\pi m e^2}$$

\Rightarrow

$$r_n \propto n^2$$

The total energy is also quantised : $E_n = \frac{-me^4}{8n^2\epsilon_0^2h^2} = -13.6\text{eV}/n^2$

The $n = 1$ state is called the ground state.

In hydrogen atom, the ground state energy is -13.6 eV .

- ❑ de Broglie's hypothesis that electron have a wavelength $\lambda = h/mv$ gave an explanation for the Bohr's quantised orbits.
- ❑ Neutrons and protons are bound in nucleus by short range strong nuclear force. Nuclear force does not distinguish between nucleons.
- ❑ The nuclear mass 'M' is always less than the total mass of its constituents. The difference in mass of a nucleus and its constituents is called the **mass defect**.

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

and

$$\Delta E_b = (\Delta M)c^2$$

The energy ΔE_b represents the binding energy of the nucleus.

For the mass number ranging from $A = 30$ to 170 the binding energy per nucleon is nearly constant at about 8MeV per nucleon.

- **Radioactive Decay Law :** The number of atoms of a radioactive sample disintegrating per second at any time is directly proportional to the number of atoms present at that time. Mathematically :

$$\frac{dN}{dt} = -\lambda N \text{ or } N_{(t)} = N_0 e^{-\lambda t}$$

where λ is called decay constant. It is defined as the reciprocal of the mean time during which the number of atoms of a radioactive substance

decreases to $\frac{1}{e}$ of their original number.

- Number of radioactive atoms N in a sample at any time t can be calculated using the formula.

$$N = N_0 \left(\frac{1}{2}\right)^{t/T}$$

Here N_0 = no. of atoms at time $t = 0$ and T is the half-life of the substance.

Half life : The half life of a radio active substances is defined as the time during which the number of atoms disintegrate to one half of its initial value.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \ln 2 \times \text{mean life}$$

or
$$0.693/\lambda = \frac{0.693}{\lambda}$$

Here
$$\lambda = \text{decay constant} = \frac{1}{\text{mean life}}$$

- Radius r of the nucleus of an atom is proportional to the cube root of its mass number thereby implying that the nuclear density is the same. (Almost) for all substances/nuclei.
- α -decay : ${}_Z X^A \rightarrow {}_{Z-2} Y^{A-4} + {}_2 \text{He}^4 + Q$
 β -decay : ${}_Z X^A \rightarrow {}_{Z+1} Y^A + {}_{-1} e^0 + \bar{\nu} + Q$
 γ -decay : When α or β -decay, the nucleus in excited state; the nucleus goes to lower energy state or ground state by the emission of γ -ray(s).

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. What is the rest mass of photon?

Ans. Zero

2. A good mirror reflects 80% of light incident on it. Which of the following is correct ?

(a) Energy of each reflected photon decreases by 20%.

(b) Total no. of reflected photons decreases by 20%. Justify your answer.

Ans. (b) Total no. of reflected photons decreases by 20%.

3. Why in a photocell the cathode is coated with alkali metals ?

Ans. Lower work function, sensitive to visible light.

4. Name the phenomenon which shows quantum nature of electromagnetic radiation.

Ans. Photoelectric effect.

5. Write Einstein's photoelectric equations and specify each term.

Ans. $\frac{1}{2}mv_{\max}^2 = h\nu - h\nu_0$

Max. K.E. of Photoelectrons = Energy of incident light – work function.

6. The Stopping potential in an experiment on photo electric effect is 1.5V : What is the maximum K.E. of photoelectrons emitted.

Ans.
$$eV_0 = (\text{K.E.})_{\max}$$
$$\Rightarrow (\text{K.E.})_{\max} = 1.6 \times 10^{-19} \times 1.5$$
$$= 2.4 \times 10^{-19} \text{J}$$

7. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it? Why?

Ans. Yes, blue light has higher frequency hence possess higher energy.

8. What is the value of impact parameter for a head on collision?

Ans. Zero

9. The photoelectric cut off voltage in a certain photoelectric experiment is 1.5V. What is the max. kinetic energy of photoelectrons emitted?

Ans. K.E = eV, \ K.E = 1.5 e Joule

$$= 1.5 \times 1.6 \times 10^{-19} \text{J}$$

$$= 2.4 \times 10^{-19} \text{J}$$

10. What is the de-Broglie wavelength of a 3 kg object moving with a speed of 2m/s?

Ans. $\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{3 \times 2} = 1.1 \times 10^{-34} \text{m}.$

11. What factors determine the maximum velocity of the photoelectrons from a surface?

Ans. (a) frequency of incident radiation

(b) work function of surface.

12. How will you justify that the rest mass of photons is zero ?

Ans. $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$, rest mass for $m_0 = \sqrt{1 - \frac{v^2}{c^2}}$ photon $v = c \Rightarrow m_0 = 0$.

13. Work functions of caesium and lead are 2.14 eV and 4.25 eV respectively. Which of the two has a higher threshold wavelength?

Ans. Work function, $\phi_0 = h\nu_0 = h \frac{c}{\lambda_0}$ or $\lambda_0 \propto \frac{1}{\phi_0}$

Hence caesium has a higher threshold wavelength for photoelectric emission.

14. What is the de-Broglie wavelength of a neutron at absolute temperature T K ?

Ans. $\lambda = \frac{h}{\sqrt{2m_n E_k}} = \frac{h}{\sqrt{2m_n \frac{3}{2} k_B T}} = \frac{h}{\sqrt{3m_n k_B T}}$, $K_B \rightarrow$ Boltzmann's Constant

15. Define atomic mass unit. Write its energy equivalent in MeV.

Ans. 1 a.m.u is $\frac{1}{12}$ of the mass of a carbon isotope

$$^{12}\text{C}_6 \quad 1 \text{ u} = 931 \text{ MeV}$$

16. What was the drawback of Rutherford's model of atom?

Ans. Rutherford's model of atom failed to explain the stability of atom.

17. What are the number of electrons and neutrons in $^{236}_{92}\text{U}$ atom?

Ans. No. of electrons 92

No. of neutrons $236 - 92 = 144$.

18. Name the series of hydrogen spectrum which has least wavelength.

Ans. Lyman series

19. Any two protons repel each other, then how is this possible for them to remain together in a nucleus.

Ans. Nuclear force between two protons is 100 times stronger than the electrostatic force.

20. Define radioactive decay constant.

Ans. The decay constant of radioactive substance is defined as the reciprocal of that time in which the number of atoms of substance becomes $\frac{1}{e^{th}}$ times the atoms present initially.

21. You are given reaction : ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_2\text{He}^4 + 24 \text{ MeV}$. What type of nuclear reaction is this?

Ans. Nuclear Fusion.

22. After losing two electrons, to which particle does a helium atom get transformed into?

Ans. α particle.

23. What is the ratio of velocities of electron in I, II and III Bohr Orbits ?

Ans. $\frac{1}{1} : \frac{1}{2} : \frac{1}{3}$ or $6 : 3 : 2$

24. Which atomic part was discovered by Rutherford ?

Ans. Nucleus

25. In nuclear reaction ${}_1^1\text{H} \rightarrow {}_0^1n + {}_Q^P\text{X}$ find P, Q and hence identify X.

Ans. $P = 0, Q = 1$

X is ${}_1^0e^0$ a positron.

26. Binding energies of deuteron (${}_1^2\text{H}$) and α -particle (${}_2^4\text{He}$) are 1.25 MeV/nucleon and 7.2 MeV/nucleon respectively. Which nucleus is more stable?

Ans. Binding energy of ${}_2^4\text{He}$ is more than deuteron ${}_1^2\text{H}$. Hence ${}_2^4\text{He}$ is more stable.

27. α -particles are incident on a thin gold foil. For what angle of deviation will the number of deflected α -particles be minimum?

Ans. 180°

28. If the amount of a radioactive substance is increased four times then how many times will the number of atoms disintegrating per unit time be increased?

Ans. Four times $\because R = -\lambda N$

29. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom?

Ans. Possible transitions are

$$n_i = 4 \text{ to } n_f = 3, 2, 1$$

$$n_i = 3 \text{ to } n_f = 2, 1$$

$$n_i = 2 \text{ to } n_f = 1$$

$$\text{Total transitions} = 6$$

For many electron system.

$$\left[\text{Max number of spectral lines} = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6 \right]$$

30. Under what conditions of electronic transition will the emitted light be monochromatic?

Ans. Only fixed two orbits are involved and therefore single energy evolve.

31. Why does only a slow neutron (.03eV energy) cause the fission in the uranium nucleus and not the fast one?

Ans. Slow neutron stays in the nucleus for required optimum time and disturbs the configuration of nucleus.

32. Write the relation for distance of closest approach.

Ans. $\gamma_0 = \frac{(Ze)(2e)}{4\pi\epsilon_0 \left(\frac{1}{2}mv^2\right)}$

33. In Bohr's atomic model, the potential energy is negative and has a magnitude greater than the kinetic energy, what does this imply?

Ans. The revolving electron is bound to the nucleus.

34. Name the physical quantity whose dimensions are same as Planck's constant.

Ans. Angular momentum

35. Define ionisation potential.

Ans. The minimum accelerated potential which would provide an electron sufficient energy to escape from the outermost orbit.

36. The ionisation potential of helium atom is 24.6 V. How much energy will be required to ionise it?

Ans. 24.6 eV

37. What is the energy possessed by an electron whose principal quantum number is infinite?

Ans. Zero $n = \infty$

$$\therefore E_n = -\frac{13.6}{n^2} \text{ eV} = 0.$$

38. What is the SI unit of work function?

Ans. Joule

39. Name the spectral series of hydrogen atom which lie in *uv* region.

Ans. Lyman Series

40. Name two series of hydrogen spectrum lying in the infra red region.

Ans. Paschan & P fund series

41. What is the order of velocity of electron in a hydrogen atom in ground state.

Ans. 10^6 ms^{-1}

42. Write a relation for the wavelength in Paschan series lines of hydrogen spectrum.

Ans. $\frac{1}{\lambda} = R \left(\frac{1}{3^2} - \frac{1}{n^2} \right), \quad n = 4, 5 \dots$

43. Arrange radioactive radiation in the increasing order of penetrating power.

Ans. α, β, γ

44. Write a relation between average life and decay constant.

Ans. $\tau = \frac{1}{\lambda} = \text{average life}$

45. Write two units for activity of radioactive element and relate them with number of disintegration per second.

Ans. $1 \text{ Curie (Ci)} = 3.7 \times 10^{10} \text{ decay/s}$
 $1 \text{ becquerel (Bq)} = 1 \text{ decay/s}$

46. The half life of a radioactive element A is same as the mean life time of another radioactive element B. Initially, both have same number of atoms. B decay faster than A. Why?

Ans.

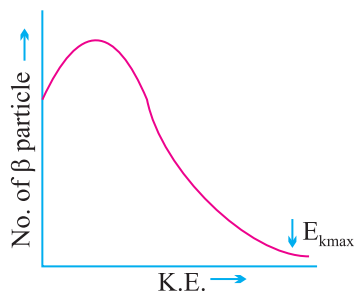
$$T_A = \tau_B = 1.44T_B$$

$$\therefore T_A > T_B$$

$$\therefore \lambda_A < \lambda_B$$

Therefore B decay faster than A.

47. Draw the graph showing the distribution of kinetic energy of electrons emitted during β decay.



48. Compare radii of two nuclei of mass numbers 1 and 27 respectively.

Ans.
$$\frac{R_1}{R_2} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$$

$$R_1 : R_2 = 1 : 3$$

49. Which element has highest value of Binding Energy per nucleon.

Ans. ${}^{56}\text{Fe}_{26}$

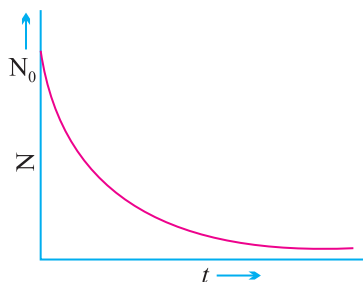
50. Mention the range of mass number for which the Binding energy curve is almost horizontal.

Ans. For $A = 30$ to 120 (A is mass number)

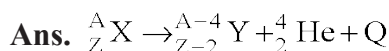
51. What is the ratio of nuclear densities of the two nuclei having mass numbers in the ratio 1 : 4?

Ans. 1 : 1 Because nuclear density is independent of mass number.

52. Draw a graph of number of undecayed nuclei to the time, for a radioactive nuclei.



53. Write an equation to represent α decay.



Atoms and Nuclie

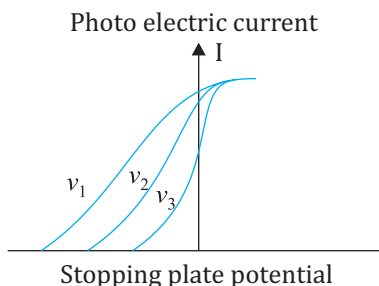
1. If a nucleus has mass defect 0.2 g. What will be its binding energy.
2. The Binding energy of helium nucleus is 28.17 max. Find its binding energy per nucleon.
3. Binding energy per nucleon for an element is 7.14 Mev. If the binding energy of the element is 28.6+ MeV. Calculate the no. of nucleons in the nucleus.
4. Calculate the mass defect of a helium nucleus. If its actual mass (atomic) is 4.001624 amu. The mass of one portion and one neutron together is 2.015941 amu.

VERY SHORT ANSWER QUESTIONS (1 Mark)

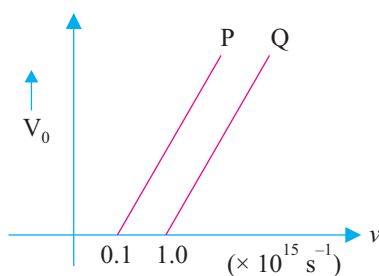
1. Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum.
2. Define the term “threshold frequency”, in the context of photoelectric emission.
3. Define the term “intensity” in photon picture of light.
4. Define intensity of radiation based on photon picture of light.
5. Plot a graph showing the variation of photoelectric current versus intensity of light.
6. Plot a graph of stopping potential (V_0) versus the frequency (ν) of incident radiation in photoelectric emission.
7. Plot a graph of the de-Broglie wavelength associated with a photon versus its momentum.
8. Plot a graph of the de-Broglie wavelength associated with electron as a function of accelerating potential.
9. A proton is accelerated through a potential difference V , subjected to a uniform magnetic field acting normal to the velocity of the proton. If

the potential differences is doubled, how will the radius of the circular path described by the proton in the magnetic field change?

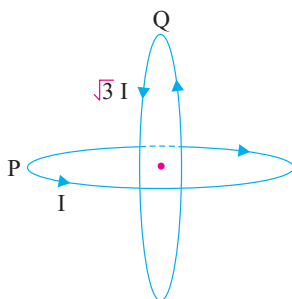
10. On the basis of the graphs shown in the figure, answer the following questions:



- (a) Which physical parameter is kept constant for the three curves?
- (b) Which is the highest frequency among, ν_1 , ν_2 and ν_3 ?
11. In the photoelectric emission, when the frequency of incident radiation is doubled, will the maximum kinetic energy of photoelectrons also be doubled? Justify your answer.
12. The figure shows the variation of stopping potential V_0 with the frequency ν of the incident radiations for two photosensitive metals P and Q. Which metal has smaller threshold wavelength? Justify your answer.

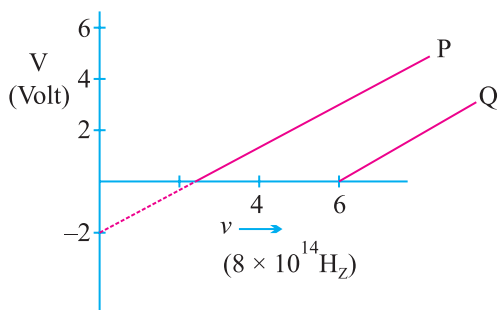


13. Plot a graph of de-Broglie wavelength associated with electron as a function of its kinetic energy.



SHORT ANSWER QUESTIONS (2 Marks)

1. Write one similarity and one difference between matter wave and an electromagnetic wave.
2. Does a photon have a de-Broglie wavelength? Explain.
3. A photon and an electron have energy 200 eV each. Which one of these has greater de-Broglie wavelength?
4. The work function of the following metal is given Na = 2.75 eV, K = 2.3 eV, Mo = 4.14 eV, Ni = 5.15 eV which of these metal will not give a photoelectric emission for radiation of wave length 3300 \AA from a laser source placed at 1m away from the metal. What happens if the laser is brought nearer and placed 50 cm away.
5. Represent graphically Variation of the de-Broglie wavelength with linear momentum of a particle.
6. In a photoelectric effect experiment, the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q are shown in Fig. :



- (i) Which of the two metals has greater value of work function?
 - (ii) Find maximum K.E. of electron emitted by light of frequency $\nu = 8 \times 10^{14} \text{ Hz}$ for metal P.
7. Do all the photons have same dynamic mass? If not, Why?
 8. Why photoelectrons ejected from a metal surface have different kinetic energies although the frequency of incident photons are same?

9. Find the ratio of de-Broglie wavelengths associated with two electrons 'A' and 'B' which are accelerated through 8V and 64 volts respectively.
10. Explain the terms stopping potential and threshold frequency.
11. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals?
12. Define distance of the closest approach. An α -particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α -particle of double the kinetic energy?
13. An α particle and a proton are accelerated by same potential. Find ratio of their de Broglie wavelengths. **Ans.** $[1:2\sqrt{2}]$
14. Which of the following radiations α , β and γ are :
 - (i) similar to x-rays?
 - (ii) easily absorbed by matter
 - (iii) travel with greatest speed?
 - (iv) similar to the nature of cathode rays?
15. Some scientist have predicted that a global nuclear war on earth would be followed by 'Nuclear winter'. What could cause nuclear winter?
16. If the total number of neutrons and protons in a nuclear reaction is conserved how then is the energy absorbed or evolved in the reaction?
17. In the ground state of hydrogen atom orbital radius is 5.3×10^{-11} m. The atom is excited such that atomic radius becomes 21.2×10^{-11} m. What is the principal quantum number of the excited state of atom?
18. Calculate the percentage of any radioactive substance left undecayed after half of half life.
19. Why is the density of the nucleus more than that of atom?
20. The atom ${}^8_8\text{O}^{16}$ has 8 protons, 8 neutrons and 8 electrons while atom ${}^4_4\text{Be}^8$ has 4 proton, 4 neutrons and 4 electrons, yet the ratio of their atomic masses is not exactly 2. Why?
21. What is the effect on neutron to proton ratio in a nucleus when β^- particle is emitted ? Explain your answer with the help of a suitable nuclear reaction.
22. Why must heavy stable nucleus contain more neutrons than protons?

23. Show that the decay rate R of a sample of radio nuclide at some instant is related to the number of radio active nuclei N at the same instant by the expression $R = -N\lambda$.
24. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purpose?
25. Write two characteristic features of nuclear forces which distinguish them from coulomb force.
26. Half life of certain radioactive nuclei is 3 days and its activity is 8 times the 'safe limit'. After how much time will the activity of the radioactive sample reach the 'safe limit'?
27. Derive $mvr = \frac{nh}{2\pi}$ using de-Broglie equation.
28. Draw graph of number of scattered particles to scattering angle in Rutherford's experiment.
29. If the energy of a photon is 25 eV and work function of the material is 7eV, find the value of stopping potential.
30. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines?
- Ans.** (i) 820nm, (ii) 365 nm
31. The radius of the inner most electron orbit of a hydrogen atom 0.53 Å. What are the radii of the $n = 2$ and $n = 3$ orbits. [Hint: $r = n^2 r_0$]
32. The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of the electron in this state?
[Hint : K.E = $-(T.E)$, P.E. = $2T.E$]
33. Why is the wave nature of matter not more apparent to our daily observations ?
34. From the relation $R = R_0 A^{1/3}$ where R_0 is a constant and A is the mass number of a nucleus, show that nuclear matter density is nearly constant.

Ans. Nuclear matter density = $\frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} = 2.3 \times 10^{17} \text{ kg / m}^3$$

$$= \text{Constant}$$

35. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

$$\begin{aligned}
 \text{Ans. } E &= \Delta mc^2 \quad \Delta m = 1.6605 \times 10^{-27} \text{ kg} \\
 &= 1.6605 \times 10^{-27} \times (3 \times 10^8)^2 \\
 &= 1.4924 \times 10^{-10} \text{ J} \\
 &= \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} \text{ eV} \\
 &= 0.9315 \times 10^9 \text{ eV} \\
 &= 931.5 \text{ MeV}
 \end{aligned}$$

36. Write four properties of nuclear force.

SHORT ANSWER QUESTIONS (3 Marks)

1. Explain the working of a photocell? Give its two uses.
2. Find the de-Broglie wavelength associated with an electron accelerated through a potential difference V.
3. What is Einstein's explanation of photo electric effect? Explain the laws of photo electric emission on the basis of quantum nature of light.
4. Light of intensity I and frequency ν is incident on a photosensitive surface and causes photoelectric emission. Justify with the help of graph, the effect on photoelectric current when
 - (i) the intensity of light is gradually increased
 - (ii) the frequency of incident radiation is increased
 - (iii) the anode potential is increased

In each case, all other factors remain the same.
5. Write Einstein's photoelectric equation. State Clearly the three salient features observed in photoelectric effect which can be explained on the basis of the above equation.
6. Explain the effect of increase of (i) frequency (ii) intensity of the incident radiation on photo electrons emitted by a metal.
7. X-rays of wave length λ fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected,

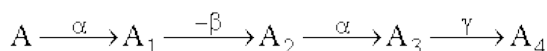
prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$.

$$\text{Ans. } E = \frac{hc}{\lambda} = \frac{P^2}{2m} \therefore P = \sqrt{\frac{2mhc}{\lambda}}, \lambda_e = \frac{h}{P} = \sqrt{\frac{h\lambda}{2mc}}$$

8. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having velocities V_1 and V_2 respectively. Find the ratio of de-Broglie wavelengths of the two particles.

Ans. 1 : 1

9. Give one example of a nuclear reaction. Also define the Q -value of the reaction. What does $Q > 0$ signify?
10. Explain how radio-active nucleus can emit β -particles even though nuclei do not contain these particles. Hence explain why the mass number of radioactive nuclide does not change during β -decay.
11. Define the term half life period and decay constant. Derive the relation between these terms.
12. State the law of radioactive decay. Deduce the relation $N = N_0 e^{-\lambda t}$, where symbols have their usual meaning.
13. Give the properties of α -particles, β -particles and γ -rays.
14. With the help of one example, explain how the neutron to proton ratio changes during alpha decay of a nucleus.
15. Distinguish between nuclear fusion and fission. Give an example of each.
16. A radioactive nucleus A undergoes a series of decays according to following scheme



The mass number and atomic number of A_4 are 172 and 69 respectively. What are these numbers for A ?

Ans. Mass no. of $A = 180$, Atomic no. of $A = 72$

17. Obtain a relation for total energy of the electron in terms of orbital radius. Show that total energy is negative of K.E. and half of potential energy.

$$E = \frac{-e^2}{8\pi\epsilon_0 r}$$

18. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.
19. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV. What is

- (a) the kinetic energy,
 - (b) the potential energy of the electron?
 - (c) Which of the answers above would change if the choice of the zero of potential energy is changed to (i) + 0.5 eV (ii) – 0.5 eV.
- Ans.** (a) When P.E. is chosen to be zero at infinity $E = -3.4$ eV, using $E = -\text{K.E.}$, the K.E. = + 3.4 eV.
- (b) Since P.E. = – 2E, PE = – 6.8 eV.
- (c) If the zero of P.E. is chosen differently, K.E. does not change. The P.E. and T.E. of the state, however would alter if a different zero of the P.E. is chosen.
- (i) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be $-3.4 - 0.5 = -3.9$ eV.
- (ii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be $-3.4 - (-0.5) = -2.9$ eV.
- 20.** What is beta decay? Write an equation to represent β^- and β^+ decay. Explain the energy distribution curve is β decay.
- 21.** Using energy level diagram show emission of γ rays by ${}^{60}_{27}\text{Co}$ nucleus and subsequent β decay to obtain ${}^{60}_{28}\text{Ni}$.

LONG ANSWER QUESTIONS (5 Marks)

1. State Bohr's postulates. Using these postulates, derive an expression for total energy of an electron in the n^{th} orbit of an atom. What does negative of this energy signify?
2. Define binding energy of a nucleus. Draw a curve between mass number and average binding energy per nucleon. On the basis of this curve, explain fusion and fission reactions.
3. State the law of radioactive disintegration. Hence define disintegration constant and half life period. Establish relation between them.
4. What is meant by nuclear fission and fusion. Draw Binding Energy Vs Mass Number curve and explain four important features of this curve.
5. Briefly explain Rutherford's experiment for scattering of α particle with the help of a diagram. Write the conclusion made and draw the model suggested.

NUMERICALS

1. Ultraviolet light of wavelength 350 nm and intensity 1 W/m^2 is directed at a potassium surface having work function 2.2eV.
 - (i) Find the maximum kinetic energy of the photoelectron.
 - (ii) If 0.5 percent of the incident photons produce photoelectric effect, how many photoelectrons per second are emitted from the potassium surface that has an area 1cm^2 .

$$E_{K_{\max}} = 1.3 \text{ eV}; n = 8.8 \times 10^{11} \frac{\text{photo electron}}{\text{second}} \text{ or } r = \frac{N h \nu}{t} = n h \nu$$

2. A metal surface illuminated by $8.5 \times 10^{14} \text{ Hz}$ light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by $12.0 \times 10^{14} \text{ Hz}$ light emits elections whose maximum energy is 1.97eV. From these data find work function of the surface and value of Planck's constant. [Work Function = 3eV]
 3. An electron and photon each have a wavelength of 0.2 nm. Calculate their momentum and energy.
 - (i) $3.3 \times 10^{-24} \text{ kgm/s}$
 - (ii) 6.2 keV for photon
 - (iii) 38eV for electron
 4. What is the (i) Speed (ii) Momentum (ii) de-Broglie wavelength of an electron having kinetic energy of 120eV?
- Ans.** (a) $6.5 \times 10^6 \text{ m/s}$; (b) $5.92 \times 10^{-24} \text{ kg m/s}$; (c) 0.112 nm.
5. If the frequency of incident light in photoelectric experiment is doubled then does the stopping potential become double or more than double, justify? (More than double)

Long Answer Question :

6. (A) Why wave theory of light could not explain the photoelectric effect? State two reasons. Draw graph between
 - (i) frequency ν vs stopping potential V_0 .
 - (ii) Intensity vs photoelectric current.
 - (iii) anode potential vs photoelectric current.

- 6.(B) 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%.

(9.1%)

7. For what kinetic energy of a neutron will the associated de-Broglie wavelength be $5.6 \times 10^{-10}\text{m}$?

Ans.
$$\sqrt{2m_n \times \text{K.E.}} = \frac{h}{\lambda}$$

$$\Rightarrow \text{K.E.} = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$$

$$= \left(\frac{6.625 \times 10^{-34}}{5.6 \times 10^{-10}}\right)^2 \frac{1}{2 \times 1.67 \times 10^{-27}}$$

$$= 3.35 \times 10^{-21}\text{J}$$

8. A nucleus of mass M initially at rest splits into two fragments of masses $\frac{M}{3}$ and $\frac{2M}{3}$. Find the ratio of de-Broglie wavelength of the fragments.

Ans. Following the law of conservation of momentum,

$$\frac{M}{3}v_1 + \frac{2M}{3}v_2 = 0$$

or
$$\left|\frac{M}{3}v_1\right| = \left|\frac{2M}{3}v_2\right|$$

$$\lambda = \frac{h}{mv} \Rightarrow \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{2\frac{M}{3}v_2}{\frac{M}{3}v_1}\right| = 1$$

9. An electron and a proton are possessing same amount of K.E., which of the two have greater de-Broglie, wavelength? Justify your answer.

Ans.
$$E_e = \frac{1}{2}m_e v_e^2$$

and
$$E_p = \frac{1}{2}m_p v_p^2$$

$$\Rightarrow m_e v_e = \sqrt{2E_e m_e} \text{ and } m_p v_p = \sqrt{2E_p m_p}$$

But,
$$E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$$

$\therefore \lambda_e > \lambda_p.$

- 10.** The electron in a given Bohr orbit has a total energy of -1.51 eV. Calculate the wavelength of radiation emitted, when this electron makes a transition to the ground state.

Ans. 1028 \AA

- 11.** Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in third Bohr orbit of hydrogen atom.

Ans. (-1.51 eV)

- 12.** Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant $= 1.0987 \times 10^7 \text{ m}^{-1}$.

Ans. $\lambda_l = 6553 \text{ \AA}, \lambda_s = 3640 \text{ \AA}$

- 13.** What will be the distance of closest approach of a 5 MeV α -particle as it approaches a gold nucleus? (given Atomic no. of gold $= 79$)

Ans. $4.55 \times 10^{-14} \text{ m}$

- 14.** A 12.5 MeV alpha – particle approaching a gold nucleus is deflected 180° . What is the closest distance to which it approaches the nucleus?

Ans. $1.82 \times 10^{-14} \text{ m}$

- 15.** Determine the speed of the electron in $n = 3$ orbit of hydrogen atom.

Ans. $7.29 \times 10^5 \text{ ms}^{-1}$

- 16.** There are $4\sqrt{2} \times 10^6$ radioactive nuclei in a given radio active element. If half life is 20 seconds, how many nuclei will remain after 10 seconds?

Ans. 4×10^6

- 17.** The half life of a radioactive substance is 5 hours. In how much time will $15/16$ of the material decay?

Ans. 20 hours

- 18.** At a given instant, there are 25% undecayed radioactive nuclei in a sample. After 10 seconds, the number of undecayed nuclei reduces 12.5%. Calculate the mean life of nuclei.

Ans. 14.43

19. Binding energy of ${}_2\text{He}^4$ and ${}_3\text{Li}^7$ nuclei are 27.37 MeV and 39.4 MeV respectively. Which of the two nuclei is more stable? Why?

Ans. ${}_2\text{He}^4$ because its BE/nucleon is greater.

20. Find the binding energy and binding energy per nucleon of nucleus ${}_{83}\text{Bi}^{209}$.

Given : mass of proton = 1.0078254 u. mass of neutron = 1.008665 u.

Mass of ${}_{83}\text{Bi}^{209} = 208.980388\text{u}$.

Ans. 1639.38 MeV and 7.84 MeV/Nucleon

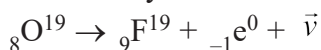
21. Is the fission of iron (${}_{26}\text{Fe}^{56}$) into (${}_{13}\text{Al}^{28}$) as given below possible?



Given mass of ${}_{26}\text{Fe}^{56} = 55.934940$ and ${}_{13}\text{Al}^{28} = 27.98191 \text{ U}$

Ans. Since Q value comes out negative, so this fission is not possible

22. Find the maximum energy that β -particle may have in the following decay :



Given

$$m({}_8\text{O}^{19}) = 19.003576 \text{ a.m.u.}$$

$$m({}_9\text{F}^{19}) = 18.998403 \text{ a.m.u.}$$

$$m({}_{-1}\text{e}^0) = 0.000549 \text{ a.m.u.}$$

Ans. 4.3049 MeV

23. The value of wavelength in the lyman series is given as

$$\lambda = \frac{913.4n_i^2}{n_i^2 - 1} \text{ \AA}$$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decreases or increase.

Ans. $\lambda_{21} = \frac{913.4 \times 2^2}{2^2 - 1} = 1218 \text{ \AA}$

$$\lambda_{31} = \frac{913.4 \times 3^2}{3^2 - 1} = 1028 \text{ \AA}$$

$$\lambda_{41} = \frac{913.4 \times 4^2}{4^2 - 1} = 974.3 \text{ \AA}$$

$$\lambda_{41} < \lambda_{31} < \lambda_{21}$$

24. The half life of ${}^{238}_{92}\text{U}$ undergoing α decay is 4.5×10^9 years what is the activity of 1g. sample of ${}^{238}_{92}\text{U}$.

Ans.

$$\begin{aligned} T_{1/2} &= 4.5 \times 10^9 \text{ y} \\ &= 4.5 \times 10^9 \times 3.16 \times 10^7 \text{ s} \\ &= 1.42 \times 10^{17} \text{ s} \end{aligned}$$

$$\begin{aligned} 1\text{g of } {}^{238}_{92}\text{U} \text{ contains} &= \frac{1}{238} \times 6.025 \times 10^{23} \text{ atom} \\ &= 25.3 \times 10^{20} \text{ atoms} \end{aligned}$$

$$\begin{aligned} \therefore \text{decay rate} = R = \lambda N &= \frac{0.693}{T} \times N \\ &= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} \text{ s}^{-1} \\ &= 1.23 \times 10^4 \text{ bq.} \end{aligned}$$

Answer to 2 Marks Question

1. Similarity : Both follow wave equation (partial differential equation)
dissimilarity : Matter waves

- (a) cannot be radiated in empty space.
(b) are associated with the particles, not emitted by it

2. Yes, $\lambda = \frac{hc}{E}$

3. $\lambda = \frac{h}{p}$ for photon $P = \frac{E}{C}$ and $\lambda = \frac{hc}{E}$ for electron $P = \sqrt{2mE}$

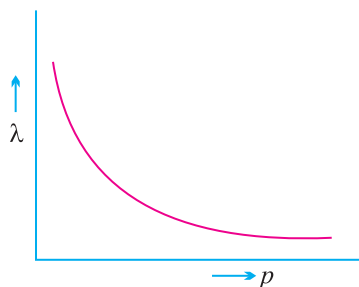
$$\lambda_{\text{photon}} = 2.4 \times 10^{-8} \text{ m}, \lambda_{\text{electron}} = 3.6 \times 10^{-10} \text{ m}$$

4. $\lambda = 3300 \text{ \AA}, E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}} \text{ eV} \approx 3.8 \text{ eV}$

Work function of M_0 & $\text{Ni} > 3.8 \text{ eV}$ hence no photoelectron emission from M_0 and Ni .

5. $\lambda = \frac{h}{p}$

$$\Rightarrow \lambda \propto \frac{1}{p}$$



6. Q

$$\text{K.E.}_{\text{max}} \approx 1.3 \text{ eV} \quad \text{As } \frac{h\nu_0}{e} = -2V$$

7. $E = mc^2$, $h\nu = mc^2$, $m = \frac{h\nu}{c^2}$, no, it depends upon frequency.

8. $\text{KE} = h\nu - h\nu_0$. The electrons in the atom of metal occupy different energy levels, thus have different minimum energy required to be 'ejected' from the atom. So the e^- with higher energy will have higher kinetic energy.

9. Decreases, $\lambda = \frac{1}{\sqrt{V}} \therefore \frac{\lambda_1}{\lambda_2} = \frac{2\sqrt{2}}{1}$

11. $\text{KE}_{\text{max}} = h\nu - w_0 \Rightarrow \text{KE}_{\text{max}}$ decreases with increase in w_0 .

12. Distance of closest approach is defined as the minimum distance between the charged particle and the nucleus at which initial kinetic energy of the particle is equal to electrostatic potential energy.

$$\text{for } \alpha \text{ particle, } \frac{KZe(2e)}{r} = \frac{1}{2}mv_{\alpha}^2$$

$$r \propto \frac{1}{\text{K.E.}}$$

$\therefore r$ will be halved.

14. (i) Similar to x-rays — γ -rays.

(ii) α -particle.

(iii) γ -rays.

(iv) β -particle.

15. Nuclear radioactive waste will hang like a cloud in the earth atmosphere and will absorb sun radiations.

16. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

17. $n = 2$ as $r_n \propto n^2$

18. From relation $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ when $t = T/2$

$$\frac{N}{N_0} = \left(-\right)^{1/2}$$

or

$$\frac{N}{N_0} = \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.9 \%$$

19. Because radius of atom is very large than radius of nucleus.

20. Due to mass defect or different binding energies.

21. Decreases as number of neutrons decreases and number of protons increases. $N \rightarrow P + {}_{-1}e^0$

22. To counter repulsive coulomb forces, strong nuclear force required between neutron-neutron, neutron-proton and proton-proton.

23. $N = N_0 e^{-\lambda t}$ differentiating both sides we get $\frac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N$ i.e.,
decay rate

$$R = -\frac{dN}{dt} = \lambda N$$

24. For fusion, temperature required is from 10^6 to 10^7 K. So, to carry out fusion for peaceful purposes we need some system which can create and bear such a high temperature.

25. Nuclear forces are short range forces (within the nucleus) and do not obey inverse square law while coulomb forces are long range (infinite) and obey inverse square law.

26.

$$\left(\frac{A}{8A}\right) = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

or

$$\left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/3}$$

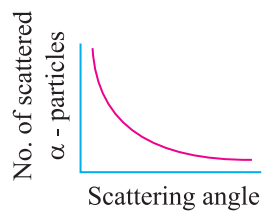
or

$$3 = \frac{t}{3}$$

\Rightarrow

$$t = 9 \text{ days.}$$

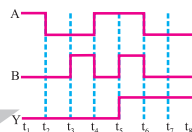
28.



29.

$$V_0 = (E - \phi_0)/e = \frac{(25 - 7)eV}{e} = 18V.$$





Unit IX

Electronic Devices

Unit IX

ELECTRONIC DEVICES

KEY POINTS

ELECTRONIC DEVICES

1. Solids are classified on the basis of

(i) Electrical conductivity	Resistivity	Conductivity
Metals	$\rho(\Omega\text{m})$ $10^{-2} - 10^{-8}$	$\sigma(\text{Sm}^{-1})$ $10^2 - 10^8$
Semi-conductors	$10^{-5} - 10^6$	$10^{-6} - 10^5$
Insulators	$10^{11} - 10^{19}$	$10^{-19} - 10^{-11}$

(ii) Energy Bands

(a) Metals \rightarrow

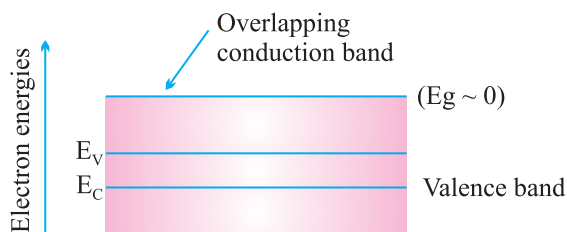


Fig. (a)

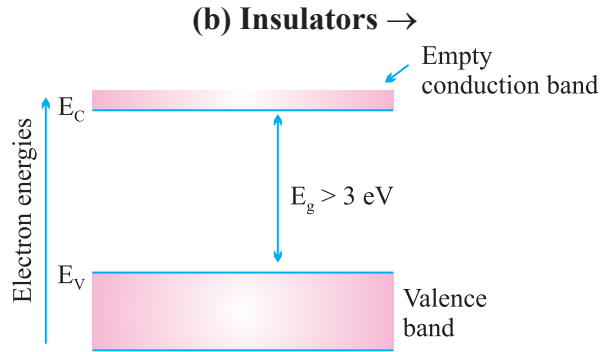


Fig (b)

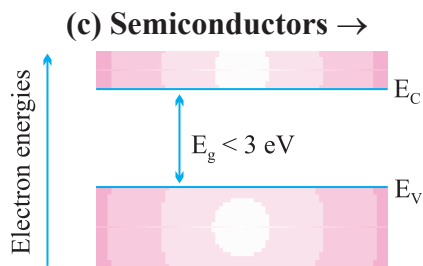
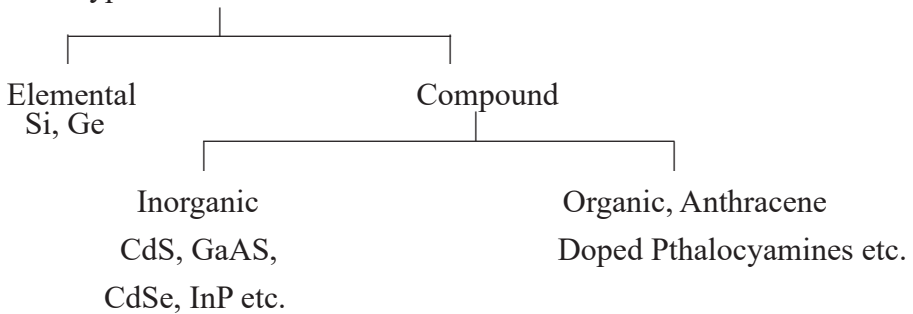


Fig (c)

2. Types of Semi-conductors

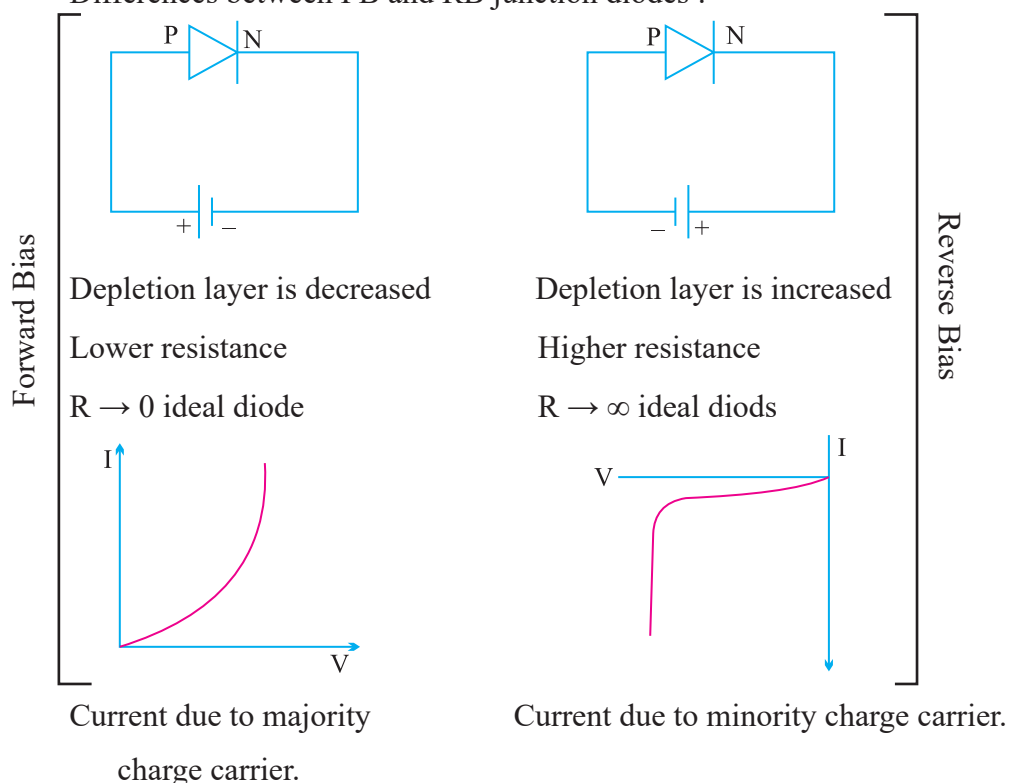
2 Types of semi-conductors



3. In intrinsic semiconductors (Pure Si, Ge) carrier (electrons and holes) are generated by breaking of bonds within the semiconductor itself. In extrinsic semiconductors carriers (e and h) are increased in numbers by 'doping'.
4. An intrinsic semiconductor at 0 K temperature behaves as an insulator.
5. Pentavalent (donor) atom (As, Sb, P etc) when doped to Si or Ge give n -type and trivalent (acceptor) atom (In, Ga, Ag, etc) doped with Si or Ge give p -type semiconductor. In n -type semiconductor electrons are the majority charge carriers & in p -type holes are the majority charge carriers.

6. Net charge in p -type or n -type semiconductor remains zero.
7. Diffusion and drift are the two processes that occur during formation of p - n junction.
8. Diffusion current is due to concentration gradient and drift current is due to electric field.
9. In depletion region movement of electrons and holes depleted it of its free charges.
10. p - n Junction is the most important semiconductor device because of its different behaviours in forward biasing (as conductor for $V > V_b$) and reverse biasing (as insulator for $V < V_B$) a p - n junction can be used as Rectifier, LED, photodiode, solar cell etc.

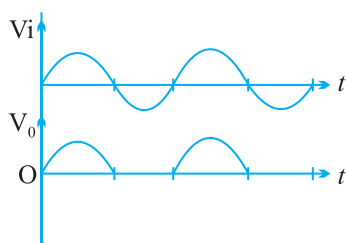
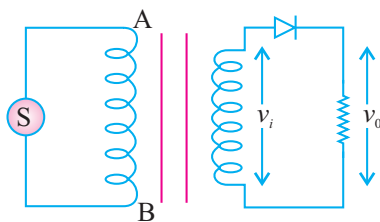
Differences between FB and RB junction diodes :



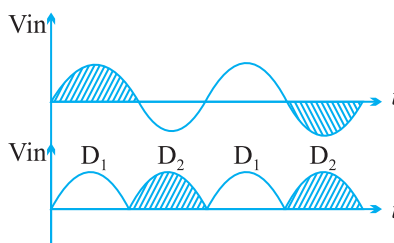
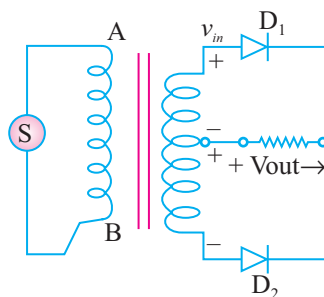
11. In half wave rectifier frequency output pulse is same as that of input and in full wave rectifier frequency of output is double of input.

Rectifier p - n junction diode

Half Wave Rectifier



Full Wave Rectifier



12. When a zener diode is reverse biased, voltage across it remains steady for a range of currents above zener breakdown. Because of this property, the diode is used as a voltage regulator.

QUESTIONS

VERY SHORT ANSWER QUESTIONS

1. Name the process involved in the formation of p - n junction diode.
[Drift and Diffusion]
2. Name three processes involved in the formation of solar cell.
[generation, separation and collection]
3. Distinguish between intrinsic and extrinsic semiconductors on the basis of energy band diagrams.
4. How does energy gap in intrinsic semiconductor vary when it is doped with a(i) pentavalent impurity (ii) trivalent impurity?
5. Which type of extrinsic semiconductor has more mobility and why?

6. Name the factors which determines (i) frequency and (ii) intensity of light emitted by LED. [(i) Bandgap (ii) doping]

7. How does the width of depletion region of a p - n junction diode change with decrease in reverse bias?

8. What is the direction of diffusion current in a function diode? [p - n]

9. Zener diode has higher dopant density as compared to ordinary p - n function diode. How does it effect (i) width of deflection layer and (ii) function field.

$$[(i) \downarrow (ii) \uparrow \text{ as } E_{\beta} = \frac{V_B}{d}]$$

10. How does the height of potential barrier vary with increase in temp. [\uparrow]

11. Write the relation between number density of holes and number density of free electrons in an intrinsic semiconductor.

Ans. $n_e = n_h$

12. Write the value of resistance offered by an ideal diode when (i) forward based (ii) reverse biased.

Ans. (i) Zero (ii) infinite

13. Write any one use of (i) photodiode (ii) LED.

Ans. (i) Use of Photodiode

- (a) In detection of optical signal
- (b) In demodulation of optical signal
- (c) In light operated switches
- (d) In electronic counters

(ii) Use of LED

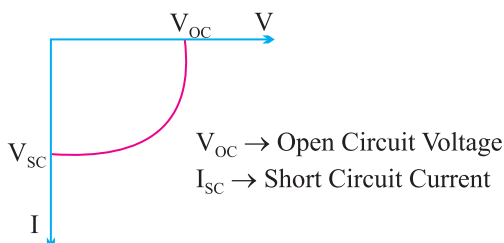
- (a) Infrared LEDs are used in burglar alarm
- (b) In optical communication
- (c) LED's are used as indicator lamps in radio receivers
- (d) In remote controls

14. A semiconductor is damaged when strong current passes through it. Why ?

Ans. Because bonds break up, crystal lattice breakdown takes place and crystal lattice becomes useless.

15. Draw I–V characteristic of a solar cell.

Ans.



16. What is the direction of diffusion current in a junction diode ?

Ans. The direction of diffusion current is from P to N in a semiconductor junction diode.

17. Draw a circuit diagram showing the biasing of a photodiode.

18. Name the semiconductor device that can be used to regulate an unregulated dc power supply.

Ans. Zener diode

19. Name the *p-n* junction diode which emits spontaneous radiation when forward biased.

Ans. Light emitting diode (LED)

20. Name the material used to make a light emitting diode.

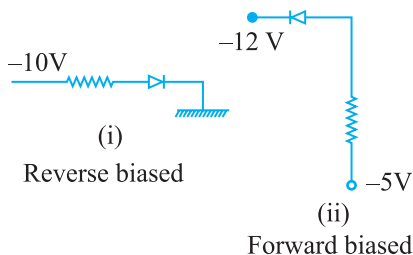
Ans. GaAs and GaP

21. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. When polarity of the battery is reversed, the current drops to almost zero. Name the semiconductor device.

Ans. P–N junction

(Junction Diode)

22. In the following diagram write which of the diode is forward biased and which is reverse biased ?



23. How does the energy gap in semiconductor vary, when doped, with a pentavalent impurity ?

Ans. The energy gap decreases.

19. What is the order of energy gap in a conductor, semiconductor and insulator.

Ans. Conductor—no energy gap

Semiconductor < 3 eV

Insulator > 3 eV

20. The ratio of the number of free electrons to holes n_e/n_h for two different materials A and B are 1 and < 1 respectively. Name the type of semiconductor to which A and B belong.

Ans. $\frac{n_e}{n_h} = 1 \Rightarrow n_e = n_h \therefore$ Intrinsic semiconductor

$\frac{n_e}{n_h} < 1 \Rightarrow n_e < n_h \therefore p$ type extrinsic semiconductor

SHORT ANSWER QUESTIONS (2 MARKS)

1. If the frequency of the input signal is f . What will be the frequency of the pulsating output signal in case of :

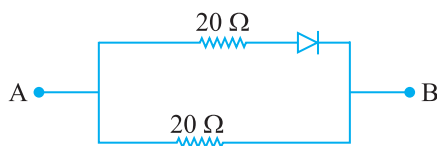
(i) half wave rectifier ?

(ii) full wave rectifier ?

2. Find the equivalent resistance of the network shown in figure between point A and B when the p - n junction diode is ideal and :

(i) A is at higher potential

(ii) B is at higher potential

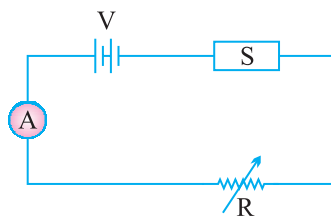


3. Potential barrier of p - n . junction cannot be measured by connecting a sensitive voltmeter across its terminals. Why ?

4. Diode is a non linear device. Explain it with the help of a graph.

5. A n -type semiconductor has a large number of free electrons but still it is electrically neutral. Explain.

6. The diagram shows a piece of pure semiconductor S in series with a variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter A constant, when semiconductor S is heated ? Give reason.

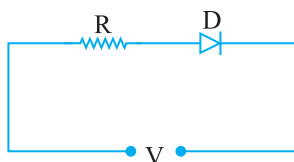


7. In the given circuit, D is an ideal diode. What is the voltage across R ?

When the applied voltage V makes the diode.

(a) Forward bias ?

(b) Reverse bias ?



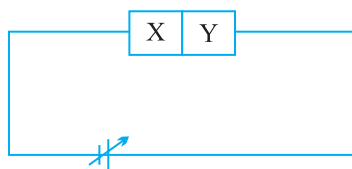
8. What are the characteristics to be taken care of while doping a semiconductor ? Justify your answer.

Ans. (a) The size of the dopant atom should be such that it do not distort the pure semiconductor lattice.

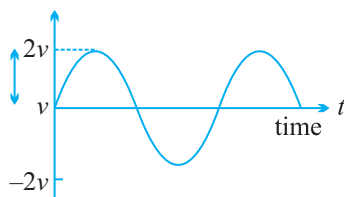
(b) It can easily contribute a charge carrier on forming covalent bond with pure Si or Ge.

9. Which special type of diode can act as a voltage regulator ? Give the symbol of this diode and draw the general shape of its V-I characteristics.
10. Show the donor energy level in energy band diagram of *n*-type semiconductor.
11. Show the acceptor energy level in energy band diagram of *p*-type semiconductor.
12. What is the value of knee voltage in
 - (a) Ge junction diode.
 - (b) Si junction diode.
13. Describe the working principle of a solar cell. Mention three basic processes involved in the generation of emf.
14. Two semiconductor materials X and Y shown in the given figure, are made by doping germanium crystal with indium and arsenic respectively. The two

are joined at lattice level and connected to a battery as shown.



- (i) Will the junction be forward biased or reversed biased ?
 - (ii) Sketch a V-I graph for this arrangement.
15. Following voltage waveform is fed into half wave rectifier that uses a silicon diode with a threshold voltage of 0.7 V. Draw the output voltage waveform.



SHORT ANSWER QUESTIONS (3 MARKS)

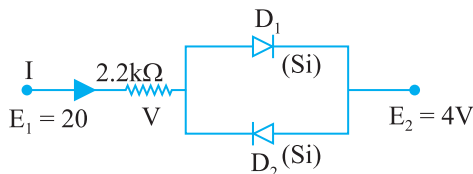
1. What is depletion region in p - n junction diode. Explain its formation with the help of a suitable diagram.
2. What is rectification ? With the help of labelled circuit diagram explain half wave rectification using a junction diode.
3. With the help of a circuit diagram explain the V-I graph of a p - n junction in forward and reverse biasing.
4. What is p - n junction ? How is p - n junction made ? How is potential barrier developed in a p - n junction.
5. Give three differences between forward bias and reverse bias.
6. Show the biasing of a photodiode with the help of a circuit diagram. Draw graphs to show variations in reverse bias currents for different illumination intensities.
7. Write three differences between n -type semiconductor and p -type semiconductor.

LONG ANSWER QUESTIONS (5 MARKS)

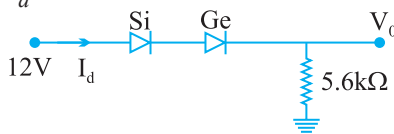
3. What is p - n junction diode ? Define the term dynamic resistance for the junction. With the help of labelled diagram, explain the working of p - n junction as a full wave rectifier.

NUMERICALS

- In a p - n junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.
 - Find the height of potential barrier.
 - What should be the minimum kinetic energy of a conduction electron which can diffuse from the n -side to the p -side ?
- An LED is constructed from a p - n junction of a certain semiconducting material whose energy gap is 1.9 eV. What is the wavelength of light emitted by this LED ? [Ans. $\lambda = 6.54 \times 10^{-7}$ m]
- Determine the current I for the network. (Barrier voltage for Si diode is 0.7 volt).



4. Determine V_0 and I_d for the network.

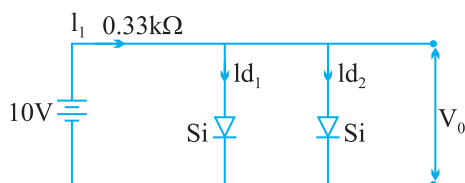


5. A p - n junction is fabricated from a semiconductor with a band gap of 2.8 eV. Can it detect a wavelength of 600 nm ? Justify your answer.

Ans. Energy of photon of wavelength 600 nm = 2.07 eV working condition of photodiode $h\nu \geq E_g$ but $E_g > h\nu$ so photodiode can not detect the given wavelength

6. Determine V_0 , I_{d1} and I_{d2} for the given network. Where D_1 and D_2 are made of silicon.

$$\left(I_{d1} = I_{d2} = \frac{I_1}{2} = 14.09 \text{ mA} \right)$$



Ans. $V_0 = V_{si} = 0.7V$

$$I_1 = \frac{10 - 0.7}{.33 \times 10^3}$$

$$= 28.18 \text{ mA}$$

$$\therefore I_{d1} = I_{d2} = \frac{28.18}{2}$$

$$= 14.09 \text{ mA}$$

7. Pure Si at 300 K has equal electron (n_e) and hole (n_h) concentration of $1.5 \times 10^{16}/\text{m}^3$. Doping by indium increases n_h to $4.5 \times 10^{22}/\text{m}^3$. Calculate n_e in the doped silicon. **[Ans. : $5 \times 10^9 \text{ m}^{-3}$]**
8. The solar radiation spectrum shows that maximum solar intensity is near to energy $h\nu = 1.5 \text{ eV}$. Answer the following :
- Why are Si and GaAs are preferred materials for solar cells.
 - Why Cd S or CdSe ($E_g \sim 2.4 \text{ eV}$) are not preferred.
 - Why we do not use materials like PbS ($E_g \sim 0.4 \text{ eV}$).

- Ans.** (i) For photo-excitation, $h\nu > E_g$. Si has $E_g \sim 1.1 \text{ eV}$ and for GaAs, $E_g \sim 1.53 \text{ eV}$.
GaAs is better than Si because of its relatively higher absorption coefficient.
- (ii) If we choose CdS or CdSe, we can use only the high energy component of the solar energy for photo-conversion and a significant part of energy will be of no use.
- (iii) The condition $h\nu > E_g$ is satisfied, but if we use PbS, most of solar radiation will be absorbed on the top-layer of solar cell and will not reach in or near depletion region.

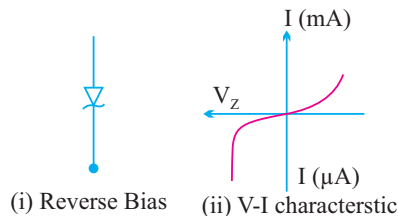
SHORT ANSWER QUESTIONS (2 MARKS)

1. Frequency of output in half wave rectifier is f and in full wave rectifier is $2f$.
2. Equivalent resistance is
 - (i) 10Ω , As diode is forward biased
 - (ii) 20Ω , diode is reverse biased
3. Because there is no free charge carrier in depletion region.
6. On heating S, resistance of semiconductors S is decreased so to compensate the value of resistance in the circuit R is increased.
9. In this case diode is sensitive and it is easier to observe fractional change in current with change in intensity.

16. (a) V

(b) Zero

21. Zener diode

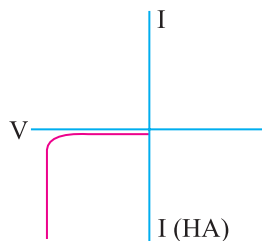


26. Ge ~ 0.3 V

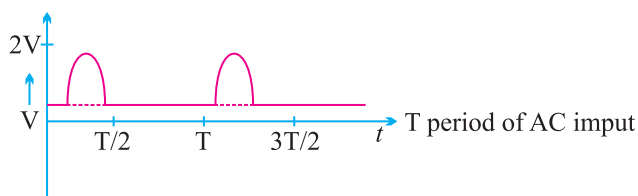
Si ~ 0.7 V

29. (i) Reverse bias

(ii)



31. Output waveform is :



NUMERICALS

1. (i) $V = Ed = 7 \times 10^5 \times 300 \times 10^{-9} = 0.21 \text{ V}$

(ii) Kinetic energy = $eV = 0.21 \text{ eV}$

4. $I = \frac{E_1 - E_2 - V_d}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95 \text{ mA}$

5. $V_0 = E - V_{si} - V_{Ge} = 12 - 0.7 - 1.1 = 12 - 1.8 = 10.2 \text{ V}$

$I_d = \frac{V_0}{R} = \frac{10.2}{5.6 \times 10^3} = 1.82 \text{ mA}$. $V_0 = 12 - 0.7 - 0.3 = 11 \text{ V}$

$I_d = \frac{11}{5.6 \times 10^3} = 1.96 \text{ mA}$



CBSE
Examination
Paper Delhi–2014

Time allowed : 3 hours

Maximum marks : 70

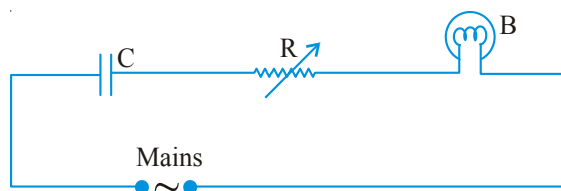
General Instructions:

- (i) All questions are compulsory.
- (ii) Question numbers 1 to 5 are very short answer questions and carry 1 mark each.
- (iii) Question numbers 6 to 10 are short answer questions and carry 2 marks each.
- (iv) Question numbers 11 to 15 are also short answer questions and carry 3 marks each.
- (v) Question numbers 16 to 18 are long answer questions and carry 5 marks each.
- (vi) Use log tables, if necessary. Use of calculators is not allowed.

SET- 1

1. Define the term ‘Mobility’ of charge carriers in a conductor. Write its SI unit.
2. “For any charge configuration, equipotential surface through a point is normal to the electric field.” Justify.
3. Two spherical bobs, one metallic and the other of glass, of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach earlier and why
4. Show variation of resistivity of copper as a function of temperature in a graph.
5. A convex lens is placed in contact with a plane mirror. A point object at a distance of 20 cm on the axis of this combination has its image coinciding with itself. What is the focal length of the lens?
6. Write the expression, in a vector form, for the Lorentz magnetic force \vec{F} due to a charge moving with velocity \vec{V} in a magnetic field \vec{B} . What is the direction of the magnetic force?
7. Out of the two magnetic materials, ‘A’ has relative permeability slightly greater than unity while ‘B’ has less than unity. Identify the nature of the materials ‘A’ and ‘B’. Will their susceptibilities be positive or negative?

8. Given a uniform electric field $\vec{E} = 5 \times 10^3 \hat{i}$ N/C, find the flux of this field through a square of 10 cm on a side whose plane is parallel to the y - z plane. What would be the flux through the same square if the plane makes a 30° angle with the x -axis?
9. For a single slit of width “ a ”, the first minimum of the interference pattern of a monochromatic light of wavelength occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance “ a ”. Explain.
10. State Kirchhoff’s rules. Explain briefly how these rules are justified.
11. A capacitor ‘C’, a variable resistor ‘R’ and a bulb ‘B’ are connected in series to the ac mains in circuits as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same: (ii) the resistor R is increased keeping the same capacitance?

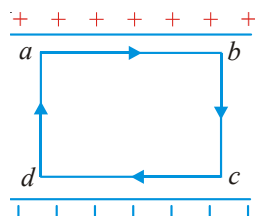


12. State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.
13. An electric dipole of length 4 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has charge ± 8 nC.
14. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has
 - (i) greater value of de-Broglie wavelength associated with it, and
 - (ii) less momentum?

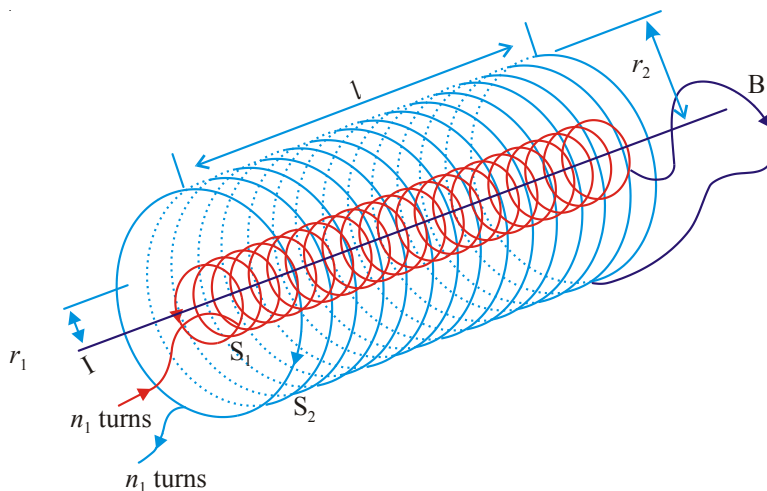
Give reasons to justify your answer.

15. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.
- (ii) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a photosensitive surface.
16. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelengths of the first member of Lyman and first member of Balmer series.
17. A potentiometer wire of length 1 m has a resistance of 10 Ω . It is connected to a 6 V battery in series with a resistance of 5Ω . Determine the emf of the primary cell which gives a balance point at 40 cm.
18. (a) Draw a labelled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.
- (b) The total magnification produced by a compound microscope is 20. The magnification produced by the eye piece is 5. The microscope is focussed on a certain object. The distance between the objective and eyepiece is observed to be 14 cm. If least distance of distinct vision is 20 cm, calculate the focal length of the objective and the eye piece.
19. (a) 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.
- (b) Suppose the lower half of the concave mirror's reflecting surface is covered with an opaque material. What effect this will have on the image of the object? Explain.
20. (a) Obtain the expression for the energy stored per unit volume in a charged parallel plate capacitor.
- (b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop abcd.





21. (a) Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d .
- (b) Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q and $q/2$ respectively. Find the ratio of their surface charge densities in terms of their radii.
22. (a) State Ampere's circuital law, expressing it in the integral form.
- (b) Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current " I " flows through the inner solenoid S_1 to the other end B , which is connected to the outer solenoid S_2 through which the same current " I " flows in the opposite direction so as to come out at end A . If n_1 and n_2 are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system.



23. Answer the following:
- (a) Name the em waves which are suitable for radar systems used in aircraft navigation. Write the range of frequency of these waves.

- (b) If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now? Explain.
- (c) An em wave exerts pressure on the surface on which it is incident. Justify.
24. (a) Deduce the expression, $N = N_0 e^{-\lambda t}$, for the law of radioactive decay.
- (b) (i) Write symbolically the process expressing the β^+ decay of ${}^{22}_{11}\text{Na}$. Also write the basic nuclear process underlying this decay.
- (ii) Is the nucleus formed in the decay of the nucleus of ${}^{22}_{11}\text{Na}$, an isotope or isobar?
25. (a)(i) 'Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.
- (ii) Light waves each of amplitude " a " and frequency " ω ", emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos(\omega t + \phi)$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.
- (b) 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 $\lambda/3$.

OR

- (a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a polaroid gets polarised?
- (b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$, where μ , is the refractive index of glass with respect to air and i_B is the Brewster's angle.
26. (a) Describe a simple experiment (or activity) to show that the polarity of emf induced in a coil is always such that it tends to produce a current which opposes the change of magnetic flux that produce it.
- (b) The current flowing through an inductor of self inductance L is continuously increasing. Plot a graph showing the variation of
- Magnetic flux versus the current
 - Induced emf versus dI/dt
 - Magnetic potential energy stored versus the current.

OR



- (a) Draw a schematic sketch of an ac generator describing its basic elements. State briefly its working principle. Show a plot of variation of
- Magnetic flux and
 - Alternating emf versus time generated by a loop of wire rotating in a magnetic field.
- (b) Why is choke coil needed in the use of fluorescent tubes with ac mains?
27. (a) State briefly the processes involved in the formation of p - n junction explaining clearly how the depletion region is formed.
- (b) Using the necessary circuit diagrams, show how the V-I characteristics of a p - n junction are obtained in
- Forward biasing
 - Reverse biasing
- How are these characteristics made use of in rectification?

Set-II (Questions Uncommon to Set-I)

- Define the term 'electrical conductivity' of a metallic wire. Write its S.I. unit.
- Show variation of resistivity of Si with temperature in a graph.
- An electric dipole of length 2 cm, when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole, if it has a charge of $\pm 4nC$.
- 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? Give reasons to justify your answer.
- Given a uniform electric field $\vec{E} = 2 \times 10^3 \hat{i}$ N/C, find the flux of this field through a square of side 20cm, whose plane is parallel to the y - z plane. What would be the flux through the same square, if the plane makes an angle of 30° with the x -axis?
- A 12.9 eV beam of electrons is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelength of the first member of Paschen series and first member of Balmer series.

22. Answer the following:
- Name the em waves which are used for the treatment of certain forms of cancer. Write their frequency range.
 - Thin ozone layer on top of stratosphere is crucial for human survival. Why?
 - Why is the amount of the momentum transferred by the em waves incident on the surface so small?
24. A potentiometer wire of length 1.0 m has a resistance of 15Ω . It is connected to a 5Ω battery in series with a resistance of 5Ω . Determine the emf of the primary cell which gives a balance point at 60 cm.

SET-III (Questions Uncommon to set-I and II)

- Define the term 'drift velocity' of charge carriers in a conductor and write its relationship with the current flowing through it.
- Plot a graph showing variation of current versus voltage for the material GaAs.
- An electric dipole of length 1 cm, which placed with its axis making an angle of 60° with uniform electric field, experiences a torque of $6\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge $\pm 2nC$.
- A deuteron and an alpha particle are accelerated with the same accelerating potential. Which one of the two has
 - greater value of de-Broglie wavelength, associated with it and
 - less kinetic energy'. Explain.
- A 12.3 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited? Calculate the wavelengths of the second member of Lyman series and second member of Balmer series.
- Answer the following questions:
 - Name the em waves which are produced during radioactive decay of a nucleus. Write their frequency range.
 - Welders wear special glass goggles while working. Why? Explain.
 - Why are infrared waves often called as heat waves? Give their one application.
- A potentiometer wire of length 1 m has a resistance of 5Ω . It is connected to a 8 V battery in series with a resistance of 15Ω . Determine the emf of the primary cell which gives a balance point at 60 cm.

Solutions

SET-I

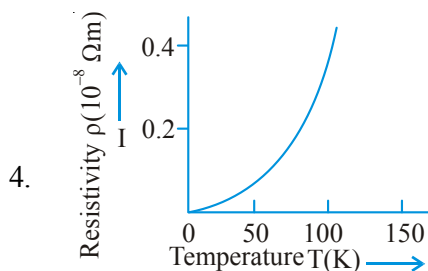
- Mobility is defined as the magnitude of the drift velocity per unit electric field.

$$\mu = \frac{|v_d|}{E} = \frac{a\tau}{E} = \frac{eE}{m} \frac{\tau}{E} = \frac{e}{m} \tau$$

where τ is the average collision time for electrons.

The SI unit of mobility is m^2/Vs or $\text{m}^2\text{V}^{-1}\text{S}^{-1}$

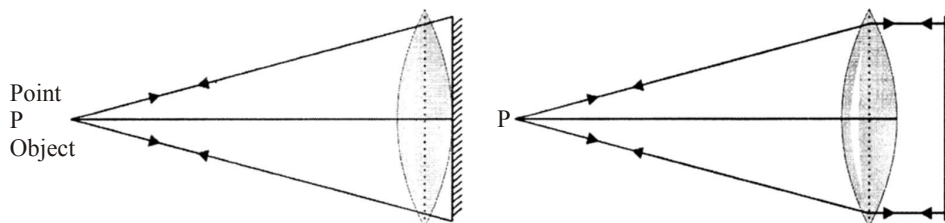
- The work done in moving a charge from one point to another on an equipotential surface is zero. If electric field is not-normal to the equipotential surface, it would have non-zero component along the surface. In that case work would be done in moving a charge on an equipotential surface.
- Glass would reach earlier. This is because there is no effect of electromagnetic induction in glass, due to presence of Earth's magnetic field, unlike in the case of metallic ball.



- The focal length of the lens = 20 cm

Explanation:

As the image of this combination coincides with the object itself, the rays from the object, after refraction from the lens should fall normally on the plane



mirror, so that they retrace their path. So the rays from the point object after refraction from the lens must form parallel beam. For clarity, mirror has been placed at a small distance from the lens.

6. Lorentz force, $\vec{F} = q(\vec{v} \times \vec{B})$

Obviously, the force on charged particle is perpendicular to both velocity \vec{v} and magnetic field \vec{B} .

7. A \longrightarrow Paramagnetic ($\because \mu_r > 1$)

B \longrightarrow Diamagnetic ($\because \mu_r < 1$)

Susceptibility for A \rightarrow Positive

Susceptibility for B \rightarrow Negative

8. Here, $\vec{E} = 5 \times 10^3 \hat{i}$ N/C, *i.e.* field is along positive direction of x-axis.
Surface area, $A = 10 \text{ cm} \times 10 \text{ cm}$

$$= 0.10 \text{ m} \times 0.10 \text{ m}$$

$$= 10^{-2} \text{ m}^2$$

(i) When plane parallel to y-z plane, the normal to plane is along x axis. Hence

$$\theta = 0^\circ$$

$$\phi = EA \cos \theta$$

$$\theta = 5 \times 10^3 \times 10^{-2} \cos 0^\circ$$

$$= 50 \text{ NC}^{-1} \text{ m}^2$$

(ii) When the plane makes a 30° angle with the x-axis, the normal to its plane makes 60° angle with x-axis. Hence

$$\theta = 60^\circ$$

$$\phi = EA \cos \theta$$

$$= 5 \times 10^3 \times 10^{-2} \cos 60^\circ$$

$$= 25 \text{ NC}^{-1} \text{ m}^2$$

9. **Case I:** The overlapping of the contributions of the wavelets from two halves of a single slit produces a minimum because corresponding wavelets from two halves have a path difference of $\lambda / 2$.

Case II: The overlapping of the wavefronts from the two slits produces first maximum because these wavefronts have the path difference, of λ

P is NAND gate and Q is OR gate.

10. Junction rule: In an electric circuit, the algebraic sum of currents at any junction is zero.

At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.

$$\sum I = 0$$

Justification: This rule is based on the law of conservation of charge.

Loop rule: The algebraic sum of charges in potential around any closed loop involving resistors and cells in the loop is zero.

$$\sum \Delta V = 0$$

Justification: This rule is based on the law of conservation of energy.

11. (i) The reactance of the capacitor will decrease, this results in increase of the current in the circuit. So, the bulb will glow brighter.
(ii) Increased resistance will decrease the current in the circuit, which will decrease glow of the bulb.

12. A cyclotron makes use of the principle that the energy of the charged particles or ions can be made to increase in presence of crossed electric and magnetic fields. The magnetic field acts on the charged particle and makes them move in a circular path inside the dee. Every time the particle moves from one dee to another it is acted upon by the alternating electric field, and is accelerated by this field, which increases the energy of the particle.

13. Torque,

$$\tau = pE \sin \theta$$

$$4\sqrt{3} = pE \sin 60^\circ$$

$$4\sqrt{3} = pE \times \frac{\sqrt{3}}{2} \Rightarrow pE = 8$$

Now, potential energy, $U = -pE \cos \theta$

$$= -8 \cos 60^\circ$$

$$= -8 \times \frac{1}{2} = -4\text{J}$$

14. (i) de Broglie wavelength. $\lambda = \frac{h}{\sqrt{2mqV}}$

Here V same for proton and deuteron.

As mass of proton $<$ mass of deuteron and $q_p = q_d$

Therefore, $\lambda_p > \lambda_d$ for same accelerating potential.

(ii) We know that momentum $= \frac{h}{\lambda}$

Therefore, $\lambda_p > \lambda_d$

So, momentum of proton will be less than that of deuteron.

15. (i) Power $= nh\nu$

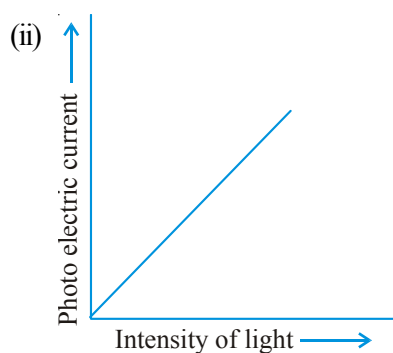
where n = number of photons per second

$$2.0 \times 10^{-3} = n \times 6.6 \times 10^{-34} \times 6 \times 10^{14}$$

$$n = \frac{2.0 \times 10^{-3}}{6.6 \times 10^{-34} \times 6 \times 10^{14}}$$

$$= \frac{2.0 \times 10^{-3}}{39.6 \times 10^{-20}}$$

$$= 5 \times 10 \text{ photons per second}$$



16. Here, $\Delta E = 12.5 \text{ eV}$

Energy of an electron in the n th orbit of hydrogen atom is $E_n = -\frac{13.6}{n^2} \text{ eV}$

For ground state $n = 1$,

$$E_1 = -\frac{13.6}{1^2} \text{ eV} = -13.6 \text{ eV}$$

For first excited state $n = 2$,

$$E_2 = -\frac{13.6}{2^2} eV = -3.4 \text{ eV}$$

For second excited state $n = 3$,

$$E_3 = -\frac{13.6}{3^2} eV = -1.51 \text{ eV}$$

Energy required to excite hydrogen atoms from ground state to the second excited state

$$\begin{aligned} &= E_{\text{final}} - E_{\text{initial}} \\ &= -1.51 - (-13.6) = 12.09 \text{ eV} \end{aligned}$$

Thus hydrogen atoms would be excited upto third energy level ($n = 3$).

For Lyman series,

$$\frac{1}{\lambda} = R \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{2^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{3}{4}$$

$$\frac{1}{\lambda} = 0.82275 \times 10^7 \text{ m}^{-1}$$

$$\lambda = 122 \times 10^{-9} \text{ m} = 122 \text{ nm}$$

For Balmer series

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\frac{1}{\lambda} = 0.15236 \times 10^7$$

$$\lambda = 656.3 \text{ nm}$$

17. Here, $l = 1 \text{ m}$, $R_1 = 10\Omega$, $V = 6\text{V}$, $R_2 = 5\Omega$

Current flowing in potentiometer wire,

$$I = \frac{V}{R_1 + R_2} = \frac{6}{10 + 5} = \frac{6}{15} = 0.4\text{A}$$

Potential drop across the potentiometer wire

$$V = IR = 0.4 \times 10 = 4\text{V}$$

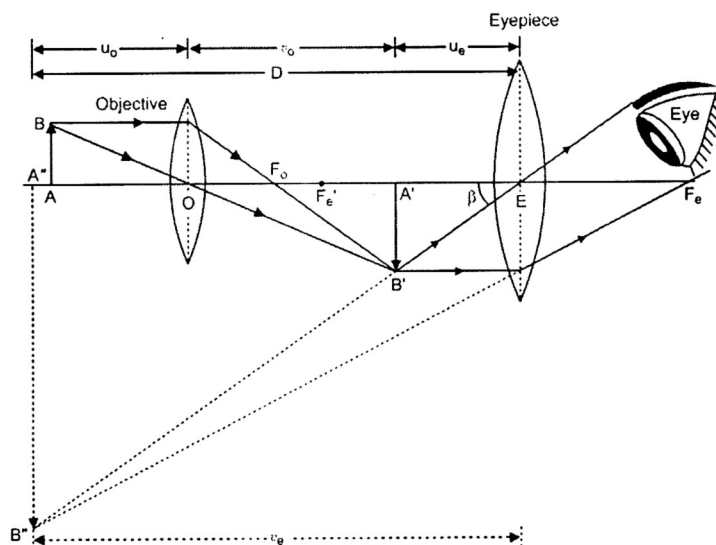
Potential gradient,

$$K = \frac{V'}{l} = \frac{4}{1} = 4\text{V/m}$$

Emf of the primary cell = Kl

$$= 4 \times 0.4 = 1.6\text{V}$$

18. (a)



- (b) Here, $m = -20$, $m_e = 5$, $v_e = -20 \text{ cm}$

For eyepiece, $m_e = \frac{v_e}{u_e}$

$$\Rightarrow 5 = \frac{-20}{u_e} \Rightarrow u_e = \frac{-20}{5} = -4\text{cm}$$

Using lens formula,

$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$-\frac{1}{20} + \frac{1}{4} = \frac{1}{f_e}$$

$$\frac{-1+5}{20} = \frac{1}{f_e} \quad \Rightarrow \quad f_e = 5 \text{ cm}$$

Now, total magnification

$$m = m_e \times m_0$$

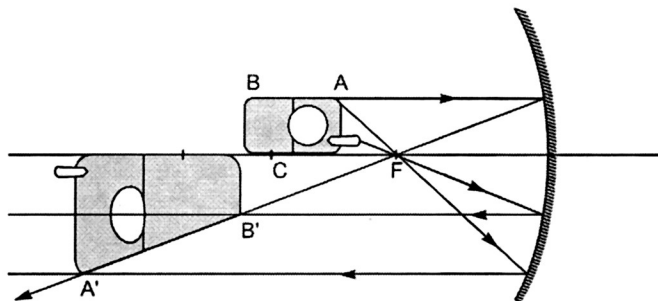
$$-20 = 5 \times m_0$$

$$m_0 = 1 - \frac{v_0}{f_0}$$

$$-4 = 1 - \frac{10}{f_0}$$

$$-5 = \frac{10}{f_0} \quad \Rightarrow \quad f_0 = 2 \text{ cm.}$$

19. (a)



The position of the image of different parts of the mobile phone depends on their position with respect to the mirror. The image of the part which is on the plane

perpendicular to principal axis will be on the same plane. It will be of the same size, *i.e.*, $B'C = BC$. The images of the other parts of the phone are getting magnified in accordance with their object distance from the mirror.

(b) Taking the laws of reflection to be true for all points of the remaining (uncovered) part of the mirror, the image will be that of the whole object. As the area of the reflecting surface has been reduced, the intensity of the image will be low (in this case half).

20. (a) When a capacitor is charged by a battery, work is done by the charging battery at the expense of its chemical energy. This work is stored in the capacitor in the form of electrostatic potential energy.

Consider a capacitor of capacitance C . Initial charge on capacitor is zero. Initial potential difference between capacitor plates = zero. Let a charge Q be given to it in small steps. When charge is given to capacitor, the potential difference between its plates increases. Let at any instant when charge on

capacitor be q , the potential difference between its plates $V = \frac{q}{C}$.

Now work done in giving an additional infinitesimal charge dq to capacitor

$$dW = V dq = \frac{q}{C} dq.$$

The total work done in giving charge from 0 to Q will be equal to the sum of all such infinitesimal works, which may be obtained by integration. Therefore total work

$$W = \int_0^Q V dq = \int_0^Q \frac{q}{C} dq$$

If V is the final potential difference between capacitor plates, then $Q = CV$

$$W = \frac{(CV)^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$$

This work is stored as electrostatic potential energy of capacitor *i.e.*,



Electrostatic potential energy,

$$U = \frac{Q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$$

If V is the final potential difference between capacitor plates, then
 $Q = CV$

Energy density: Consider a parallel plate capacitor consisting of plates, each of area A , separated by a distance d . If space between the plates is filled with a medium of dielectric constant K , then

Capacitance of capacitor, $C = \frac{K \epsilon_0 A}{d}$

If σ is the surface charge density of plates, then electric field strength between the plates

$$E = \frac{\sigma}{K \epsilon_0} \quad \Rightarrow \quad \sigma = K \epsilon_0 E$$

Charge on each plate of capacitor $Q = \sigma A = K \epsilon_0 E A$

$$\therefore \text{Energy stored by capacitor, } U = \frac{Q^2}{2C} = \frac{(K \epsilon_0 E A)^2}{2(K \epsilon_0 A / d)} = \frac{1}{2} K \epsilon_0 E^2 A d$$

But Ad = volume of space between capacitor plates

Energy stored, $U = \frac{1}{2} K \epsilon_0 E^2 A d$

$$\text{Electrostatic Energy stored per unit volume, } u_e = \frac{U}{Ad} = \frac{1}{2} K \epsilon_0 E^2$$

This is expression for electrostatic energy density in medium of dielectric constant K .

$$\text{In air or free space } (K = 1), \text{ therefore energy density, } u_e = \frac{1}{2} K \epsilon_0 E^2$$

(b) Work done in moving a charge q from a to $b = 0$

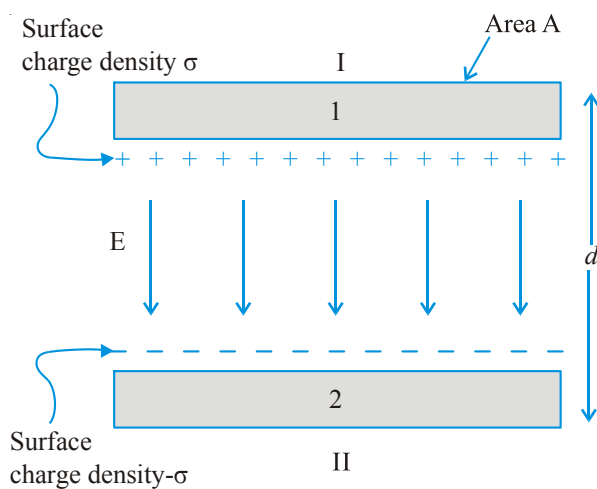
Work done in moving a charge q from c to $d = 0$

This is because the electric field is perpendicular to the displacement.

Now, work done from b to $c = -$ work done from d to a

Therefore, total work done in moving a charge q over a closed loop $= 0$.

OR



In the region between the plates the net electric field is equal to the sum of the electric fields due to the two charged plates. Thus, the net electric field is given by

$$E = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$$

The electric field is constant in the region between the plates. Therefore, the potential difference between the plates will be

$$V = \frac{\sigma d}{\epsilon_0}$$

Now, capacitance,

$$C = \frac{Q\epsilon_0}{\sigma d} = \frac{\epsilon_0 A}{d}$$

Surface charge density $\sigma = \frac{Q}{A}$, where A is the area of cross-section of the plates.

- (b) When two charged spherical conductors are connected by a conducting wire, they acquire the same potential.

$$\frac{kq_1}{R_1} = \frac{kq_2}{R_2}$$

Or
$$\frac{q_1}{R_1} = \frac{q_2}{R_2} \Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$$

Hence, the ratio of surface charge densities

$$\begin{aligned} \frac{\sigma_1}{\sigma_2} &= \frac{q_1 / 4\pi R_1^2}{q_2 / 4\pi R_2^2} = \frac{q_1 R_2^2}{q_2 R_1^2} \\ &= \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1} \end{aligned}$$

21. (a) The line integral of magnetic field (B) around any closed path in vacuum is μ_0 times the net current (I) threading the area enclosed by the curve.

- (b) Magnetic field, $B = \mu_0 n I$

- (i) Magnitude of net magnetic field inside the combined system on the axis,

$$\begin{aligned} B &= B_1 - B_2 \\ &= \mu_0 n_1 I - \mu_0 n_2 I \\ &= \mu_0 (n_1 - n_2) I \end{aligned}$$

- (ii) Outside the combined system, net magnetic field is zero.

22. (a) Microwaves

Frequency range : 10^{10} Hz to 10^{12} Hz

- (b) Average surface temperature will be lower. This is because there will be no green house effect in absence of atmosphere.

- (c) An electromagnetic wave exerts pressure on the surface on which it is incident because these waves carry both energy and momentum.
23. (a) **Radioactive decay Law:** The rate of decay of radioactive nuclei is directly proportional to the number of undecayed nuclei at that time.

Derivation of Formula

Suppose initially the number of atoms in radioactive element is N_0 and N the number of atoms after time t .

After time t , let dN be the number of atoms which disintegrate in a short interval

dt , then rate of disintegration will be $\frac{dN}{dt}$, this is also called the activity of the substance/element.

According to Rutherford-Soddy law

$$\frac{dN}{dt} \propto N$$

or
$$\frac{dN}{dt} = -\lambda N \quad \dots(i)$$

where λ is a constant, called decay constant or disintegration constant of the element. Its unit is s^{-1} . Negative sign shows that the rate of disintegration decreases with increase of time. For a given element/substance λ is a constant and is different for different elements. Equation (i) may be rewritten as

$$\frac{dN}{N} = -\lambda dt$$

Integrating \log_e , $N = -\lambda t + C \quad \dots(ii)$

where C is a constant of integration.

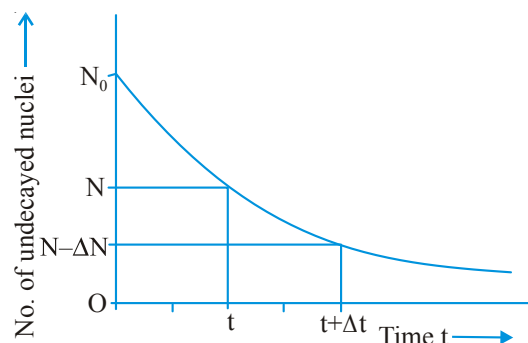
At $t = 0, N = N_0$

$\therefore \log_e N_0 = 0 + C \Rightarrow C = \log_e N_0$

\therefore Equation (ii) gives $\log_e N = -\lambda t + \log_e N_0$

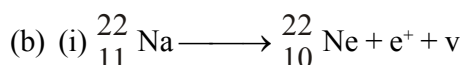
or $\log_e N - \log_e N_0 = -\lambda t$



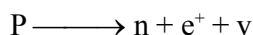


According to this equation, the number of undecayed atoms/nuclei of a given radioactive element decreases exponentially with time (i.e., more rapidly at first and slowly afterwards).

Mark of $N = \frac{N_0}{16}$ in terms of $T_{1/2}$ is shown in fig.



Basic nuclear process:



(ii) Isobar

24. (a) (i) The light waves, originating from two independent monochromatic sources, will not have a constant phase difference. Therefore, these sources will not be coherent and therefore would not produce a sustained interference pattern.
- (ii) The resultant displacement will be given by

$$\begin{aligned} y &= y_1 + y_2 \\ &= a \cos \omega t + a \cos(\omega t + \phi) \\ &= a [\cos \omega t + \cos(\omega t + \phi)] \\ &= 2a \cos(\phi / 2) \cos(\omega t + \phi / 2) \end{aligned}$$

The amplitude of the resultant displacement is $2a \cos(\phi / 2)$

The intensity of light is directly proportional to the square of amplitude of the wave. The resultant, intensity will be given by

$$I = 4a^2 \quad \text{or} \quad a^2 = \frac{I}{4}$$

- (b) A path difference of λ , corresponds to a phase difference of 2π

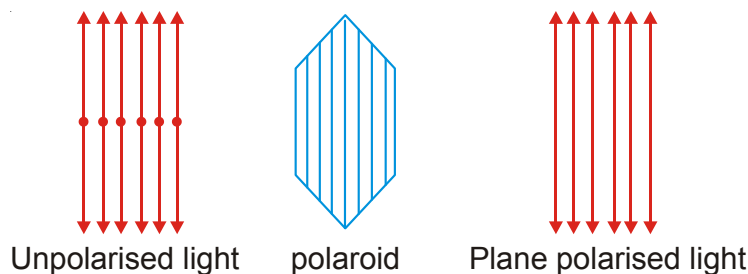
$$\therefore \text{Intensity,} \quad I = 4a^2 \quad \text{or} \quad a^2 = \frac{I}{4}$$

A path difference of $\frac{\lambda}{3}$ corresponds to a phase difference of $\frac{2\pi}{3}$.

$$\therefore \text{Intensity} = 4 \times \frac{I}{4} \cdot \cos^2 \frac{2\pi}{3}$$

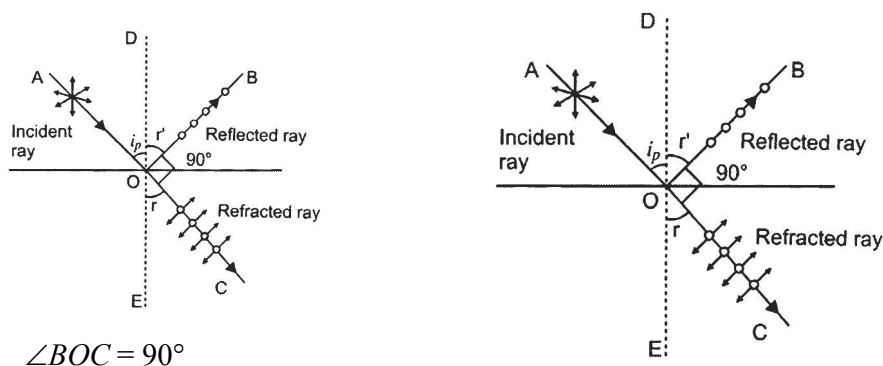
OR

- (a) A polaroid consists of long chain molecules aligned in a particular direction. The electric vectors along the direction of the aligned molecules get absorbed. So, when an unpolarised light falls on a polaroid, it lets only those of its electric vectors that are oscillating along a direction perpendicular to its aligned molecules to pass through it. The incident light thus gets linearly polarised.



Whenever unpolarised light is incident on the boundary between two transparent media, the reflected light gets partially or completely polarised. When reflected light is perpendicular to the refracted light, the reflected light is a completely polarised light.

- (b) Condition : The reflected ray is totally plane polarised, when reflected and refracted rays are perpendicular to each other.



If i_p is angle of incidence, r' is angle of reflection and r the angle of refraction, then according to law of reflection

$$i_p = r'$$

and from fig, $r' + 90^\circ + r = 180^\circ$

$$\Rightarrow i_p + r = 90^\circ \quad \dots(i)$$

$$\Rightarrow r = (90^\circ - i_p) \quad \dots(ii)$$

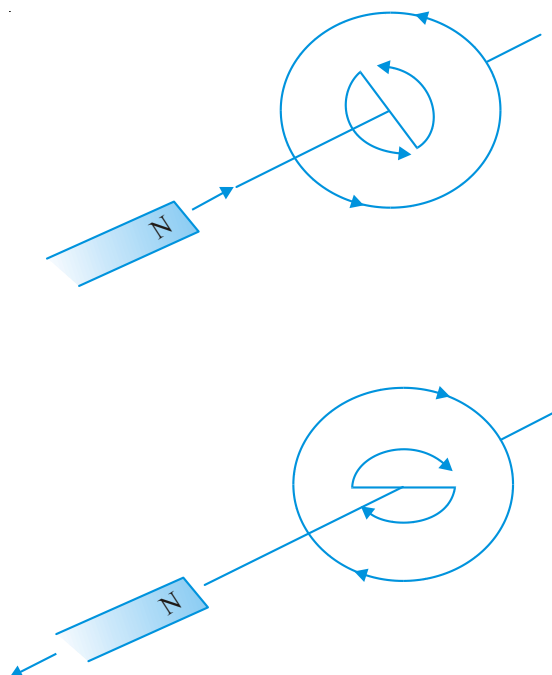
From Snell's law, refractive index of second medium relative to first medium (air) say.

$$n = \frac{\sin i_p}{\sin r} = \frac{\sin i_p}{\sin(90^\circ - i_p)} = \frac{\sin i_p}{\cos i_p}$$

$$\Rightarrow n = \tan i_p$$

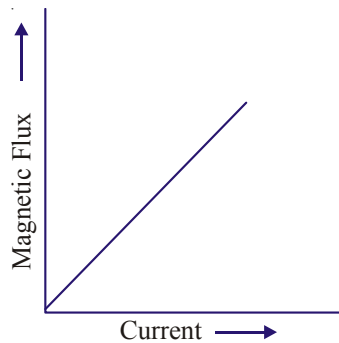
\therefore Angle of incidence, $i_p = \tan^{-1}(n)$.

25. (a) When the North pole of a bar magnet moves towards the closed coil, the magnetic flux through the coil increases. This produces an induced emf which produces (or tend to produce if the coil is open) an induced current in the anti-clockwise sense. The anti-clockwise sense corresponds to the

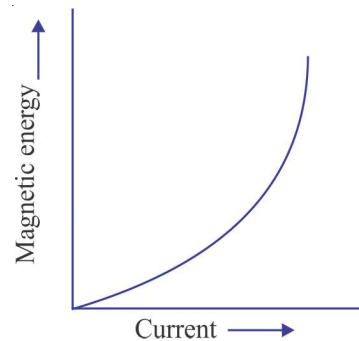
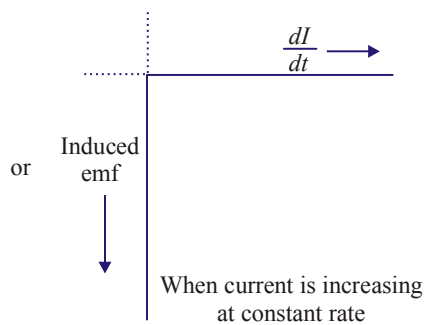
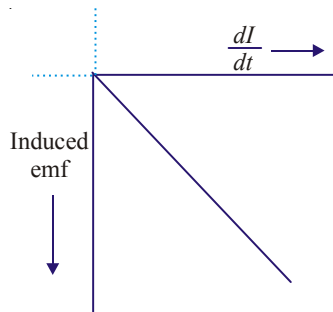


generation of North pole which opposes the motion of the approaching N pole of the magnet. The face of the coil, facing the approaching magnet, then has the same polarity as that of the approaching pole of the magnet. The induced current, therefore, is seen to oppose the change of magnetic flux that produces it. When a North pole of a magnet is moved away from the coil, the current (I) flows in the clock-wise sense which corresponds to the generation of South pole. The induced South pole opposes the motion of the receding North pole.

(b) (i) Magnetic flux versus the current

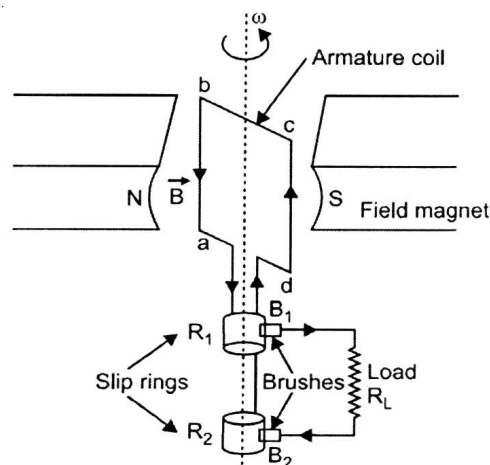


(ii) Induced emf versus $\frac{dI}{dt}$



OR

(a) Working: When the armature coil is rotated in the strong magnetic field, the magnetic flux linked with the coil changes and the current is induced in the coil, its direction being given by Fleming's right hand rule. Considering the armature to be in vertical position and as it rotates in anticlockwise direction, the wire ab moves upward and cd downward, so that the direction of induced current is shown in fig. In the



external circuit, the current flows along $B_1 R_L B_2$. The direction of current remains unchanged during the first half turn of armature. During the second half revolution, the wire ab moves downward and cd upward, so the direction of current is reversed and in external circuit it flows along $B_2 R_L B_1$. Thus the direction of induced emf and current changes in the external circuit after each half revolution.

Expression for Induced emf: If N is the number of turns in coil, f the frequency of rotation, A area of coil and B the magnetic induction, then induced emf

$$e = - \frac{d\phi}{dt} = \frac{d}{dt} \{ NBA (\cos 2\pi f t) \}$$

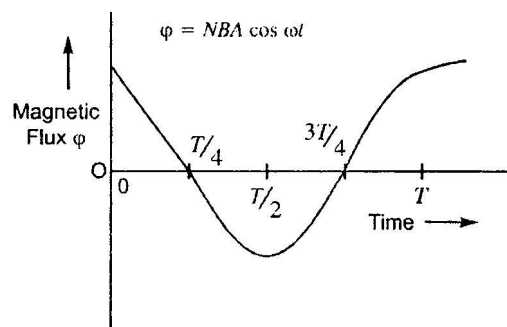
$$= 2\pi NBA f \sin 2\pi f t$$

Obviously, the emf produced is alternating and hence the current is also alternating.

Current produced by an ac generator cannot be measured by moving coil ammeter; because the average value of ac over full cycle is zero.

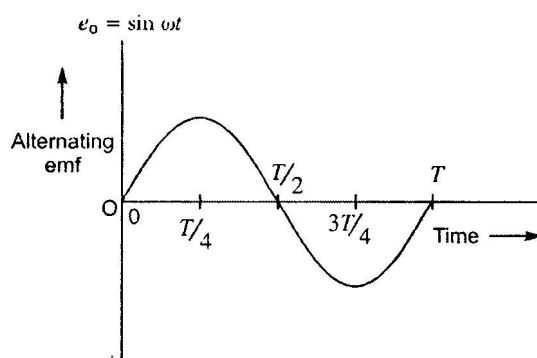
The source of energy generation is the mechanical energy of rotation of armature coil.

(i) Plot of variation of magnetic flux with time,

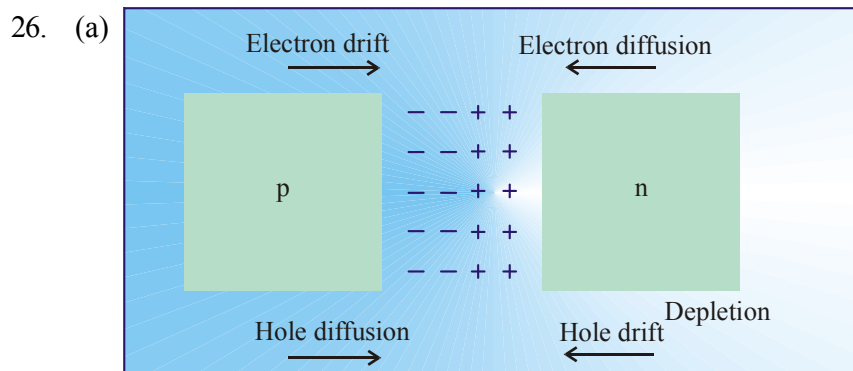


(ii) Plot of variation of alternating emf with time.

$$e = NAB\omega \sin \omega t$$



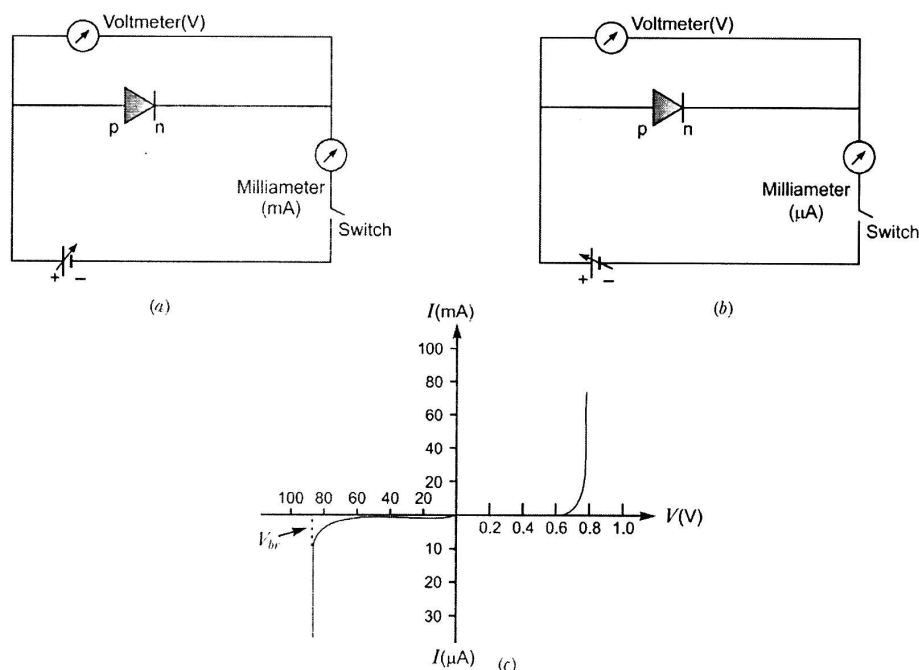
(b) Choke coil reduces the voltage across the fluorescent tube without wastage of power.



Two processes occur during the formation of a p - n junction are diffusion and drift. Due to the concentration gradient across p and n -sides of the junction, holes diffuse from p -side to n -side ($p \rightarrow n$) and electrons diffuse from n -side to p -side ($n \rightarrow p$). This movement of charge carriers leaves behind ionised acceptors (negative charge ϕ - immobile) on the p -side and donors (positive charge immobile) on the n -side of the junction. This space charge region on either side of the junction together is known as depletion region.

- (b) The circuit arrangement for studying the V - I characteristics of a diode are shown in Fig. (a) and (b). For different values of voltages the value of current is noted. A graph between V and I is obtained as in Figure (c).

From the V - I characteristic of a junction diode it is clear that it allows current to pass only when it is forward biased. So if an alternating voltage is applied across a diode the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify alternating voltages.



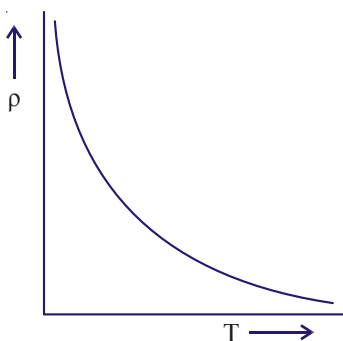
SET-II (Questions Uncommon to Set-I)

- The reciprocal of the resistivity of a material is called its conductivity and is denoted by σ .

$$\text{Conductivity} = \frac{1}{\text{Resistivity}}$$

The SI unit of conductivity is $\text{ohm}^{-1} \text{m}^{-1}$ or S m^{-1} .

$$2. \quad \text{Modulation index} = \frac{A_m}{A_c} = \frac{2}{5} = 0.4$$



Resistivity of Si decreases with increasing temperatures.

$$10. \quad \text{Torque,} \quad \tau = pE \sin \theta$$

$$8\sqrt{3} = pE \times \frac{\sqrt{3}}{2}$$

$$pE = 16$$

Potential energy,

$$u = -pE \cos \theta = -16 \times \frac{1}{2} = -8 \text{ J}$$

15. (i) de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

$$\text{For same } V, \lambda \propto \frac{h}{\sqrt{mq}}$$

$$\therefore \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p}{m_p} \cdot \frac{2e}{e}} = \sqrt{8} = 2\sqrt{2}$$

Clearly, $\lambda_p > \lambda_\alpha$. Hence, proton has a greater de-Broglie wavelength.

(ii) Kinetic energy, $K = qV$

For same V , $K \propto q$

$$\frac{K_p}{K_\alpha} = \frac{q_p}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$$

Clearly, $\lambda_p > \lambda_\alpha$.

Hence, proton has less kinetic energy.

16. Here, $\vec{E} = 2 \times 10^3 \hat{i}$ N/C

i.e., field is along positive direction of x -axis.

Surface area, $A = 20 \text{ cm} \times 20 \text{ cm}$
 $= 0.20 \text{ m} \times 0.20 \text{ m} = 4 \times 10^{-2} \text{ m}^2$

(i) When plane parallel to $y-z$ plane, the normal to plane is along x -axis.

Hence $\theta = 0^\circ$.

$$\phi = EA \cos \theta$$

$$= 2 \times 10^3 \times 4 \times 10^{-2} \cos 0^\circ = 80 \text{ NC}^{-1} \text{ m}^2$$

(ii) When the plane makes a 30° angle with the x -axis, the normal to its plane makes 60° angle with x -axis.

Hence, $\theta = 60^\circ$

$$\phi = EA \cos \theta$$

$$= 2 \times 10^3 \times 4 \times 10^{-2} \cos 60^\circ = 40 \text{ NC}^{-1} \text{ m}^2.$$

20. Energy of an electron, $E_n = \frac{13.6}{n^2} \text{ eV}$

For $n = 1, E_1 = \frac{13.6}{1^2} = -13.6 \text{ eV}$

For $n = 2, E_2 = \frac{13.6}{2^2} = -3.4 \text{ eV}$

For $n = 3, E_3 = \frac{13.6}{3^2} = -1.51 \text{ eV}$

For $n = 4, E_4 = \frac{13.6}{4^2} = -0.85 \text{ eV}$

Energy required to excite hydrogen atoms from ground state to excited state $= E_f - E_i$
 $= -0.85 - (-13.6) = 12.75 \text{ eV}$

Thus, hydrogen atom would be excited upto level $n = 4$.

For Paschen series

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

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{3^2} - \frac{1}{4^2} \right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{9} - \frac{1}{16} \right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{7}{144}$$

$$\lambda = \frac{36}{5.485 \times 10^7} = 6.56 \times 10^{-7} \text{ m} = 656 \text{ nm}$$

For Balmar Series

$$\frac{1}{\lambda} = R \left[\frac{1}{2^2} - \frac{1}{3^2} \right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \left[\frac{1}{4} - \frac{1}{9} \right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{5}{36}$$

$$\lambda = \frac{36}{5.485 \times 10^7} = 6.56 \times 10^{-7} \text{ m} = 656 \text{ nm}$$

(a) X rays of γ rays

Range: 10^{18} Hz to 10^{22} Hz.

(b) Ozone layer absorbs the ultraviolet radiations from the sun and prevents it from reaching the earth's surface,

(c) Momentum transferred, u

$$p = \frac{u}{c}$$

Where

u = energy transferred

c = speed of light

Due to the large value of speed of light (c), the amount of momentum transferred by the em waves incident on the surface is small.

24. Current

$$I = \frac{V}{R_1 + R_2}$$

$$= \frac{5}{15 + 5} = 0.05 \text{ A}$$

Potential drop across the potentiometer wire

$$V = IR = 0.25 \times 15 = 3.75 \text{ V}$$

Potential gradient,

$$k = \frac{V}{l} = \frac{3.75}{1.0} = 3.75 \text{ V/m}$$

\therefore Unknown emf of the cell = KI

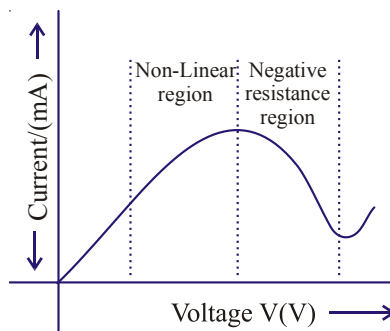
$$= 3.75 \times 0.6 = 2.25 \text{ V.}$$

SET-111 (Questions Uncommon to Set-1 and II)

- Drift velocity is defined as the average velocity acquired by the free electrons in a conductor under the influence of an electric field applied across the conductor. It is denoted by v_d .

$$\begin{aligned} \text{2. Modulation index} &= \frac{A_m}{A_c} \\ &= \frac{1.5}{3.0} = 0.5 \end{aligned}$$

- There is more than one value of V for the same current I . A material exhibiting such behaviour is GaAs.



- Torque,

$$\tau = pE \sin q$$

$$6\sqrt{3} = pE \sin 60^\circ$$

$$6\sqrt{3} = pE \times \frac{\sqrt{3}}{2}$$

$$pE = 12$$

Potential energy,

$$U = -pE \cos q$$

$$= -12 \cos 60^\circ$$

$$= -12 \times \frac{1}{2} = -6 \text{ J}$$

- (a) de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

For same V, $\lambda = \alpha \frac{1}{\sqrt{mq}}$

$$\therefore \frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_d q_d}} = \sqrt{\frac{2m_d \times 2q_d}{m_d q_d}} = \frac{2}{1}$$

$$\therefore \lambda_\alpha > \lambda_d$$

(b) Kinetic energy, $K = qV$

So, $q_\alpha > K_d$

For same V, we have $K_\alpha > K_d$

20. The energy of electron in the nth orbit of hydrogen atom is

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

when the incident beam of energy 12.3 eV is absorbed by hydrogen atom. Let the electron jump from $n = 1$ to $n = n$ level.

$$E = E_n - E_1$$

$$12.3 = -\frac{13.6}{n^2} - \left(-\frac{13.6}{1^2}\right)$$

$$\Rightarrow 12.3 = 13.6 \left[1 - \frac{1}{n^2}\right]$$

$$\Rightarrow \frac{12.3}{13.6} = 1 - \frac{1}{n^2}$$

$$\Rightarrow 0.9 = 1 - \frac{1}{n^2}$$

$$\Rightarrow n^2 = 10 \quad \Rightarrow \quad n = 3$$

That is the hydrogen atom would be excited upto second excited state.



For Lyman Series

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

$$\Rightarrow \frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{1} - \frac{1}{9} \right]$$

$$\Rightarrow \frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{8}{9}$$

$$\Rightarrow \lambda = \frac{9}{8 \times 1.097 \times 10^7} = 1.025 \times 10^{-7} = 102.5 \text{ nm}$$

For Balmer Series

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{4} - \frac{1}{16} \right]$$

$$\Rightarrow \frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{3}{16}$$

$$\Rightarrow \lambda = 4.86 \times 10^{-7} \text{ m} \Rightarrow \lambda = 486 \text{ nm}$$

24. (a) em waves : γ -rays (gamma rays)
Range : 10^{19} Hz to 10^{23} Hz
- (b) This is because the special glass goggles protect the eyes from large amount of UV radiations produced by welding arcs.
- (c) Infrared waves are called heat waves because water molecules present in the materials readily absorb the infra red rays get heated up.

Application: They are used in green houses to warm the plants.

25. Current flowing in the potentiometer

$$I = \frac{V}{R_1 + R_2}$$
$$= \frac{8}{5 + 15} \text{ A} = \frac{8}{20} \text{ A} = 0.4 \text{ A}$$

Potential drop across the potentiometer wire

$$V = IR$$

$$= 0.4 \times 5 = 2 \text{ V}$$

Potential gradient

$$K = \frac{V}{l}$$

$$= \frac{2}{1} = 2 \text{ Vm}^{-1}$$

$$\therefore \text{Unknown emf of the cell} = kl'$$

$$= 2 \times 0.6 \text{ V} = 1.2 \text{ V}$$



CBSE Examination Paper, Delhi Region-2015 (code no. 55/1/1/D)

Time allowed : 3 hours

Maximum marks : 70

- (i) All questions are compulsory. There are 26 questions in all.
- (ii) This question paper has five sections : Section A, Section B, Section C, Section D and Section E.
- (iii) Section A contains five questions of one mark each, Section B contains five questions of two marks questions of four marks and Section E contains 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.
- (iv) Use log tables, if necessary. Use of calculators is not allowed.

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2\text{N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{Mass of neutron} = 1.675 \times 10^{-27} \text{ kg}$$

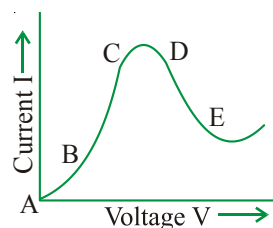
$$\text{Mass of proton} = 1.673 \times 10^{-27} \text{ kg} \quad \text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$

$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ LK}^{-1}$$

SECTION-A

1. Define capacitor reactance. Write its S.I. units.?
2. What is the electric flux through a cube of side 1 cm which encloses an electric dipole?
3. A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens?

4. Graph showing the variation of current versus voltage for a material GaAs is shown the figure. Identify the region of
- negative resistance
 - where Ohm's law is obeyed.



SECTION-B

- A proton and an α -particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.
- Show that the radius of the orbit in hydrogen atom varies as n^2 , where n is the principal quantum number of the atom.
- Use the mirror equation to Show that an object placed between f and $2f$ of a concave mirror pro image beyond $2f$.

OR

Find an expression for intensity of transmitted light when a polaroid sheet is rotated between I polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum?

- Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge.

SECTION-C

- Name the parts of the electromagnetic spectrum which is
 - suitable for radar systems used in aircraft navigation.
 - used to treat muscular strain.
 - used as a diagnostic tool in medicine.

Write in brief, how these waves can be produced.

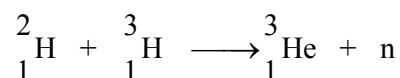
- A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of f 1.0 cm is used, what is the angular magnification of the telescope?
 - If this telescope is used to view the moon, what is the diameter of the image of the moon for objective lens? The diameter of the moon is 3.48×10^6 m and the radius of lunar orbit is 3.8.

11. Write Einstein's photoelectric equation and mention which important features in photoelectric effect explained with the help of this equation. The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of light the surface changes from λ_1 to λ_2 . Derive the expressions for the threshold wavelength λ_0 and w_0 for the metal surface.
12. In the study of Geiger-Marsden experiment on scattering of α -particles by a thin foil of ... trajectory of α -particles in the coulomb field of target nucleus. Explain briefly how one gets the ... on the size of the nucleus from this study.

From the relation $R = R_0 A^{1/3}$, where R_0 is constant and A is the mass number of the nucleus, nuclear matter density is independent of A .

OR

Distinguish between nuclear fission and fusion. Show how in both these processes energy is released. Calculate the energy release in MeV in the deuterium-tritium fusion reaction:



Using the data.

$$m({}^2_1\text{H}) = 2.014102 \text{ u} \quad m({}^3_1\text{H}) = 3.016049 \text{ u}$$

$$m({}^4_2\text{He}) = 4.002603 \text{ u} \quad m_n = 1.008665 \text{ u}$$

$$1 \text{ u} = 931.5 \text{ MeV}/c^2$$

13. A cell of emf ' E ' and internal resistance ' r ' is connected across a variable load resistor R . Draw the terminal voltage V versus (i) R and (ii) the current I . It is found that when $R = 4\Omega$, the current is 1 A and when R is increased to 9Ω , the current reduces. Find the values of the emf E and internal resistance r .
14. Two capacitors of unknown capacitances C_1 and C_2 are connected first in series and then in parallel battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, the value of C_1 and C_2 . Also calculate the charge on each capacitor in parallel combination.
15. State the principle of working of a galvanometer.

A galvanometer of resistance G is converted into a voltmeter to measure upto V volts by connecting resistance R_1 in series with the coil. If a resistance R_2 is

connected in series with it, then it can measure $V/2$ volts. Find the resistance, in terms of R_1 and R_2 , required to be connected to convert it into a volt meter that can read upto 2 V. Also find the resistance G of the galvanometer in terms of R_1 and R_2 .

16. With what considerations in view, a photodiode is fabricated? State its working with the help of a suitable diagram.

Even though the current in the forward bias is known to be more than in the reverse bias, yet the photodiode works in reverse bias. What is the reason?

17. Answer the following questions:

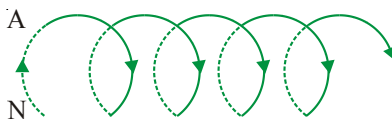
- In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1° . Find the spacing between the two slits.
- Light of wavelength 5000 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected?

18. An inductor L of inductance X_L is connected in series with a bulb B and an ac source.

How would brightness of the bulb change when (i) number of turns in the inductor is reduced, (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case.

SECTION-E

- State Ampere's circuital law. Use this law to obtain the expression for the magnetic field inside an air cored toroid of average radius ' r ', having ' n ' turns per unit length and carrying a steady current I .
- An observer to the left of a solenoid of N turns each of cross section area ' A ' observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic moment $m = NIA$.

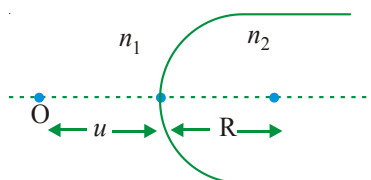


OR

- (a) Define mutual inductance and write its S.I. units.
 - (b) Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.
 - (c) In an experiment, two coils c_1 and c_2 are placed close to each other. Find out, the expression for the emf induced in the coil c_1 due to a change in the current through the coil c_2 .
20. (a) Using Huygens's construction of secondary wavelets explain how a diffraction pattern is obtained on a screen due to a narrow slit on which a monochromatic beam of light is incident normally.
- (b) Show that the angular width of the first diffraction fringe is half that of the central fringe.
- (c) Explain why the maxima at $\theta = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$ become weaker and weaker with increasing n .

OR

- (a) A point object 'O' is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature R which separates the second medium of refractive index n_2 from the front as shown in the figure. Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1 , n_2 and R .

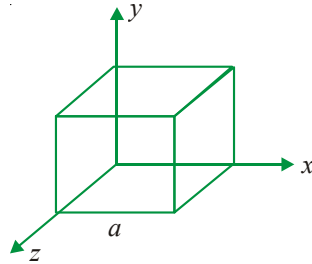


- (b) When the image formed above acts as a virtual object for a concave spherical surface separating medium n_2 from n_1 ($n_2 > n_1$), draw this ray diagram and write the similar (similar to (a)) formula and obtain the expression for the lens maker's formula.
21. (a) An electric dipole of dipole moment \vec{p} consists of point charges $+q$ and $-q$ separated by a distance $2a$ apart. Deduce the expression for the electric field \vec{E} due to the dipole at a distance x from the center of dipole on its axial line

in terms of the dipole moment \vec{p} . Hence show that in the limit $a \rightarrow 0$

$$\vec{E} = \frac{2\vec{p}}{(4\pi\epsilon_0 x^3)}.$$

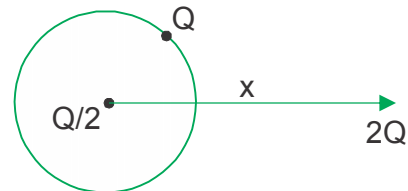
- (b) Given the electric field in the region $\vec{E} = 2xi$, find the net electric flux through the cube and enclosed by it.



OR

- (a) Explain, using suitable diagrams, the difference in the behaviour of a (i) conductor and (ii) dielectric the presence of external electric field. Define the term polarization of a dielectric and write its expression with susceptibility.
- (b) A thin metallic spherical shell of radius R carries a charge Q on its surface. A

point charge $\frac{Q}{2}$ is placed at its centre C and an other charge $+2Q$ is placed outside the shell at a distance x from the centre as shown in the figure. Find (i) the force on the charge at the centre of shell and at the point A, (ii) the electric flux through the shell.



SECTION-A

- The imaginary/virtual resistance offered by a capacitor to the flow of an alternating current is called capacitor reactance, $X_C = \frac{1}{\omega C}$. Its SI unit is ohm.

- Net electric flux is zero.

Reason : (i) Independent to the shape and size.
(ii) Net charge of the electric dipole is zero.

- Concave lens, in medium of high refractive index, behaves as a convex lens (or a converging lens).

Reason :
$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1 \right) \left(-\frac{1}{R} - \frac{1}{R} \right)$$

Since $m > m_g \quad \zeta \Rightarrow \quad \frac{1}{f_m} = +ve \text{ value}$

So, $f_m > 0$. Hence acts a convex lens.

- Side bands (Lower side band and upper side band) are produced due to superposition of low frequency modulating signals on high frequency carrier waves.

Reason: The frequency of lower side band is $\omega_c - \omega_m$ and of upper side band is $\omega_c + \omega_m$.

- (i) In region DE , material offers negative resistance, because $\text{slop } \frac{\Delta V}{\Delta I} < 0$.

(ii) The region BC approximately passes through the origin, (or current also increases with the increase of voltage). Hence, it follows Ohm's law and

in this region $\frac{\Delta V}{\Delta I} > 0$.

SECTION—B

6. de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$

Where, m = mass of charge particle, q = charge of particle, V = potential difference

(i) $\lambda_2 = \frac{h^2}{\sqrt{2mqV}}$

$$V = \frac{h^2}{\sqrt{2mq\lambda^2}}$$

$$\therefore \frac{V_p}{V_\alpha} = \frac{2m_\alpha q_\alpha}{2m_p q_p} = \frac{2 \times 4m \cdot 2q}{2mq} = \frac{8}{1}$$

$$\therefore V_p : V_\alpha = 8 : 1$$

(ii) $\lambda = \frac{h}{mu}, \lambda_p = \frac{h}{m_p u_p}, \lambda_\alpha = \frac{h}{m_\alpha V_\alpha}$

$$\lambda_p = \lambda_\alpha$$

$$\frac{h}{m_p u_p} = \frac{h}{m_\alpha u_\alpha}$$

$$\frac{u_p}{u_\alpha} = \frac{m_\alpha}{m_p} = \frac{4}{1} = 4 : 1$$

7. Hydrogen atom

Let r be the radius of the orbit of a hydrogen atom. Forces acting on electron are centrifugal force and electrostatic attraction (F_e)

At equilibrium.

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{1}{4r\epsilon_0} \frac{e^2}{r^2}$$

According to Bohr's postulate

$$mvr = \frac{nh}{2\pi} \Rightarrow u = \frac{nh}{2\pi mr}$$

$$m\left(\frac{nh}{2\pi mr}\right)^2 \cdot \frac{1}{r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2} \Rightarrow \frac{mn^2h^2}{4\pi^2m^2r^2r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2}$$

$$r = \frac{m^2h^2\epsilon_0}{\pi me^2} \Rightarrow \therefore r \propto n^2$$

8. Mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$2f < u < f$ object between f and $2f$

$$\Rightarrow \frac{1}{2f} > \frac{1}{u} > \frac{1}{f} \Rightarrow \frac{-1}{2f} < \frac{-1}{u} < \frac{-1}{f}$$

$$\frac{1}{f} - \frac{1}{2f} < \frac{1}{f} - \frac{1}{u} < 0 \quad \left[\frac{1}{f} - \frac{1}{u} = \frac{1}{v} \right]$$

$$\frac{1}{f} - \frac{1}{2f} < \frac{1}{v} < 0. \Rightarrow \frac{1}{2f} < \frac{1}{v} < 0$$

Also $u < 0 \therefore$ image is real.

$u > 2f$, image of formed beyond $2f$.

OR

Let P_1 and P_2 be the crossed polaroids, and no light transmitted through polaroid P_2 .

Let I_0 be the intensity of the polarised light through polaroid P_1 .

If another polaroid P_3 is inserted between P_1 and P_2 and polaroid P_3 , is at an angle θ with the polaroid.

Then intensity of light through polaroid P_3 is

$$I_3 = I_0 \cos^2 \theta$$

If this light I_3 again passes through the polaroid P_2 then

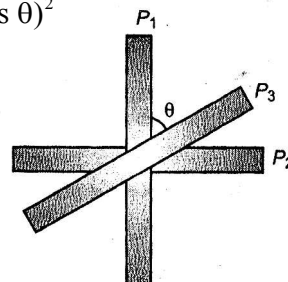
$$I_2 = I_3 \cos^2 (90 - \theta)$$

From equation (1) and (2), we get

$$I_2 = I_0 \cos^2 \theta (90 - \theta)$$

$$= \frac{I_0}{4} (2 \sin \theta \cos \theta)^2$$

$$= \frac{I_0}{4} \sin^2 (2\theta)$$



For maximum value of I_2 ,

$$\sin 2\theta = \pm 1$$

$$\Rightarrow 2\theta = 90^\circ$$

$$\Rightarrow \theta = 45^\circ$$

It is possible only when polaroid P_3 is placed at angle 45° from each polaroid P_1 (or P_2).

9. Condition of balance of a Wheatstone bridge: The circuit diagram of Wheatstone bridge is shown in fig. P , Q , R and S are four resistance forming a closed bridge, called Wheatstone bridge. A battery is connected across A and C , while a galvanometer is connected between B and D . At balance, there is no current in galvanometer.

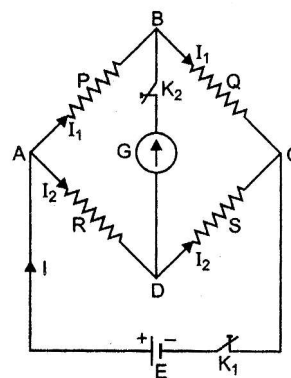
Derivation of Formula: Let the current given by battery in the balanced position be I . This current on reaching point A is divided into two parts I_1 and I_2 . As there is no current in galvanometer in balanced state, current in resistances P and Q is I_1 and in resistances R and S it is I_2 .

Applying Kirchhoff's I law at point A

$$I - I_1 - I_2 = 0 \text{ or } I = I_1 + I_2 \quad \dots(i)$$

Applying Kirchhoff's II law to closed mesh $ABDA$

$$-I_2 P + I_2 R = 0 \text{ or } I_1 P = I_2 R \quad \dots(ii)$$



Applying Kirchhoff's II law to mesh BCDB

$$-I_1P + I_2R = 0 \text{ or } I_1Q = I_2S \quad \dots(iii)$$

Dividing equation (ii) by (iii), we get

$$\frac{I_1P}{I_1Q} = \frac{I_2R}{I_2S} \text{ or } \frac{P}{Q} = \frac{R}{S} \quad \dots(iv)$$

This is the condition of balance of Wheatstone bridge.

SECTION-C

10. (a) Microwave, (b) Infrared, (c) X-rays

Microwave are produced by special vacuum tubes, like klystrons, magnetrons and gunn diodes.

Infrared are produced by the vibrating molecules and atoms in hot bodies.

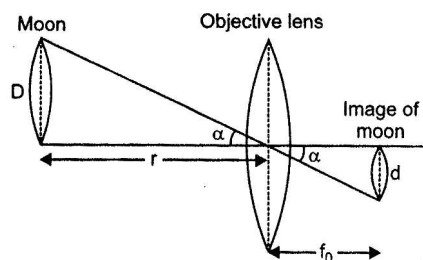
X-rays are produced by the bombardment of high energy electrons on a metal target of high atomic weight (like tungsten).

11. (i) Given $f_0 = 15 \text{ m}$, $f_e = 1.0 \text{ cm} = 1.0 \times 10^{-2} \text{ m}$

Angular magnification of telescope.

$$m = \frac{f_0}{f_e}$$

$$= \frac{15}{1.0 \times 10^{-2}} = -1500$$



Negative sign shows that the final image is inverted.

- (ii) Let D be diameter of moon, d diameter of image of moon formed by objective and r the distance of moon from objective lens, then from Fig.

$$\frac{D}{r} = \frac{d}{f_0}$$

$$\Rightarrow d = \frac{D}{r} \cdot f_0 = \frac{3.48 \times 10^6}{3.8 \times 10^8} \times 15\text{m} = 0.137\text{cm} = 13.7$$

12. Einstein's photoelectric equation:

Where ν = incident frequency; ν_0 = threshold frequency, V_0 = stopping potential

- (i) Incident energy of photon is used in to (a) to liberate electron from the metal surface (b) rest of the energy appears as maximum energy electron.
- (ii) Only one electron can absorb energy of one photon. Hence increasing intensity increases the numbers of electrons hence current.
- (iii) If incident energy is less than work function, no emission of electron will take place.
- (iv) Increasing ν (incident frequency) will increase maximum kinetic energy of electrons but number of electrons emitted will remain same.

For wavelength

$$\begin{aligned} \frac{hc}{\lambda_1} &= \phi_0 + K \\ &= \phi_0 + eV_0 \quad \dots(i) \text{ where } K = eV_0 \end{aligned}$$

Form wavelength λ_2

$$\frac{hc}{\lambda_1} = \phi_0 + 2eV_0 \quad \dots(ii) \text{ (because KE is doubled)}$$

Form equation (i) and (ii), we get

$$\begin{aligned} \frac{hc}{\lambda_2} &= \phi_0 + 2 \left(\frac{hc}{\lambda_1} - \phi_0 \right) \\ &= \phi_0 + \frac{2hc}{\lambda_1} - 2\phi_0 \end{aligned}$$

$$\Rightarrow \lambda_0 = \frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2}$$

For threshold wavelength λ_0 , kinetic energy, $K = 0$

and work function $\lambda_0 = \frac{hc}{\lambda_0}$

$$\therefore \frac{hc}{\lambda_0} = \frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2}$$

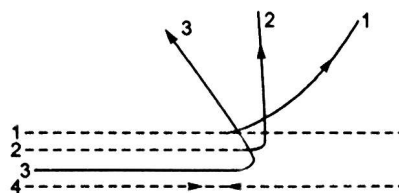
$$\Rightarrow \frac{1}{\lambda_0} = \frac{2}{\lambda_1} - \frac{1}{\lambda_2}$$

$$\Rightarrow \lambda_0 = \frac{\lambda_1 \lambda_2}{2\lambda_2 - \lambda_1}$$

Work function, $\lambda_0 = \frac{hc(2\lambda_2 - \lambda_1)}{\lambda_1 \lambda_2}$

13.

- (i) For large impact parameter, almost all alpha particles go nearly undeviated and have small deflection. This shows that the mass of the atom is concentrated in a small volume in the form of nucleus and gives an idea of size of nucleus.



- (ii) An alpha particle having small impact parameter suffers large scattering and in case of head-on-collision, the alpha particle rebounds back.

The radius (size) R of nucleus is related to its mass number (A) as

$$R = R_0 A^{1/3}$$

If m is the average mass of a nucleon, then mass of nucleus = mA , where A is mass number

$$\text{Volume of nucleus} = \frac{4}{3} \pi R^3 = \frac{4}{3} \pi (R_0 A^{1/3})^3 = \frac{4}{3} \pi R_0^3 A$$

$$\text{Density of nucleus } \rho_N = \frac{\text{mass}}{\text{volume}} = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{m}{\frac{4}{3}\pi R_0^3} = \frac{3m}{4\pi R_0^3}$$

Clearly nuclear density ρ_N is independent of mass number A.

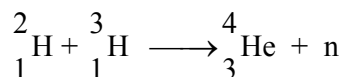
OR

Nuclear fission	Nuclear fusion
(i) Heavy nucleus splits into two smaller nuclei.	(i) Two lighter nuclei combine to form a heavy nucleus.
(ii) It takes place at ordinary temperature.	(ii) It requires extremely high temperature of the order of 10^7 K.

In both the process, mass of nucleus participating in the reaction is greater than mass of the product nuclei. This difference in mass (Δm) is converted into energy and released.

$$\text{Mass defect} = \Delta m$$

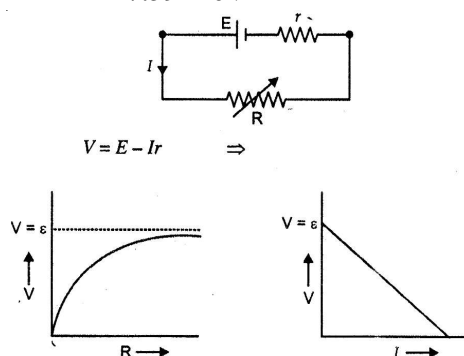
$$\text{Energy released} = \Delta m \times 931 \text{ MeV}$$



$$\Delta m = (+2.014102 + 3.016049 - 4.002603 - 1.008665) \text{ u} \\ = 0.018883 \text{ u}$$

$$\text{Energy released} = \Delta m \times 931.5 \text{ MeV} = 0.018883 \times 931 \text{ MeV} \\ = 17.59 \text{ MeV}$$

14.



$$\begin{array}{ll}
 R_1 = 4\Omega & R_2 = 9\Omega \\
 I_1 = I \text{ A,} & I_2 = 0.5 \text{ A} \\
 E = IR + It & I_2 = 0.5 \text{ A} \\
 E = I(R + r) &
 \end{array}$$

Substituting the values

$$\begin{array}{l}
 E = I(4 + r) \\
 E = (9 + r) \\
 4 + r = (9 + r) \quad \Rightarrow \quad 8r + 2r = 9 + r \\
 r = 1\Omega
 \end{array}$$

Substituting in (i), $E = 1(4 + 1) = 5\text{V} \Rightarrow r = 1\Omega \quad E = 5\text{V}$

15. Energy stored in a capacitor, $E = \frac{1}{2}CV^2$

In parallel, $0.25 = \frac{1}{2}(C_1 + C_2)(100)^2$

In series, $0.045 = \frac{1}{2}\left(\frac{C_1 C_2}{C_1 + C_2}\right)(100)^2$

From (i) $C_1 + C_2 = 0.25 \times 2 \times 10^{-4}$
 $C_1 + C_2 = 5 \times 10^{-5}$

From (ii) $\frac{C_1 C_2}{C_1 + C_2} = 0.045 \times 2 \times 10^{-4}$

$$\frac{C_1 C_2}{C_1 + C_2} = 0.09 \times 10^{-4} = 9 \times 10^{-6}$$

Form (iii) $C_1 C_2 = \frac{2 \times 0.045 \times 5 \times 10^{-5}}{10^4} = 4.5 \times 10^{-10}$

$$C_1 - C_2 = \sqrt{(C_1 + C_2)^2 - 4C_1 C_2}$$

$$C_1 - C_2 = 2.64 \times 10^{-5}$$

Solving (ii) and (iv)

$$C_1 = 38.2 \mu\text{F}$$

$$C_2 = 11.8 \mu\text{F}$$

In parallel

$$Q_1 = C_1 V = 38.2 \times 10^{-6} \times 100 = 38.2 \times 10^{-4} \text{C}$$

$$Q_2 = C_2 V = 11.8 \times 10^{-6} \times 100 = 11.2 \times 10^{-4} \text{C}$$

16. When current flows through a coil kept in uniform radial magnetic field, it experiences a torque which tends to rotate the coil and produces an angular deflection. The deflection of the coil is directly proportional to the current.

$$Q = \frac{NAB}{K} I$$

Let I_g be the current through galvanometer at full deflection

To measure V volts, $V = I_g (G + R_1)$... (i)

$\frac{V}{2}$ volts, $\frac{V}{2} = I_g (G + R_2)$... (ii)

2 V volts, $2 V = I_g (G + R_3)$... (iii)

To measure for conversion of range dividing (i) by (ii),

$$2 = \frac{G + R_1}{G + R_2}$$

$$G = R_1 - 2R_2$$

Putting the value of G in (i), we have

$$I_g = \frac{V}{R_1 - 2R_2 + R_1}$$

$$I_g = \frac{V}{2R_1 - 2R_2}$$

Substituting the value of G and I_g in equation (iii), we have

$$2 V = \frac{V}{2R_1 - 2R_2} (R_1 - 2R_2 + R_2)$$

$$4R_1 - 4R_2 = R_1 - 2R_2 + R_2$$

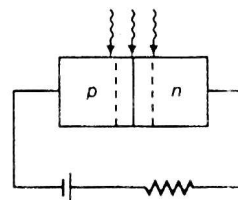
$$R_3 = 2R_1 - 2R_2$$



17. A photodiode (for special purpose) is fabricated with a transparent window to allow light to fall on the junction of the diode.

When the junction of photodiode is reverse bias it is illuminated with light of energy $h\nu > E_g$ of the semiconductor, the electron-hole pairs are generated due to absorption of photon.

Due to electric field of the function, electron are collected in n side and holes are collected on p-side and produces an emf. When an external load is connected, an electric current flows in the external circuit. The magnitude of the electric current depends on the intensity of incident light.



Reason of Reverse Biasing :

If there is no illumination, majority electrons are more than minority holes in n region of the diode. On illumination the junction, some electrons-hole pairs are generated. Let the excess electrons and holes generated are Δn and Δp respectively. So, at a particular illumination,

$$n' = n + \Delta n$$

and

$$p' = p + \Delta p$$

Since, $\Delta n = \Delta p$ and $n > p$

$$\text{Hence,} \quad \frac{\Delta n}{n} \ll \frac{\Delta p}{p}$$

It means the minority carriers dominated reverse bias current is more easily measurable, than change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias light intensity.

21. (a) $\lambda = 600 \text{ nm}$, $\beta_0 = 0.1^\circ = 0.1 \times \frac{\pi}{180} = \frac{\pi}{180^\circ}$

$$d = ?$$

Angular width of fringes

$$\beta_0 = \frac{\lambda}{d},$$

where d = separation between two slits

$$\Rightarrow \quad \delta = \frac{600 \times 10^{-9} \times 1800}{\pi}$$

$$= 3.43 \times 10^{-4} \text{ m} = 0.34 \text{ m}$$

(b) $\lambda = 5000 \text{ \AA} = 5000 \times 10^{-10} \text{ m} = 5 \times 10^{-7} \text{ m}$

Reflected ray : No change in wavelength and frequency.

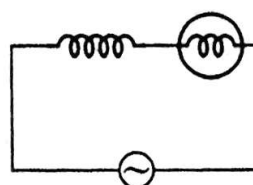
Refracted ray : Frequency remains same, wavelength decreases

$$\text{Wavelength } \lambda = \frac{\lambda}{\mu}$$

22. Brightness of the bulb depends on square of the I_{ms} (i.e., I_{rms}^2)

$$\text{Impedance of the circuit, } Z = \sqrt{R^2 + (\omega L)^2}$$

And Current in circuit, $I = \frac{V}{Z}$



- (i) $X_L = \omega L$, If number of turns in the inductor, coil is reduced, then impedance of the combination will decrease. It results in increase in current. Hence, brightness of the bulb increases.
- (ii) When iron (being a ferromagnetic substance) rod is inserted in the coil, its inductance increases appears across the inductor, leaving less voltage across the bulb. Hence, brightness of the bulb decreases.
- (iii) On inserting a capacitor, the impedance of the circuit becomes

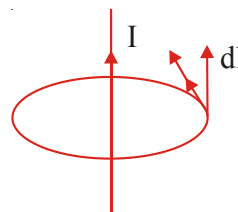
$$Z' = \sqrt{R^2 + (X_L - X_C)^2}, \text{ i.e., } Z' < Z$$

- (a) If $X_L = X_C$ then $Z' = R$. It results in increase in current resulting in increase in brightness of the bulb.

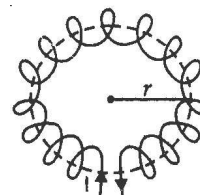
SECTION–E

- (a) **Ampere's circuital law:** The line integral of magnetic field around any closed path in vacuum/air is equal μ_0 times the total current enclosed by that path.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$



Consider an air cored toroid of average radius ' r ' having ' n ' turns per unit length and carrying a steady current I .



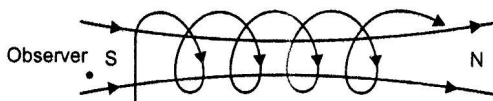
Consider an ampere loop of radius r as shown. Apply Ampere's circuital law.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 2\pi r n I$$

Where $2\pi r \cdot n$ is the number of times the current is threading.

$$\vec{B} \cdot 2\pi r = \mu_0 2\pi r n I$$

$$\vec{B} = \mu_0 n I$$



For observer, current is flowing in clockwise direction hence we will see magnetic field lines towards south pole.

The solenoid can be regarded as a combination of circular loops placed side by side, each behaving like a magnet of magnetic moment IA , where I is the current and A area of the loop. These magnets neutralise each other except at the ends where south and north poles appear. Magnetic moment of bar magnet

$$= NIA$$

OR

- (a) When current flowing in one of two nearby coils is changed, the magnetic linked with the coil changes; due to which an *emf* is induced in it (other

coil). This phenomenon of electromagnetic induction is called mutual induction. The coil, in which current is changed is called the the coil in which current is changed is called the primary coil and the coil in which emf is induced is called the secondary coil.

The SI unit of mutual inductance is henry.

- (b) Suppose there are two coils C_1 and C_2 . The current I_1 is flowing in primary coil C_1 due to which effective magnetic flux ϕ_2 is linked with secondary coil C_2 . By experiments

$$\phi_2 \propto I_1 \text{ or } \phi_2 = MI_1$$

where M is a constant, and is called the coefficient of mutual induction or mutual inductance From (i)

$$M = \frac{\phi_2}{I_1}$$

If $I_1 = 1$ ampere, $M = \phi_2$

i.e., **the mutual inductance between two coils is numerically equal to the effective flux linkage with secondary coil, when current flowing in primary coil is 1 ampere.**

Mutual Inductance of Two Co-axial Solenoids:

Consider two long co-axial solenoid each of length l with number of turns N_1 and N_2 wound one on other. Number of turns per unit length in outer (primary) solenoid, $n = \frac{N_1}{l}$ If I_1 is the current in primary solenoid, the magnetic field produced within this solenoid.

$$B_1 = \frac{\mu_0 N_1 I_1}{l} \quad \dots(i)$$

The flux linked with each turn of inner solenoid coil is $\phi_2 = B_1 A_2$, where A_2 is the cross-sectional area inner solenoid. The total flux linkage with inner coil of N_2 -turns.

$$\Phi_2 = N_2 \phi_2 = N_2 B_1 A_2 = N_2 \left(\frac{\mu_0 N_1 I_1}{l} \right) A_2 = \frac{\mu_0 N_1 N_2}{l} A_2 I_1$$

By definition **Mutual Inductance**, $M_{21} = \frac{\Phi_2}{I_1} = \frac{\mu_0 N_1 N_2 A_2}{l}$

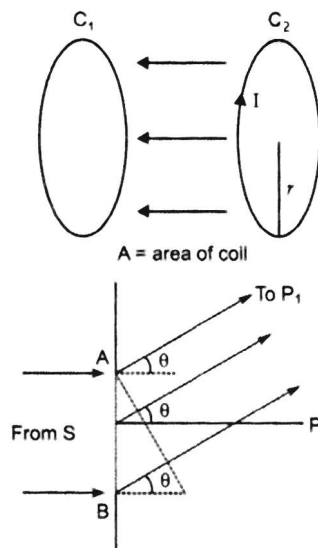
If n_1 is number of turns per unit length of outer solenoid and r_2 is radius of inner solenoid then $M_{21} = \mu_0 n_1 N_2 \pi r_2^2$.

- (c) When the current in coil C_2 changes, the flux linked with C_1 changes. This change in flux linked with C_1 induces emf in C_1 .

Flux linked with $C_1 = \text{flux of } C_2$

25. (a) When a plane wavefront from a distance source illuminates a slit, each point within the slit becomes a source of secondary spherical wavelets. These spherical wavelets go on increasing in size, and superpose on each other, in the region between slit and screen.

- (i) If all path differences are zero, then all the parts of the slit contribute in phase. This gives maximum intensity at point P.
- (ii) If all path differences are non-zero, these secondary wavelets may either superpose in phase or out of phase, resulting in either occurrence of intensity of light or in zero occurrence.



These variation in the light intensity on the screen is termed as diffraction of light.

- (b) The angular width of central maxima is the angular separation between the first minima on the two sides of the central maximum.

Position of first minima $\sin \theta = n\lambda$

$$\theta_1 = \pm \frac{\lambda}{d}$$

Similarly $\theta_2 = \pm \frac{2\lambda}{d}$

Angular width of first diffraction fringe

$$\beta_0 = \frac{\lambda}{d}$$

Angular width of central maxima

$$\frac{+\lambda}{d} \text{ to } \frac{-\lambda}{d}$$

$$\beta'_\theta = \frac{2\lambda}{d}$$

Hence angular width of the first diffraction fringe is half of the central fringe.

(c) The path difference between the extreme rays can be given as

$$BC = BP_1 - AP_1 = a \sin \theta$$

where 'a' is the size of the slit.

If the slit is divided into three equal parts, first two-third of the slit which have a path difference of $\frac{\lambda}{2}$ will contribute no intensity at the point.

However, the remaining one-third of the slit contributes to the intensity at the point between two minima. Hence, the intensity of light will be much weaker than the central maxima.

So, path difference $a \sin \theta = \left(n + \frac{1}{2}\right)\lambda$

where $n = 2, 3, 4$, etc.

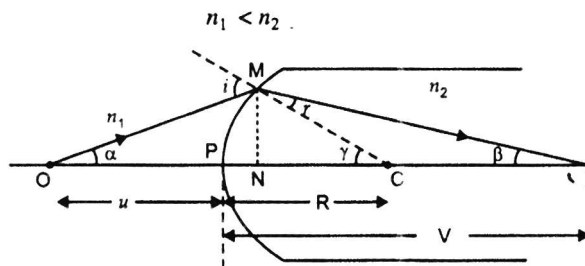
Since wavelength of light λ is in the range 700 nm to 400 nm.

So, $a \sin \theta = \left(n + \frac{1}{2}\right)\lambda$

$\Rightarrow \theta = \left(n + \frac{1}{2}\right) \frac{\lambda}{a}$

OR

(a)



- (i) all angles are small hence, $\sin \theta = \theta$, $\beta = \tan \beta$
(ii) Curvature of the surface is small hence PN is negligible.

Consider $\triangle OMC$ and $\triangle MCI$

$$i = \alpha + \gamma \quad \dots(i)$$

$$\gamma = r + \beta \quad \dots(ii)$$

Using Snell's law $n_1 \sin i = n_2 \sin r$

$$n_1 \sin i = n_2 r$$

$$n_1 (\alpha + \gamma) = n_2 (\lambda - \beta)$$

$$n_1 (\tan \alpha + \tan \alpha) = n_2 (\tan \gamma - \tan \beta)$$

$$n_1 \left(\frac{MN}{NO} + \frac{MN}{NC} \right) = n_2 \left(\frac{MN}{NC} - \frac{MN}{NI} \right)$$

$$NO = PO = -u$$

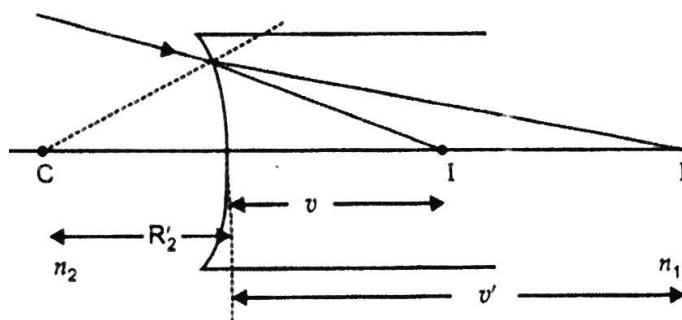
$$NC = PC = +R$$

$$NI = PI = +v$$

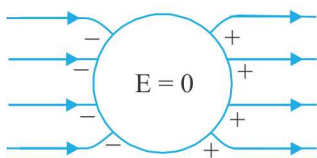
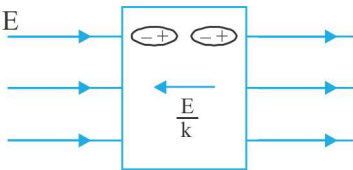
$$n_1 \left[\frac{1}{-n} + \frac{1}{R} \right] = n_2 \left[\frac{1}{R} - \frac{1}{v} \right]$$

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

(b)



(a)

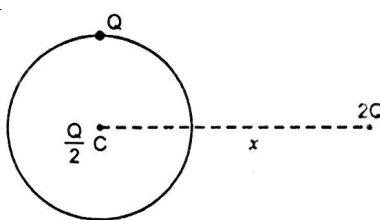
Conductor	Dielectric
	
1. No electric field lines inside conductor. 2. Electric field inside conductor is zero.	1. Alignment of atoms takes place due to electric field. 2. This results in a small electric field inside dielectric opposite direction. Net field inside the dielectric is $\frac{E}{K}$

Polarization of a dielectric : The induced dipole moment developed per unit volume in an ... called polarization (P).

$$P = \chi \epsilon E$$

$\chi \rightarrow$ susceptibility ; $\epsilon \rightarrow$ relative permeability ; $E \rightarrow$ electric field

(b)



(i) Force on $\frac{Q}{2}$ at $C = 0$ because there is no electric field inside the shell.

Force on $2Q$ charge.

Charge can be considered to be at C for a conducting sphere.

$$F_A = \frac{K 2Q \frac{3Q}{2}}{x^2} = \frac{3KQ^2}{x^2} \text{ along } \overrightarrow{CA}$$

$$(ii) \quad \phi = \frac{q}{\epsilon_0} = \frac{Q}{2\epsilon_0}$$

$\frac{Q}{2\epsilon_0}$ is the flux coming out of the shell.

$$\frac{n_2}{-v} + \frac{n_1}{v'} = \frac{n_1 - n_2}{R'} \quad \dots(i)$$

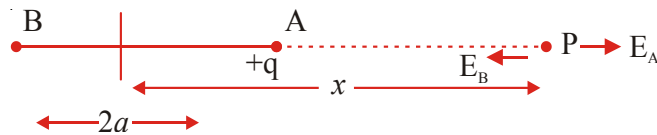
Adding (iii) and (iv)

$$\frac{n_1}{-u} + \frac{n_2}{v} + \frac{n_2}{-v} + \frac{n_1}{v'} = (n_2 - n_1) \left(\frac{1}{R} - \frac{1}{R'} \right)$$

$$\frac{1}{-u} + \frac{1}{v} = \left(\frac{n_2 - n_1}{n_1} \right) \left(\frac{1}{R} - \frac{1}{R'} \right)$$

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1} \right) \left(\frac{1}{R} - \frac{1}{R'} \right)$$

26. (a)



$$|\vec{EA}| = \frac{kq}{(a-a)^2}$$

$$|\vec{EA}| = \frac{kq}{(a+a)^2}$$

$$|\vec{E}_{net}| = |\vec{E}_A| - |\vec{E}_B| = \frac{kq}{(x-a)^2} - \frac{kq}{(x+a)^2}$$

$$\vec{E}_{net} = \frac{K2px}{(x^2 - a^2)^2}$$

If $x \gg a$

$$(x^2 - a^2) = x^2$$

$$\vec{E}_{net} = \frac{k2\vec{p}x}{4} = \frac{1}{8\pi\epsilon_0} \frac{2\vec{p}}{3}$$

(b) $E = 2x \, i$

Flux through surface (1),

$$\begin{aligned}\phi_1 &= \vec{E} \cdot \vec{A} \\ &= 2 \times 0 \times i \cdot a^2 i = 0\end{aligned}$$

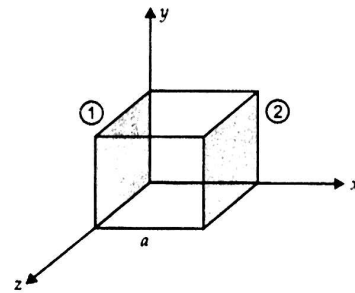
Flux through surface (2)

$$\begin{aligned}\phi_2 &= 2ai \cdot a^2 i \\ &= 2a^3\end{aligned}$$

Net flux through the cube

$$\phi_{net} = \phi_2 - \phi_1 = 2a^3 \text{ outward}$$

Hence charge enclosed $= 2\epsilon_0 a^3$



CBSE Examination Paper - 2016

Delhi (Code No. 55/1/1/D)

Time : 3 hours

Maximum marks: 70

Instructions: Same as CBSE Sample Question Paper–2016

SECTION-A

1. 'A point charge $+Q$ is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive.



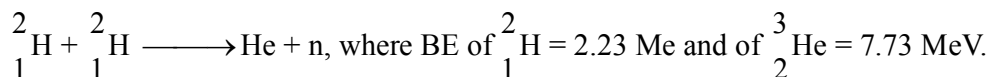
2. How does the electric flux due to a point charge enclosed by a spherical Gaussian surface get affected when its radius is increased?
3. Write the underlying principle of a moving coil galvanometer.
4. Define 'quality factor' of resonance in series LCR circuit. What is its SI unit?

SECTION-B

5. Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, m_2 ($m_1 > m_2$). Which one of the two represents a particle of smaller mass and why?
8. A nucleus with mass number $A = 240$ and $BE/A = 7.6$ MeV breaks into two fragments each of $A = 120$ with $BE/A = 8.5$ MeV. Calculate the released energy.

OR

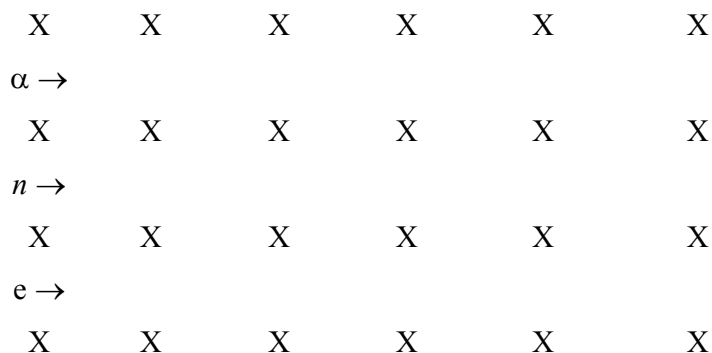
Calculate the energy in fusion reaction:



9. Two cells of emfs 1.5 V and 2.0 V having internal resistances $0.2\ \Omega$ and $0.3\ \Omega$ respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell.
10. State Brewster's law.
The value of Brewster angle for a transparent medium is different for light of different colours. Give reason.

SECTION-C

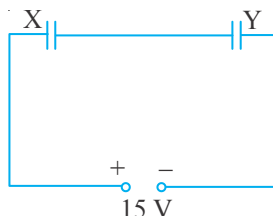
11. A charge is distributed uniformly over a ring of radius ' a '. Obtain an expression for the electric intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge.
12. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.
13. (i) Write the expression for the magnetic force acting on a, charged particle moving with velocity v in the presence of magnetic field B .
(ii) A neutron, an electron an alpha particle moving equal velocities, enter in magnetic field. Going into the plane of the paper as shown. Trace their path in the field in magnetic



14. (i) Define mutual inductance.
(ii) A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 20 A in 0.5 s, what is the change of flux linkage with other coil?



15. Two parallel plate capacitors X and Y have the same area of plates and same separation and air between the plates while Y contains a dielectric medium of $\epsilon_r = 4$.



- (i) Calculate capacitance of capacitor if equivalent of the combined system.
 - (ii) Calculate the potential difference between the plates of X and Y.
 - (iii) Estimate the ratio of electrostatic energy stored in X and Y.
16. Two long straight carry steady current I_1 and I_2 separated by distance a are flowing in the same direction, show how the magnetic field set up in one produces force on the other. Obtain the expression for this force. Hence define one ampere.
17. How are em waves produced by oscillating charges?

Draw a sketch of linearly polarized em propagating in the Z-direction. Indicating Oscillating electric and magnetic fields.

OR

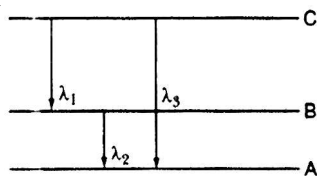
Write Maxwell's generalization of Ampere's Circuital Law. Show that in the process the current produced within the plates of the capacitor is

$$i = \epsilon_0 \frac{d\Phi_E}{dt}$$

where Φ_E is the electric flux produced during charging of the capacitor plates.

20. (a) Calculate the distance of an object of height h from a concave mirror of radius 20 cm to obtain a real image of magnification 2. Find the location of image also.
- (b) Using mirror formula, explain why does a convex mirror always produce a virtual image.
21. (a) State Bohr's quantization condition for defining stationary orbits. How does it explain the stationary orbits?

- (b) Find the relation between the three wavelengths λ_1 , λ_2 and λ_3 from the energy level diagram shown below.



22. Draw a schematic ray diagram of reflecting telescope showing how rays coming from a distant object are received at the eye-piece. Write in two important advantages over refracting telescope.

SECTION-E

23. (a) An ac source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L , C and R . Use the phasor diagram to obtain expressions for impedance of the circuit and phase with the voltage. What is circuit in this condition called?
- (b) In a series L_R circuit $X_L = R$ and power factor of the circuit is P_1 . When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2 . Calculate $\frac{P_1}{P_2}$

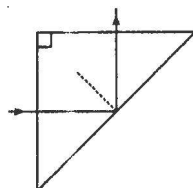
OR

- (i) Write the function of a transformer. State its principle of working with the help of diagram. Mention various energy losses in this device.
- (ii) The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are respectively 220 V and 1100 W. Calculate
- Number of turns in secondary
 - Voltage in primary
 - Voltage across secondary
 - Current in secondary
 - Power in secondary
24. (i) In Young's double slit experiment, deduce the condition for (a) constructive, and (b) destructive interference at a point on the screen. Draw a graph showing variation of intensity in the interference pattern against position 'x' on the screen.

- (ii) Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out three distinguishing features.

OR

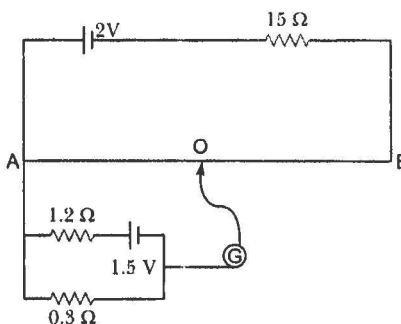
- (i) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism.
- (ii) What is dispersion of light? What is its cause?
- (iii) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in figure. What must be minimum value of refractive index of glass? Give relevant calculation



26. (i) Define the term drift velocity
- (ii) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of free electron density and relaxation time. On what factors does resistivity of a conductor depend?
- (iii) Why alloys like constantan and manganin are used for making standard resistors?

OR

- (i) State the principle of working of a potentiometer.
- (ii) In the following potentiometer circuit AB is a uniform wire of length l in and resistance R the potential gradient along the wire and balance length $AO (=l)$.



Solutions

1. Let the distance of point A and B from charge Q be r_A and r_B respectively.

$$V_A = \frac{+Q}{4\pi\epsilon_0 r_A} \text{ and } V_B = \frac{+Q}{4\pi\epsilon_0 r_B}$$

$$\therefore V_A - V_B = \frac{+Q}{4\pi\epsilon_0 r_A} \left(\frac{1}{r_A} - \frac{1}{r_B} \right)$$

Also $r_A < r_B$

$$\Rightarrow \frac{1}{r_A} > \frac{1}{r_B} \Rightarrow \frac{1}{r_A} - \frac{1}{r_B} > 0$$

$$\Rightarrow \frac{1}{r_A} - \frac{1}{r_B} \text{ has positive value}$$

Also Q is positive.

2. As per Gauss's theorem,

Electric $\phi = \frac{q}{\epsilon_0}$ where q is the charge enclosed by a closed surface through which flux is ϕ . Electric flux does not depend on the radius, hence it remains unaffected.

3. A current carrying coil, in the presence of a magnetic field, experiences a torque, which produces proportionate deflection.

i.e., Deflection, $\theta \propto \tau$ (Torque)

4. Microwaves are considered suitable for radar systems used in aircraft navigation due to their short wavelength or resonant curve.

5. The quality factor (Q) of series LCR circuit is defined as the ratio of the resonant to frequency band width of the resonant curve.

$$Q = \frac{\omega_r}{\omega_2 - \omega_1} = \frac{\omega_r L}{R}$$

Clearly, smaller the value of R , larger is the quality factor and sharper the resonance. Thus quality factor determines the nature of sharpness of resonance.

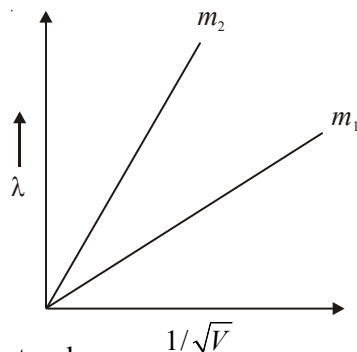
It has no units.

7. As,
$$l = \frac{h}{\sqrt{2mqV}} \text{ or } \lambda = \left(\frac{h}{\sqrt{2q}} \cdot \frac{1}{\sqrt{m}} \right) \frac{1}{\sqrt{V}}$$

or
$$\frac{\lambda}{\frac{1}{\sqrt{V}}} = \frac{h}{\sqrt{2q}} \cdot \frac{1}{\sqrt{m}}$$

As the charge on two particles is same, we get

\therefore Slope $\alpha = \frac{1}{\sqrt{m}}$



Hence, particle with lower mass (m_2) will have greater slope.

8. Binding energy of nucleus with mass number 240,

$$BE_1 = 240 \times 7.6 = 1824 \text{ MeV}$$

Binding energy of two fragments

$$BE_2 = 2 \times 120 \times 85 = 2040 \text{ MeV}$$

$$\therefore \text{Energy released} = BE_2 - BE_1$$

$$= (2040 - 1824) \text{ MeV} = 216 \text{ MeV}$$

OR

Initial binding energy

$$BE_1 = (2.23 + 2.23) = 4.46 \text{ MeV}$$

Final binding energy

$$BE_2 = 7.73 \text{ MeV}$$

Energy released

$$= (7.73 - 4.46) \text{ MeV} = 3.27 \text{ MeV}$$

9.
$$\begin{array}{ll} E_1 = 1.5 \text{ V}, & r_2 = 0.2 \Omega \\ E_2 = 2.0 \text{ V}, & r_2 = 0.3 \Omega \end{array}$$

emf of equivalent cell'

$$E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

$$= \left(\frac{1.5 \times 0.3 + 2 \times 0.2}{0.2 + 0.3} \right) = \frac{0.45 + 0.40}{0.5} \text{V} = 1.7 \text{V}$$

Internal resistance of equivalent cell

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1 r_2}{r_1 + r_2}$$

$$= \left(\frac{0.2 \times 0.3}{0.2 + 0.3} \right) \Omega = \frac{0.06}{0.5} \Omega = 0.12 \Omega$$

10. **Brewster's Law:** When unpolarised light is incident on the surface separating two media at polarising angle, the reflected light gets completely polarised only when the reflected light and the refracted light are perpendicular to each other.

Now, refractive index of denser (second) medium with respect to rarer (first) medium is given by

$$\mu = \tan i_p \text{ where } i_p = \text{polarising angle.}$$

Since refractive index is different for different colour (wavelengths), Brewster's angle is different for different colours.

11. Consider a point P on the axis of uniformly charged ring at a distance x from its centre O . Point P is at distance $r = \sqrt{R^2 + x^2}$ from each element dl of ring. If q is total charge on ring, then,

$$\text{charge per metre length, } \lambda = \frac{q}{2\pi R}.$$

The ring may be supposed to be formed of a large number of ring elements.

Consider an element of length dl situated at A .

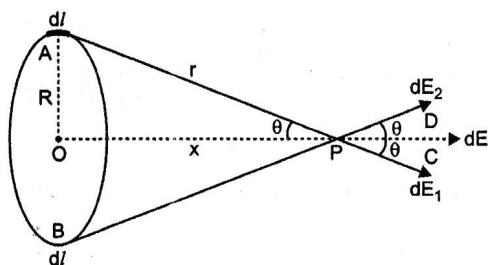
The charge on element, $dq = \lambda dl$

The electric field at P due to this element

$$dE_1 = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{\lambda dl}{r^2}, \text{ along } \overrightarrow{PC}$$

The electric field strength due to opposite symmetrical element of length dl at B is

$$\overrightarrow{dE_2} = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{\lambda dl}{r^2}, \text{ along } \overrightarrow{PD}$$



If we resolve \overrightarrow{dE} and \overrightarrow{dE}_2 along the axis and perpendicular to axis, we note that the components perpendicular to axis are oppositely directed and so get cancelled, while those along the axis are added up. Hence, due to symmetry of the ring, the electric field strength is directed along the axis.

The electric field strength due to charge element of length dl , situated at A, along the axis will be

$$dE = dE_1 \cos \theta = \frac{1}{4\pi\epsilon_0} \frac{\lambda dl}{r^2} \cdot \frac{\lambda dl}{r^2}, \text{ along } \overrightarrow{PD}$$

But, $\cos \theta = \frac{x}{r}$

$$\therefore dE = \frac{1}{4\pi\epsilon_0} \frac{\lambda dx}{r^3} = \frac{1}{4\pi\epsilon_0} \frac{\lambda x}{r^3} dt$$

The resultant electric field along the axis will be obtained by adding fields due to all elements of the ring, *i.e.*,

$$E = \int \frac{1}{4\pi\epsilon_0} \frac{\lambda x}{r^3} dl = \frac{1}{4\pi\epsilon_0} \frac{\lambda x}{r^3} \int dt$$

But, $\int dl = \text{whole length of ring} = 2\pi R$ and $r = (R^2 + x^2)^{1/2}$

$$E = \frac{1}{4\pi\epsilon_0} \frac{qx}{(R^2 + x^2)^{3/2}} 2\pi R$$

As, $\lambda = \frac{q}{2\pi R}$,

$$E = \frac{1}{2\pi\epsilon_0} \frac{\left(\frac{q}{2\pi R}\right)x}{(R^2 + x^2)^{3/2}} 2\pi R$$

or,
$$E = \frac{1}{2\pi\epsilon_0} \frac{qx}{(R^2 + x^2)^{3/2}}, \text{ along the axis}$$

At large distances *i.e.*, $x \gg R$,
$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{x^2}$$

i.e., the electric field due to a point charge at a distance x .

For points on the axis at distances much larger than the radius of ring, the ring behaves like a point charge.

12. The three characteristic features which cannot be explained by wave theory are:

- (i) Kinetic energy of emitted electrons is found to be independent of the intensity of incident light.
- (ii) There is no emission of electrons if frequency of incident light is below a certain frequency (threshold frequency).
- (iii) Photoelectric effect is an instantaneous process.

The direction of force experienced by the particles will be according to Reming's left hand rule

14. (i) Mutual inductance of two coils is the magnetic flux linked with the secondary coil when a unit current flows through the primary coil,

i.e.,
$$\phi_2 = MI_1 \quad \text{or} \quad M = \frac{\phi_2}{I_1}$$

- (ii) Change of flux for small change in current

$$d\phi = Md_1 = 1.5 (20 - 0) \text{ weber} = 30 \text{ weber}$$

15. (i)
$$C_x = \frac{4\epsilon_0 A}{d} C = 4C \quad \text{then} \quad C_y = \frac{4\epsilon_0 A}{d} C = 4C$$

For series combination of C_x and C_y

$$\frac{1}{C} = \frac{1}{C_x} + \frac{1}{C_y}$$

$$\Rightarrow \frac{1}{4} = \frac{1}{C} + \frac{1}{4C} = \frac{5}{4C} \quad \Rightarrow \quad C = 5\mu F$$

$$\therefore C_x = 5\mu F \text{ and } C_y = 4 \times 5 = 20\mu F$$

(ii) Total charge $Q = CV = 4\mu\text{F} \times 15\text{ V} = 60\mu\text{C}$

$$V_x = \frac{Q}{C_x} = \frac{60\mu\text{C}}{5\mu\text{F}} = 12\text{ V}$$

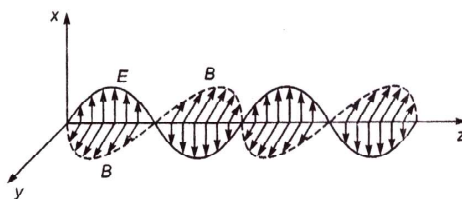
$$V_y = \frac{Q}{C_y} = \frac{60\mu\text{C}}{5\mu\text{F}} = 3\text{ V}$$

(iii)
$$\frac{U_x}{U_y} = \frac{(Q^2/2C_x)}{(Q^2/2C_y)} = \frac{C_y}{C_x} = \frac{4C}{C} = \frac{4}{1}$$

$\Rightarrow U_x : U_y = 4 : 1$

16. Refer to NCERT Book.

17. (a) An oscillating charge produces an oscillating electric field in space, which produces an oscillating magnetic field. The oscillating electric and magnetic fields regenerate each other, and this results in the production of em waves in space.
- (b) Electric field is along j-axis and magnetic field is along y-axis.



Ampere's circuital law is given by

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_c$$

For a circuit containing capacitor, during its charging or discharging the current within the plates of the capacitor varies, producing displacement current I_d . Hence, Ampere's circuital law is generalised by Maxwell, given as

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_c + \mu_0 I_e$$

The electric flux (ϕ_E) between the plates of capacitor changes with time, producing current within the plates which is proportional to $\frac{d\phi_E}{dt}$. Thus we get

$$I_e = \epsilon_0 \frac{d\phi_E}{dt}$$

20. (a) $R = -20$ cm and $M = -2$

$$\text{Focal length } f = \frac{R}{2} = -10 \text{ cm}$$

$$\text{Magnification } M = -\frac{v}{u} = -2 \text{ (given)}$$

$$\therefore u = 2v$$

Using mirror formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{2v} + \frac{1}{v} = -\frac{1}{10}$$

$$\Rightarrow \frac{3}{2v} = -\frac{1}{10} \Rightarrow v = -15 \text{ cm}$$

$$\therefore v = 2 \times (-15) = -30 \text{ cm}$$

(b) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Using sign convention for convex mirror we get

$$f > 0, u < 0$$

\therefore Form the formula:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

As f is positive and u is negative v is always positive, hence image is always virtual.

21. (a) Only those orbits are stable for which the angular momentum of revolving electron is an integral multiple of $\left(\frac{h}{2\pi}\right)$ where h is the planck's constant.

Thus the angular momentum (L) of the orbiting electron is quantised. That is $L =$

$$\frac{nh}{2\pi}$$

According to de Broglie hypothesis

$$\text{Linear momentum} = \frac{h}{\lambda}$$

and for circular orbit

orbits $L = mvp$, where m is the mass of quantised

$$= r_n \frac{h}{\lambda}$$

Also,
$$L = \frac{nh}{2\pi}$$

$$\therefore \frac{r_n h}{\lambda} = \frac{nh}{2\pi} \quad \text{or} \quad 2\pi r = n\lambda$$

Hence, circumference of permitted orbits are integral multiples of the wavelength

$$(b) \quad E_C - E_B = \frac{hc}{\lambda_1} \quad \dots(1)$$

$$E_B - E_A = \frac{hc}{\lambda_2} \quad \dots(2)$$

$$E_C - E_A = \frac{hc}{\lambda_3} \quad \dots(3)$$

Adding (1) and (2), we have

$$E_C - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \quad \dots(4)$$

From (3) and (4), we have

$$\begin{aligned} \frac{hc}{\lambda_3} &= \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} \\ &\Rightarrow \lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2} \end{aligned}$$

22. Advantages:

- (i) No chromatic aberration.
- (ii) Easy mechanical support (high mechanical support is required, because mirror

weights much less than a lens of equivalent optical quality.)

- (iii) Large gathering power.
- (iv) Large magnifying power.
- (v) Large resolving power.
- (iv) Spherical aberration is also removed by using parabolic mirror.

24. (a) Phase difference (ϕ) in series LCR circuit is given by

$$\begin{aligned}\tan \phi &= \frac{V_C - V_L}{V_R} = \frac{i_m(X_C - X_L)}{i_m R} \\ &= \frac{(X_C - X_L)}{R}\end{aligned}$$

When current and voltage are in phase

$$\phi = 0 \Rightarrow X_C - X_L = 0 \Rightarrow X_C = X_L$$

This condition is called resonance and the circuit is called resonant circuit.

(b) **Case I:** $X_L = R$

$$\therefore Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + R^2} = \sqrt{2}R$$

$$\text{Power factor, } P_1 = \cos \phi \cos \phi = \frac{R}{Z} = \frac{R}{\sqrt{2}R} = \frac{1}{\sqrt{2}}$$

Case II:

$$\therefore Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2} = R$$

$$\text{Power factor, } P_2 = \frac{R}{Z} = \frac{R}{R} = 1$$

$$\therefore = \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

(i) A transformer converts low voltage ac into high voltage ac and vice versa

Refer NCERT Book.

For energy Losses, Refer NCERT Book.

(ii) $N_p = 100$, Transformer ration $K = 100$

(a) Number of turns in secondary coil

$$N_s = N_p \times K = 100 \times 100 = 10000$$

(b) Input power (P_p) = Input voltage (V_p) \times Current in primary (I_p)

$$1100 = 220 \times I_p \Rightarrow I_p = 5 \text{ A}$$

$$(c) \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{\text{Output Voltage}}{\text{Input Voltage}}$$

$$\Rightarrow V_s = \frac{5}{I_s} \times V_p = K \times V_p$$

$$= 220 \times 100 = 22000 \text{ V}$$

$$(d) \frac{\text{Input Current}}{\text{Output Current}} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$$

$$\Rightarrow \frac{5}{I_s} = 100 \text{ or } I_s = 0.05 \text{ A}$$

(e) For an ideal transformer,

Power in secondary = Power in primary

$$\Rightarrow P_s = 1100 \text{ W}$$

25. Refer to NCERT Book.

OR

(i) Refer to NCERT Book.

(ii) The phenomenon of splitting of white light into its constituent colours is called dispersion of light. Refractive index of the material is different for different colours. According to the equation, different colours deviate through different angles.

(iii) The critical angle depends on refractive index μ as

$$\sin i_c = \frac{1}{\mu}$$

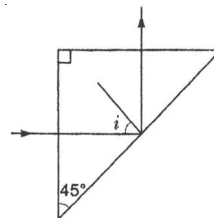
For total internal reflection,

$$\angle i = \angle i_c \text{ (critical angle)}$$

$$\Rightarrow \angle i = \angle i \Rightarrow \angle i \leq 45^\circ$$

$$\Rightarrow \sin i_c \leq \sin 45^\circ \Rightarrow \sin i_c \leq \frac{1}{\sqrt{2}}$$

$$\Rightarrow \frac{1}{\sin i_c} \geq \sqrt{2} \Rightarrow \mu \leq \sqrt{2}$$



Hence, the minimum value of refractive index must be $\sqrt{2}$.

25. (i) The average velocity acquired by the free electrons of a conductor in a direction opposite to the externally applied electric field is called drift velocity.

$$\text{Drift Velocity. } v_d = \frac{-eE\tau}{m}$$

Where,

e = charge on electron

E = external electric field

τ = relaxation time

m = mass of electron

- (ii) Refer to NCERT Book.

Resistivity of the material of a conductor depends upon the relaxation time, i.e., temperature and the number density of electrons.

- (iii) This is because constantan and manganin show very weak dependence of resistivity on temperature.

OR

- (i) When a constant current flows through a conductor of uniform area of cross-section, the potential drop across any length of the wire is directly proportional to the length, i.e., $V \propto l$
- (ii) Current flowing in the potentiometer wire

$$I = \frac{E}{R_{total}} = \frac{2.0}{15 + 10} = \frac{2}{25} \text{ A}$$

$$\therefore \text{Potential difference across the wire} = \frac{2}{25} \times 10 = \frac{20}{25} = 0.8 \text{ A}$$

$$\therefore \text{Potential gradient } k = \frac{V_{AB}}{I_{AB}} = \frac{0.8}{1.0} = 0.8 \text{ V/m}$$

Now, current flowing in the circuit containing experimental cell,

$$= \frac{1.5}{1.2 + 0.3} = 1 \text{ A}$$

Potential difference across length AO – $0.3 \times 1 = 0.3 \text{ V}$

$$\text{Length AO} = \frac{0.3}{0.8} \text{ m} = \frac{0.3}{0.8} \times 100 \text{ cm} = 37.5 \text{ cm}$$

CBSE BOARD EXAMINATION PAPER DELHI- 2017 (SOLVED)

Time: 3 Hours

Maximum Marks: 70

General Instructions:

- (i) All questions are compulsory. There are 26 questions in all.
- (ii) This questions paper has five sections: Section A Section B, Section C, Section D and Section E.
- (iii) 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.
- (iv) There is no overall choice. However, an internal choice has been provided in one questions of two marks, one question of three marks and all the three question of five marks weightage. You have to attempt only one of the choices in such questions.
- (v) You may use the following values of physical constants wherever necessary.

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$\text{Mass of electron} = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{Mass of neutron} = 1.675 \times 10^{-27} \text{ kg}$$

$$\text{Mass of proton} = 1.673 \times 10^{-27} \text{ kg}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ kg}$$

$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

SECTION A

- Q1. Does the charge given to a metallic sphere depend on whether it is hollow or solid?
Give reason for your answer.

Ans. No,

Because the charge resides only on the surface of the conductor.

- Q2. A long straight current carrying wire passes normally through the centre of circular loop. If the current through the wire increases, will there be an induced emf in the loop? Justify.

Ans. No,

As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero.

Alternatively

[Magnetic flux does not change with the change of current]

- Q3. At a place, the horizontal component of earth's magnetic field is B and angle of dip is 60° . What is the value of horizontal component of the earth's magnetic field at equator?

Ans.

$$B_H = B_E \cos \delta$$

$$B = B_E \cos 60^\circ \Rightarrow B_E = 2B$$

At equator

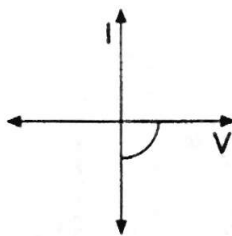
$$\delta = 0^\circ$$

\therefore

$$B_H = 2B \cos 0^\circ = 2B$$

[Alternatively, Award full one mark, if student doesn't take the value ($= 2B$) of B_E , while finding the value of horizontal component at equator, and just writes and formula only.]

- Q4. Name the junction diode whose I-V characteristics are drawn below.



Ans. Solar cell

- Q5. How is the speed of em-waves in vacuum determined by the electric and magnetic fields?

Ans. Speed of em waves is determined by the ratio of the peak values of electric and magnetic field vectors.

[Alternatively, Give full credit, if student writes directly $c = \frac{E_o}{B_o}$]

SECTION B

Q6. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for the displacement current in terms of the rate of change of electric flux.

Ans.	Explanation of flow of current through capacitor	
	Expression for displacement current	1

During charging, electric flux between the plates of capacitor keeps on changing; this results in the production of a displacement current between the plates.

$$I_d = \epsilon_0 \frac{d\phi_E}{dt} \left(/ I_d = \epsilon_0 A \frac{dE}{dt} \right)$$

Q7. Define the distance of closest approach. An α -particle of kinetic energy 'K' is bombarded on a thin gold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α -particle of double the kinetic energy?

OR

Write two important limitations of Rutherford nuclear model of the atom.

Ans.	Definition of distance of closest approach	1
	Finding of distance of closest approach when	
	Kinetic energy is doubled	1

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. Distance of closest approach (r_c) is given by

$$r_c = \frac{1}{4\pi\epsilon_0} \cdot \frac{2Ze^2}{K}$$

'K' is doubled, $\therefore r$ becomes $\frac{r}{2}$

[Alternatively: If a candidate writes directly $\frac{r}{2}$ without mentioning formula, award the mark for this part.]

OR

Two important limitation of Rutherford nuclear model

1. According to Rutherford model, electron orbiting around the nucleus, continuously radiates energy due to the acceleration; hence the atom will not remain stable.
2. As electron spirals inwards; its angular velocity and frequency change continuously; therefore it will emit a continuous spectrum.

Q8. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.

Ans. Calculation of wavelength of electron in ground state

Radius of ground state of hydrogen atom = $0.53 \text{ \AA} = 0.53 \times 10^{-10} \text{ m}$

According to de Broglie relation $2\pi r = n\lambda$

For ground state $n = 1$

$$2 \times 3.14 \times 0.53 \times 10^{-10} = 1 \times \lambda$$

$$\therefore \lambda = 3.32 \times 10^{-10} \text{ m} \\ = 3.32 \text{ \AA}$$

Alternatively

Velocity of electron, in the ground state, of hydrogen atom = $2.18 \times 10^{-6} \text{ m/s}$

Hence momentum of revolving electron

$$p = mv \\ = 9.1 \times 10^{-31} \times 2.18 \times 10^{-6} \text{ kgm/s}$$

$$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-24}}{9.1 \times 10^{-31} \times 2.18 \times 10^{-6}} \text{ m} \\ = 3.32 \text{ \AA}$$

Note: Also accept the following answer:

Let λ_n be the wavelength of the electron in the n^{th} orbit, we then have

$$2\pi r = n\lambda$$

For ground state $n = 1$

$$2\pi r_0 = \lambda$$

($r = r_0$ is the radius of the ground state)

[Alternatively]

$$\lambda n = \frac{h}{mv_n}$$

and $v_n = v_0$ (velocity of electron in ground state)

$$\lambda = \frac{h}{mv_0}$$

- Q9. Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and the eyepiece of a compound microscope has short focal lengths? Explain.

Ans. Definition of magnifying power

Reason for short focal lengths of objective and eyepiece

Magnifying power is defined as the angle subtended at the eye by the image to the angle subtended (at the unaided eye) by the object.

(Alternatively: Also accept this definition in the form of formula)

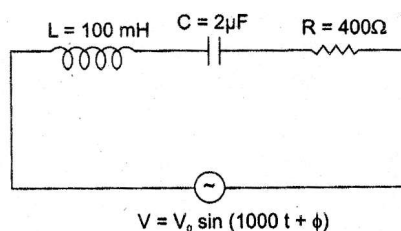
$$m = m_o \times m_e = \frac{L}{f_o} \times \frac{D}{f_e}$$

To increase the magnifying power both the objective and eyepiece must have

short focal lengths $\left(\text{as } m = \frac{L}{f_o} \times \frac{D}{f_e} \right)$

SECTION C

- Q11. (i) Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below, which one leads in phase: current or voltage?
- (ii) Without making any other change, find the value of the additional capacitor C_1 , to be connected in parallel with the capacitor C , in order to make the power factor of the circuit unity.



- Ans. (i) Calculation of phase difference between current and voltage Name of quantity which leads
- (ii) Calculation of value of 'C', is to be connected in parallel

(i) $X_L = \omega L = (1000 \times 100 \times 10^{-3}) \Omega = 100 \Omega$

$$X_c = \frac{1}{\omega C} = \left(\frac{1}{1000 \times 2 \times 10^{-6}} \right) \Omega = 500 \Omega$$

Phase angle

$$\tan \phi = \frac{X_L - X_c}{R}$$

$$\tan \phi = \frac{100 - 500}{400} = -1$$

$$\phi = -\frac{\pi}{4}$$

As $X_c > X_L$, (/phase angle is negative), hence current leads voltage

(ii) To make power factor unity

$$X_C = X_L$$

$$\frac{1}{\omega C} = 100 \quad C' = 10\mu\text{F}$$

$$C' = C + C_1 \quad 10 = 2 + C_1$$

$$C_1 = 8\mu\text{F}$$

Q12. Write the two processes that take place in the formation of a p-n junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a p-n junction.

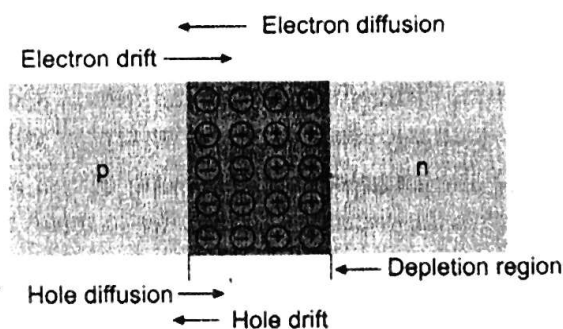
Ans. Names of the two processes

Diagram

Explanation of formation of depletion region and Barrier Potential

Diffusion

Drift



Due to the diffusion of electrons and holes across the junction a region of (immobile) positive charge is created on the n-side and a region of (immobile) negative charge is created on the p-side; near the junction; this is called depletion region.

Barrier potential is formed due to loss of electrons from n-region and gain of electrons by p-region. Its polarity is such that it opposes the movement of charge carriers across the junction.

- Q13. (i) Obtain the expression for the cyclotron frequency.
- (ii) A deuteron and a proton are accelerated by the cyclotron. Can both be accelerated with the same oscillator frequency? Give reason to justify your answer.

Ans. (i) Derivation of the expression for cyclotron frequency
(ii) Reason/justification for the correct answer

$$(i) \quad \frac{mv^2}{r} = qvB$$

$$r = \frac{mv}{qB}$$

$$\text{Frequency of revolution} \quad (v) = \frac{1}{\text{Time Period}} = \frac{v}{2\pi r}$$

$$v = \frac{qB}{2\pi m}$$

(ii) No

The mass of the two particles, i.e deuteron and proton, is different.

Since (cyclotron) frequency depends inversely on the mass, they cannot be accelerated by the same oscillator frequency.

- Q14. (i) How does one explain the emission of electrons from a photosensitive surface with the help of Einstein's photoelectric equation?
- (ii) The work function of the following metals is given: Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV and Ni = 5.15 eV. Which of these metals will not cause photoelectric emission for radiation of wavelength 3300 Å from a laser source placed 1 m away from these metals? What happens if the laser source is brought nearer and placed 50 cm away?

Ans. (i) Explanation of emission of electrons from the photosensitive surface
(ii) Identification of metals/s which does/do not cause photoelectric effect
Photoelectric emission
Effect produced

(i) Einstein's Photoelectric equation is

$$h\nu = \phi_0 + K_{\max}$$

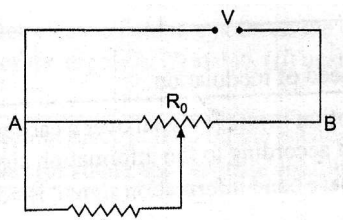
When a photon of energy ' $h\nu$ ' is incident on the metal, some part of this energy is utilized as work function to eject the electron and remaining energy appears as the kinetic energy of the emitted electron.

$$(ii) \quad E = \frac{h\nu}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3.3 \times 10^{-7} \times 1.6 \times 10^{-19}} eV$$

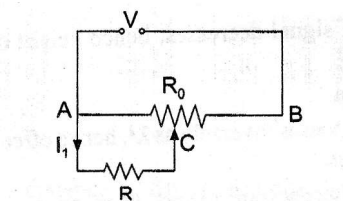
$$= 3.77 \text{ eV}$$

The work function of Mo and Ni is more than the energy of the incident photons; so photo-electric emission will not take place from these metals. Kinetic energy of photo electrons will not change, only photoelectric current will change.

Q15. A resistance of R draws current from a potentiometer. The potentiometer wire, AB, has total resistance of R_0 . A voltage V is supplied to the potentiometer. Derive an expression for the voltage across R when the sliding contact is in the middle of potentiometer wire.



Ans. Derivation of expression of voltage across resistance R



Resistance between points A & C

$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{\left(\frac{R_0}{2}\right)}$$

Effective resistance between points A & B.

$$R_2 = \left(\frac{R \frac{R_0}{2}}{R + \frac{R_0}{2}} \right) + \frac{R_0}{2}$$

Current drawn from the voltage source,

$$I = \frac{V}{\left(\frac{R \frac{R_0}{2}}{R + \frac{R_0}{2}} \right) + \frac{R_0}{2}}$$

Let current through R be I_1

$$I_1 = \frac{I \left(\frac{R_0}{2} \right)}{R + \frac{R_0}{2}}$$

Voltage across R

$$\begin{aligned} V_1 &= I_1 R \\ &= \frac{IR_0}{2 \left(R + \frac{R_0}{2} \right)} \cdot R = \frac{RR_0}{2 \left(R + \frac{R_0}{2} \right)} \cdot \frac{V}{\left(\frac{RR_0}{2R + R_0} \right) + \frac{R_0}{2}} \\ &= \frac{2RV}{R_0 + 4R} \end{aligned}$$



Q17. (i) Find equivalent capacitance between A and B in the combination given below.

Each capacitor is of $2\mu\text{F}$ capacitance.

(ii) If a dc source of 7 V is connected across AB, how much charge is drawn from the source and what is the energy stored in the network?

Ans. (i) Calculation of equivalent capacitance.
(ii) Calculation of charge and energy stored

(i) Capacitors C_2 , C_3 , and C_4 are in parallel

$$\therefore C_{235} = C_2 + C_3 + C_4$$

$$\therefore C_{234} = 6\mu\text{F}$$

Capacitors C_1 , C_{234} and C_5 are in series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{234}} + \frac{1}{C_5} = \frac{1}{2} + \frac{1}{6} + \frac{1}{2}$$

$$= 7/6 \mu\text{F}$$

$$C_{\text{equivalent}} = 6/7 \mu\text{F}$$

(ii) Charge drawn from the source

$$Q = C_{eq} V,$$

$$= \frac{6}{7} \times 7\mu\text{C} = 6\mu\text{C}$$

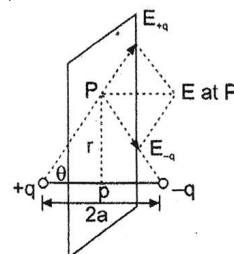
$$\begin{aligned} \text{Energy stored} \quad U &= \frac{Q^2}{2C} = \frac{6 \times 6 \times 10^{-12} \times 7}{2 \times 6 \times 10^{-6}} \text{ J} \\ &= 6/7 \mu\text{F} \end{aligned}$$

Q18. (i) Derive the expression for electric field at a point on the equatorial line of an electric dipole.

(ii) Depict the orientation of the dipole in (i) stable, (ii) unstable equilibrium in a uniform electric field.

Ans. (i) Derivation of expression of electric field on the equatorial line of the dipole

(ii) Depiction of orientation for stable and unstable equilibrium



Both are equal and their directions are as shown in the figure. Hence net electric field

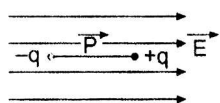
$$E_{+q} = \frac{q}{4\pi\epsilon_0(r^2 + a^2)}$$

$$E_{-q} = \frac{q}{4\pi\epsilon_0(r^2 + a^2)}$$

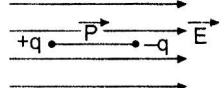
Let the point 'P' be at a distance 'r' from the mid point of the dipole.

$$\begin{aligned}\vec{E} &= [-(E_{+q} + E_{-q})\cos \theta] \hat{p} \\ &= -\frac{2qa}{4\pi\epsilon_0(r^2 + a^2)^{\frac{3}{2}}} \hat{p}\end{aligned}$$

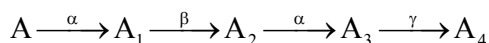
(ii) Stable equilibrium, $\theta = 0^\circ$



Unstable equilibrium, $\theta = 180^\circ$



Q19. (i) A radioactive nucleus 'A' undergoes a series of decays as given below.



The mass number and atomic number of A are 176 and 71 respectively.

Determine the mass and atomic numbers of A_4 and A,

(ii) Write the basic nuclear processes underlying β^+ and β^- decays.

Ans. (i) Determining the mass and atomic number of A_4 and A

(ii) Basic nuclear processes of β^+ and β^- decays

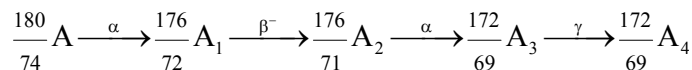
(i) A_4 : Mass Number: 172

Atomic Number: 69

(ii) A: Mass Number: 180

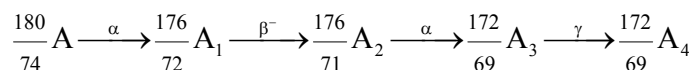
Atomic Number: 72

[Alternatively: Give full credit if student considers * decays and find atomic and mass numbers accordingly]



Gives the values quoted above.

If the student takes β^+ decay



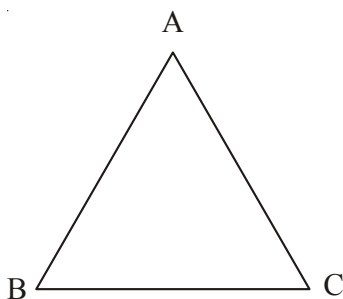
This would give the answer: (A_4 : 172,69);(A : 180,74)

Basic nuclear process for β^+ decay $p \rightarrow n + {}^0_{-1}\text{e} + \nu$

For β^- decay $n \rightarrow p + {}^0_0\text{e} + \bar{\nu}$

[Note: Give full credit of this part, if student writes the processes as conversion of proton into neutron for β^+ decay and neutron into proton for β^- decay.]

- Q20. (i) A ray of light incident on face AB of an equilateral glass prism, shows minimum deviation of 30° . Calculate the speed of light through the prism.

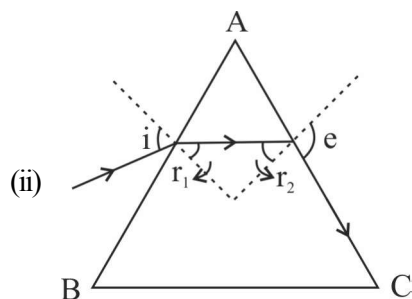


- (ii) Find the angle of incidence at face AB so that the emergent ray grazes along the face AC.

Ans. (i) Calculation of speed of light
(ii) Calculation of angle of incidence at face AB

$$\mu = \frac{\sin\left(\frac{A + \delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60^\circ + 30^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)} = \sqrt{2}$$

Also
$$\mu = \frac{c}{v} \Rightarrow v = \frac{3 \times 10^8}{\sqrt{2}} \text{ m/s}$$
$$= 2.122 \times 10^8 \text{ m/s}$$



At face AC, let the angle of incidence be r_2 , For grazing ray, $e = 90^\circ$

$$\Rightarrow \mu = \frac{1}{\sin r_2} \Rightarrow r_2 = \sin^{-1} \left(\frac{1}{\sqrt{2}} \right) = 45^\circ$$

Let angle of refraction at face AB be r_1 , Now $r_1 + r_2 = A$

$$\therefore R_1 = A - r_2 = 60^\circ - 45^\circ = 15^\circ$$

Let angle of incidence at this face be i

$$\mu = \frac{\sin i}{\sin r_1}$$

$$\Rightarrow \sqrt{2} = \frac{\sin i}{\sin 15^\circ}$$

$$\therefore i = \sin^{-1} (\sqrt{2} \cdot \sin 15^\circ)$$

Q22. Describe the working principle of a moving coil galvanometer. Why is it necessary to use (i) a radial magnetic field and (ii) a cylindrical soft iron core in a galvanometer? Write the expression for current sensitivity of the galvanometer.

Can a galvanometer as such be used for measuring the current? Explain.

OR

(a) Define the term 'self-inductance' and write its S.I. unit.



- (b) Obtain the expression for the mutual inductance of two long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2 .

Ans. Working and Principle of moving coil galvanometer

Necessity of (i) radial magnetic field

(ii) cylindrical soft iron core

Expression for current sensitivity

Explanation of use of Galvanometer to measure current

When a coil, carrying current, and free to rotate about a fixed axis, is placed in a uniform magnetic field, it experiences a torque (Which is balanced by a restoring torque of suspension).

- (i) To have deflection proportional to current / to maximize the deflecting torque acting on the current carrying coil.
- (ii) To make magnetic field radial/to increase the strength of magnetic field.

Expression for current sensitivity

$$I_s = \frac{\theta}{I} \text{ or } \frac{NAB}{K}$$

where θ is the deflection of the coil

No

The galvanometer, can only detect current but cannot measure them as it is not calibrated. The galvanometer coil is likely to be damaged by currents in the (mA/A) range]

OR

(a) Definition of self inductance and its SI unit

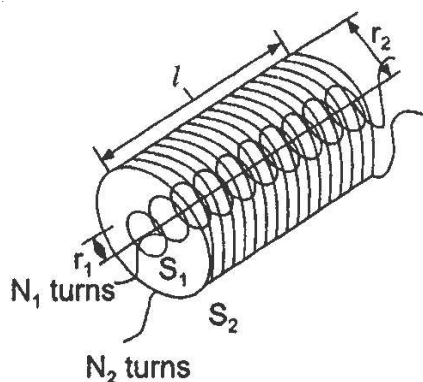
(b) Derivation of expression for mutual inductance

Self inductance of a coil equals, the magnitude of the magnetic flux, linked with it, when a unit current flows through it.

Alternatively

Self inductance, of a coil, equals the magnitude of the emf induced in it, when the current in the coil, is changing at a unit rate.

SI unit: henry / (weber/ampere) / (ohm second.)



When current I_2 is passed through coil S_2 , it in turn sets up a magnetic flux through S_1 : $\varpi_1 = (n_1 l) (\theta r_1^2) (B_2)$

$$\varpi_1 = (n_1 I) (\pi r_1^2) (\mu_0 n_2 I_2)$$

$$\varpi_1 = \mu_0 n_1 n_2 I_2 \pi r_1^2 l$$

But

$$\varpi_1 = M_{12} I_2$$

\Rightarrow

$$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$$

[Note: If the student derives the correct expression, without giving the diagram of two coaxial coils, full credit can be given]

SECTION E

- Q24. (a) Draw a labelled diagram of AC generator. Derive the expression for the instantaneous value of the emf induced in the coil.
- (b) A circular coil of cross-sectional area 200 cm^2 and 20 turns is rotated about the vertical diameter with angular speed of 50 rad s^{-1} in a uniform magnetic field of magnitude $3.0 \times 10^{-2} \text{ T}$. Calculate the maximum value of the current in the coil.

OR

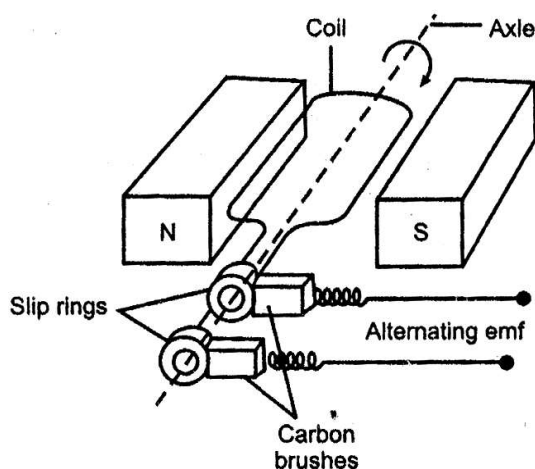
- (a) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary to primary voltage in terms of number of turns and currents in the two coils
- (b) A power transmission line feeds input power at 2200 V to a step-down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary to get the power output at 220 V.

Ans. (a) Labelled diagram of AC generator

Expression for instantaneous value of induced emf.

(b) Calculation of maximum value of current

Alternatively



[Deduct $\frac{1}{2}$ mark, If diagram is not labelled]

When the coil is rotated with constant angular speed ω the angle θ between the magnetic field and area vector of the coil, at instant, t is given by $\theta = \omega t$.

Therefore, magnetic flux, (ϕ_B), at this instant, is

$$\phi_B = BA \cos \omega t$$

\therefore Induced emf

$$e = -N \frac{d\phi_B}{dt}$$

$$e = NBA \omega \sin \omega t = e_0 \sin \omega t$$

where

$$e_0 = NBA \omega$$

(b) Maximum value of emf

$$\begin{aligned} e_0 &= NBA \omega \\ &= 20 \times 200 \times 10^{-4} \times 3 \times 10^{-2} \times 50 \text{ V} \\ &= 600 \text{ mV} \end{aligned}$$

Maximum induced current

$$i_0 = \frac{e_0}{R} = \frac{600}{R} \text{ mA}$$

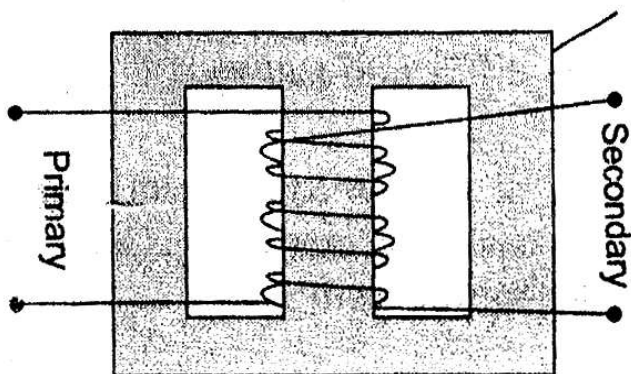
[Note 1 : If the student calculates the value of the maximum induced emf and says that “since R is not given the value of maximum induced current cannot be calculated” the $\frac{1}{2}$ mark, for the last part, of the question, can be given.]

[Note 2 : The direction of magnetic field has not been given. If the student takes this direction along the axis of rotation and hence obtains the value of induced emf and, therefore, maximum current, as zero, award full marks for this part.]

OR

- (a) Labelled diagram of a step up transformer
Derivation of ratio of secondary and primary voltage
(b) Calculation of number of turns in the secondary

(a)



[Note: Deduct $\frac{1}{2}$ mark, if labelling is not done]

- (a) When AC voltage is applied to primary coil the resulting current produces an alternating magnetic flux, which links the secondary coil.

The induced emf, in the secondary coil, having N_s turns, is

$$e_s = -N_s \frac{d\phi}{dt}$$

This flux, also induced an emf, called back emf, in the primary coil.

$$e_p = -N_p \frac{d\phi}{dt}$$

But $e_p = V_p$
 and $e_s = V_s$

$$\Rightarrow \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

For an ideal transformer

$$I_p V_p = I_s V_s$$

- Q25. (a) Distinguish between unpolarized light and linearly polarized light. How does one get linearly polarised light with the help of a polaroid?
- (b) A narrow beam of unpolarised light of intensity I_0 is incident on a polaroid P_1 . The light transmitted by it is then incident on a second polaroid P_2 with its pass axis making angle of 60° relative to the pass axis of P_1 . Find the intensity of the light transmitted by P_2 .

OR

- (a) Explain two features to distinguish between the interference pattern in Young's double slit experiment with the diffraction pattern obtained due to a single slit.
- (b) A monochromatic light of wavelength 500 nm is incident normally on a single slit of width 0.2 mm to produce a diffraction pattern. Find the angular width of the central maximum obtained on the screen.

Estimate the number of fringes obtained in Young's double slit experiment with fringe width 0.5 mm, which can be accommodated within the region of total angular spread of the central maximum due to single slit.

Ans	(a) Distinction between unpolarised and linearly polarized light	2
	Obtaining linearly polarized Light	1
	(b) Calculation of intensity of light	2

- (a) In an unpolarised light, the oscillations, of the electric field, are in random

directions, in planes perpendicular to the direction of propagation. For a polarized light, the oscillations are aligned along one particular direction.

1

Alternatively

Polarized light can be distinguished, from unpolarised light when it is allowed to pass through a Polaroid. Polaroid light does can show change in its intensity remains same in case of unpolarised light.

1

When unpolarised light wave is incident on a polaroid, then the electric vectors along the direction of its aligned molecules, get absorbed; the electric vector, oscillating along a direction perpendicular to the aligned molecules, pass through. This light is called linearly polarized light.

1

(b) According to Malus' Law:

$$I = I_0 \cos^2 \theta$$

$$I = \left(\frac{I_0}{2} \right) \cos^2 \theta, \text{ where } I_0 \text{ is the intensity of unpolarized light.}$$

$$\theta = 60^\circ \text{ (given)}$$

$$I = \frac{I_0}{2} \cos^2 60^\circ = \frac{I_0}{2} \times \left(\frac{1}{2} \right)^2 = \frac{I_0}{8}$$

OR

(a) Explanation of two features (distinguishing between interference pattern and diffraction pattern.)	2
(b) Calculation of angular width of central maxima	2
Estimation of number of fringes	1

Interference Pattern	Diffraction pattern
1. All fringes are of equal width.	1. Width of central maxima is twice the width of higher order bands.
2. Intensity of all bright bands is equal.	2. Intensity goes on decreasing for higher order of diffraction bands.

[Note: Also accept any other two correct distinguishing features.]

(b) Angular width of central maximum

$$\begin{aligned}\omega &= \frac{2\lambda}{a} \\ &= \frac{2 \times 500 \times 10^{-9}}{0.2 \times 10^{-3}} \text{ radian} \\ &= 5 \times 10^{-3} \text{ radian}\end{aligned}$$

$$\beta = \frac{\lambda D}{d}$$

Linear width of central maxima in the diffraction pattern $2XD$

$$\omega' = \frac{2\lambda D}{a}$$

Let ' n ' be the number of interference fringes which can be accommodated in the central maxima

$$\therefore n \times \beta =$$

[Award the last .5 mark if the student writes the answer as 2 (taking $d = a$), or just attempts to do these calculation.]

Q26. (i) Derive an expression for drift velocity of electrons in a conductor. Hence deduce Ohm's law.

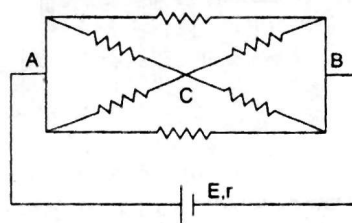
(ii) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire?

- | | |
|----------------------|---------------------|
| (a) drift speed | (b) current density |
| (c) electric current | (d) electric field |

Justify your answer.

OR

- (i) State the two Kirchhoff's laws. Explain briefly how these rules are justified.
- (ii) The current is drawn from a cell of emf E and internal resistance r connected to the network of resistors each of resistance r as shown in the figure. Obtain the expression for (i) the current drawn from the cell and (ii) the power consumed in the network.



Ans. (i) Derivation of the expression for drift velocity

Deduction of Ohm's law

(ii) Name of quantity and justification

Let an electric field E be applied the conductor. Acceleration of each electron is

$$a = \frac{eE}{m}$$

Velocity gained by the electron eE

$$v = \frac{eE}{m}t$$

Let the conductor contain n electrons per unit volume. The average value of time ' t ' between their successive collision, is the relaxation time ' τ '.

Hence average drift velocity $v_d = -\frac{eE}{m}\tau$

The amount of charge, crossing area A , in time Δt , is

$$= ne A v_d \Delta t = IZ$$

Substituting the value of v_d , we get

$$IZ = neA \left(\frac{eE}{m} \right) \tau$$

But $I = JA$, where J is the current density

$$\Rightarrow J = \left(\frac{ne^2 \tau}{m} \right) E$$

This is Ohm's law

[Note: Credit should be given if the student derives the alternative form of

Ohm's law by substituting $E = \frac{V}{l}$]

(ii) Electric current will remain constant in the wire.

All other quantities, depend on the cross sectional area of the wire.

OR

(i) Statement of Kirchhoff's laws	1+1
Justification	
(ii) Calculation of (i) current drawn and; (ii) Power consumed	

- (i) **Junction Rule:** At any Junction, the sum of currents, entering the junction, is equal to the sum of currents leaving the junction.

Loop Rule: The Algebraic sum, of changes in potential, around any closed loop involving resistors and cells, in the loop is zero. 1

$$\Sigma(\Delta V) = 0$$

Justification: The first law is in accord with the law of conservation of charge.

The Second law is in accord with the law of conservation of energy.

- (ii) Equivalent resistance of the loop

$$R = r/3$$

Hence current drawn from the cell

$$I = \frac{E}{r/3 + r} = \frac{3E}{4r}$$

Power consumed

$$P = I^2 (r/3) \\ = \frac{9E^2}{r/3 + r} = \frac{3E}{4r}$$

Power consumed

$$P = I^2 (r/3) \\ = \frac{9E^2}{16r^2} \times 4r/3 = \frac{3E^2}{4r}$$

[Note: Award the last 1½ marks for this part, if the calculations, for these parts, are done by using (any other) value of equivalent resistance obtained by the student.] 5

CBSE (DELHI) – 2018

Time – 3 hrs:

MM. – 70

General Instructions:

- (i) All questions are compulsory. There are 26 questions in all.
- (ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
- (iii) Section A contains five questions of one mark each, Section B contains five questions of two marks each, Section C contains one value based question of four marks and Section E contains three questions of five marks each.
- (iv) 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 question of five marks weightage. You have to attempt only one of the choices in such questions.
- (v) You may use the following values of physical constants wherever necessary:

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$m_0 = 40 \times 10^{-7} \text{ T mA}^{-1}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$\text{Mass of electron (} m_0 \text{)} = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{Mass of neutron} = 1.673 \times 10^{-27} \text{ kg}$$

$$\text{Mass of proton} = 1.673 \times 10^{-27} \text{ kg}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ kg}$$

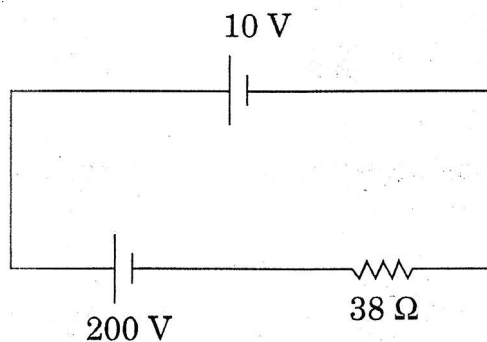
$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

SECTION-A

1. A proton and an electron travelling along parallel paths enter a region of uniform magnetic field, acting perpendicular to their paths. Which of them will move in a circular path with higher frequency ?
2. Name the electromagnetic radiations used for (a) water purification, and (b) eye surgery.
3. Draw graphs showing variation of photoelectric current with applied voltage for two incident radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity.
4. Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two — the parent or the daughter nucleus — would have higher binding energy per nucleon?

SECTION B

6. Two electric bulbs P and Q have their resistances in the ratio of 1 : 2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs.
7. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance $38\ \Omega$, as shown in the figure. Find the value of current in the circuit.

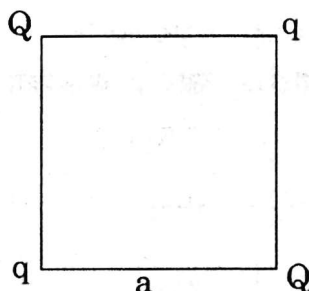


In a potentiometer arrangement for determining the emf of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of $9\ \Omega$ is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell.

8. (a) Why are infra-red waves often called heat waves ? Explain.
 (b) What do you understand by the statement, “Electromagnetic waves transport momentum”?
9. If light of wavelength 412.5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why ?

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

10. A carrier wave of peak voltage 15 V is used to transmit a message signal. Find the peak voltage of the modulating signal in order to have a modulation index of 60%.
11. Four point charges Q, q, Q and q are placed at the corners of a square side ‘ a ’ as shown in the figure.

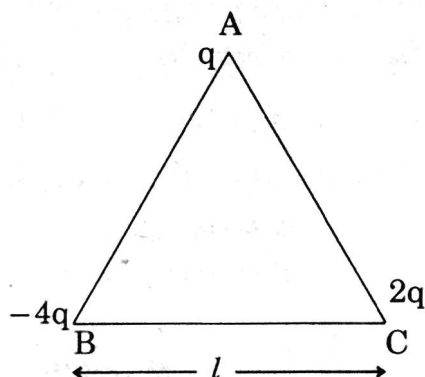


Find the

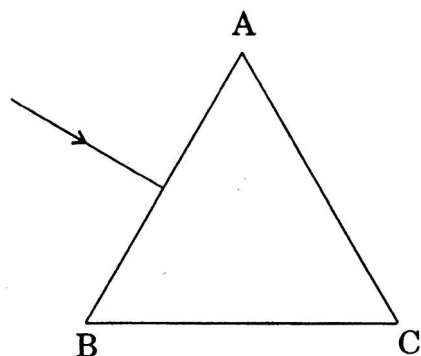
- (a) resultant electric force on a charge Q , and
 (b) potential energy of this system.

OR

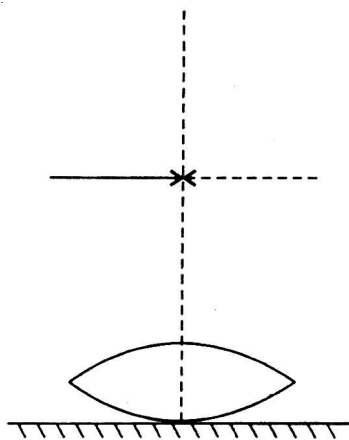
- (a) Three point charges $q, -4q$ and $2q$ are placed at the vertices of an equilateral triangle ABC of side ‘ l ’ as shown in the figure. Obtain the expression for the magnitude of the resultant electric force acting on the charge q .



- (b) Find out the amount of the work done to separate the charges at infinite distance.
12. (a) Define the term 'conductivity' of a metallic wire. Write its SI unit.
 (b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E .
13. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0.44 T . Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii).
14. (a) An iron ring of relative permeability has windings of insulated copper wire of n turns per metre. When the current in the windings is I , find the expression for the magnetic field in the ring.
 (b) The susceptibility of a magnetic material is 0.9853 . Identify the type of magnetic material. Draw the modification of the field pattern on keeping a piece of this material in a uniform magnetic field.
15. (a) Show using a proper diagram how unpolarised light can be linearly polarised by reflection from a transparent glass surface.
 (b) The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index $\frac{3}{2}$ placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face AC? Justify your answer.



16. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.
- (b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light?
17. A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x . On removing the liquid layer and repeating the experiment, the distance is found to be y . Obtain the expression for the refractive index of the liquid in terms of x and y .

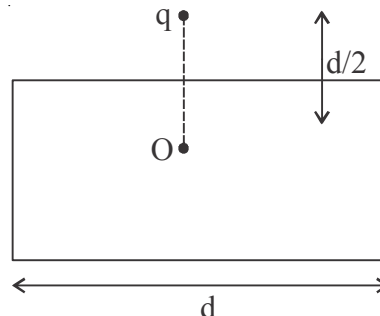


18. (a) State Bohr's postulate to define stable orbits in hydrogen atom. How does de Broglie's hypothesis explain the stability of these orbits ?
- (b) A hydrogen atom initially in the ground state absorbs a photon which excites it to the $n = 4$ level. Estimate the frequency of the photon.
19. (a) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) versus the mass number A .
- (b) A radioactive isotope has a half-life of 10 years. How long will it take for the activity to reduce to 3-125% ?
20. (a) A student wants to use two p-n junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works.

SECTION-E

24. (a) Define electric flux. Is it a scalar or a vector quantity?

A point charge q is at a distance of $d/2$ directly above the centre of a square of side d , as shown in the figure. Use Gauss' law to obtain the expression for the electric flux through the square.



- (b) If the point charge is now moved to a distance ' d ' from the centre of the square and the side of the square is doubled, explain how the electric flux will be affected.

OR

- (a) Use Gauss' law to derive the expression for the electric field (\vec{E}) due to a straight uniformly charged infinite line of charge density λ C/m.
- (b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.
- (c) Find the work done in bringing a charge q from perpendicular distance r from the line of charge.

A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current

through X is given as $I = I_0 \sin \left(\omega t + \frac{\pi}{2} \right)$.

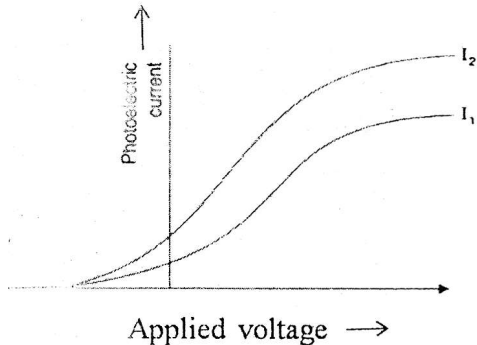
- (a) Identify the device X and write the expression for its reactance.
- (b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for X .
- (c) How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.
- (d) Draw the phasor diagram for the device X .
26. (a) Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object.
- (b) Obtain the mirror formula and write the expression for the linear magnification.
- (c) Explain two advantages of a reflecting telescope over a refracting telescope.

OR



- (a) Define a wavefront. Using Huygens' principle, verify the laws of reflection at a plane surface.
- (b) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ? Explain.
- (c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the obstacle. Explain why.

CBSE (DELHT)–2018 PHYSICS MARKING SCHEME

Q.NO.	Expected Answer/Value Points	Marks	Total Marks
1.	Electron (No explanation need to be given. If a student only writes the formula for y of charged particle (or $v_e \propto \frac{q}{m}$) award $\frac{1}{2}$ mark)	1	1
2.	(a) Ultra violet rays (b) Ultra violet rays / Laser	$\frac{1}{2}$ $\frac{1}{2}$	1
3.	 <p>(The graph I_2 corresponds to radiation of higher intensity [Note: Deduct this $\frac{1}{2}$ mark if the student does not show the two graphs starting from the same point.] (Also accept if the student just puts some indicative marks, or words, (like cross, higher intensity) -on the graph itself.</p>	$\frac{1}{2}$ $\frac{1}{2}$	1
4.	Daughter nucleus	1	1

(SECTION - B)

6. Formula

Stating that currents are equal

Ratio of powers

$$\text{Power} = I^2 R$$

(The current, in the two bulbs, is the same as they are connected in series.

$$\frac{P_1}{P_2} = \frac{I^2 R_1}{I^2 R_2} = \frac{R_1}{R_2}$$

$$= \frac{1}{2}$$

7. Writing the equation

1 mark

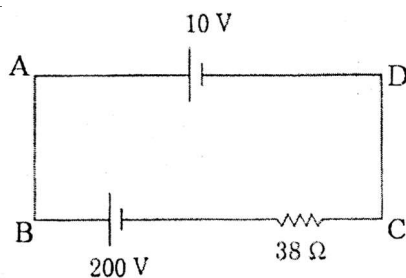
Finding the current

1 mark

By Kirchoff's law, we have, for the loop ABCD,

$$+200 - 38i - 1(0) = 0$$

$$\therefore i = \frac{190}{38} \text{ A} = 5 \text{ A}$$



Alternatively:

Finding the Net emf

1 mark

$$\text{Stating that } I = \frac{V}{R}$$

½ mark

Calculating I

½ mark

1

	<p>The two cells being in 'opposition', \therefore net $\text{emf} = (200 - 10)\text{V} = 190\text{ V}$</p> <p>Now $I = \frac{V}{R}$</p> <p>[Note: Some students may use the formulae $= \frac{\varepsilon}{r} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}$, and $r = \frac{(r_1 r_2)}{(r_1 + r_2)}$</p> <p>For two cells connected in parallel They may then say that $r = 0$; ε is indeterminate and hence I is also indeterminate Award full marks (2) to students giving this line of reasoning.</p> <p style="text-align: center;">OR</p> <p>Stating the formula Calculating r</p> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <p>(a) Reason for calling IF rays as heat rays 1 mark (b) Explanation for transport of momentum 1 mark</p> </div> <p>(a) Infrared rays are readily absorbed by the (water) molecules in most of the substances and hence increases their thermal motion. (If the student just writes that "infrared ray produce heating effects", award $\frac{1}{2}$ mark only)</p> <p>(b) Electromagnetic waves can set (and sustain) charges in motion. Hence, they are said to transport momentum. (Also accept the following: Electromagnetic waves are known to exert 'radiation pressure'. This pressure is due to the force associated with rate of change of momentum. Hence, EM waves transport momentum)</p>	1	
--	--	---	--



9.	Calculating the energy of the incident photon	1 mark
	Identifying the metals	$\frac{1}{2}$ mark
	Reason	$\frac{1}{2}$ mark

The energy of a photon of incident radiation is given by

$$E = \frac{h_c}{\lambda}$$

$$\therefore E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{(412.5 \times 10^{-9}) \times (1.6 \times 10^{-19})} \text{ eV}$$

$$\cong 3.01 \text{ eV}$$

Hence, only Na and K will show photoelectric emission

[Note: Award this $\frac{1}{2}$ mark even if the student writes the name of only one of these metals]

Reason: The energy of the incident photon is more than the work function of only these two metals.

Section C

11.

Finding the resultant force on a charge Q 2 marks
Potential Energy of the system 1 mark

- a) Let us find the force on the charge Q at the point C
Force due to the other charge Q

$$F_1 = \frac{1}{4\pi\epsilon_0} \frac{Q^2}{(a\sqrt{2})^2} = \frac{1}{4\epsilon_0} \left(\frac{Q^2}{2a^2} \right) \text{ (along AC)}$$

Force due to the charge q (at B), F_2

$$= \frac{1}{4\pi\epsilon_0} \frac{qQ}{a^2} \text{ along BC}$$

Force due to the charge q (at D), F_3

$$= \frac{1}{4\pi\epsilon_0} \frac{qQ}{a^2} \text{ along DC}$$

Resultant of these two equal forces

$$= F_{23} = \frac{1}{4\pi\epsilon_0} \frac{qQ(\sqrt{2})}{a^2} \text{ (along AC)}$$

Net force on charge Q (at point C)

$$F = F_1 + F_{23} = \frac{1}{4\pi\epsilon_0} \frac{Q}{a^2} \left[\frac{Q}{2} + \sqrt{2}q \right]$$

This force is directed along AC

(For the charge Q , at the point A, the force will have the same magnitude but will be directed along CA)

[Note : Don't deduct marks if the student does not write the direction of the net force, F]

(b) Potential energy of the system

$$= \frac{1}{4\pi\epsilon_0} \left[4 \frac{qQ}{a} + \frac{q^2}{a\sqrt{2}} + \frac{Q^2}{a\sqrt{2}} \right]$$

$$= \frac{1}{4\pi\epsilon_0\alpha} \left[4qQ + \frac{q^2}{\sqrt{2}} + \frac{Q^2}{\sqrt{2}} \right]$$

OR

(a) Finding the magnitude of the resultant force on charge q 2 marks

(b) Finding the work done 1 mark

(a) Force on charge q due to the charge -4q

$$F_1 = \frac{1}{4\pi\epsilon_0\alpha} \left(\frac{4q^2}{l^2} \right), \text{ along AB}$$

Force on the charge q, due to the charge 2q

$$F_2 = \frac{1}{4\pi\epsilon_0\alpha} \left(\frac{4q^2}{l^2} \right), \text{ along CA}$$

The forces F_1 and F_2 are inclined to each other at an angle of 120°

Hence, resultant electric force on charge q

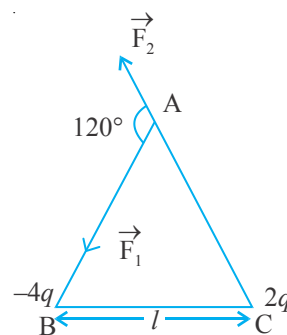
$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos \theta}$$

$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos 120^\circ}$$

$$= \sqrt{F_1^2 + F_2^2 - F_1F_2}$$

$$= \left(\frac{1}{4\pi\epsilon_0} \frac{q^2}{l^2} \right) \sqrt{16 + 4 - 8}$$

$$= \frac{1}{4\pi\epsilon_0} \left(\frac{2\sqrt{3}q^2}{l^2} \right)$$



(b) Net P.E. of the system

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q^2}{l} [-4 + 2 - 8]$$

$$= \frac{(-10) q^2}{4\pi\epsilon_0 l}$$

$$\therefore \text{Work done} = \frac{10q^2}{4\pi\epsilon_0 l} = \frac{5q^2}{2\pi\epsilon_0 l}$$

12. (a) Definition and SI unit of conductivity

$\frac{1}{2} + \frac{1}{2}$ marks

(b) Derivation of the expression for conductivity

1½ marks

Relation between current density and

electric field

$\frac{1}{2}$ mark

(a) The conductivity of a material equals the reciprocal of the resistance of its wire of unit length and unit area of cross section.

[Alternatively:

The conductivity (σ) of a material is the reciprocal of its resistivity (ρ)]

$$(\sigma = \frac{1}{\rho})$$

Its SI unit is

(b) The acceleration $\vec{a} = -\frac{e}{m} \vec{E}$

The average drift velocity, v_d , is given by

$$v_d = -\frac{eE}{m}$$

(τ = average time between collisions/
relaxation time)

If n is the number of free electrons per unit
volumes, the current I is given by

$$I = neA |vd|$$

$$= -\frac{e^2 A}{m} \tau n |E|$$

But $I = |j| A$ (j = current density)

We, therefore, get

13. (a) Formula and

Calculation of work done in the two cases

- (d) Calculation of torque in case (ii)

- (a)

$$\text{Work done} = mB (\cos\theta_1 - \cos\theta_2)$$

- (i) $\theta_1 = 60^\circ, \theta_2 = 90^\circ$

$$\therefore \text{work done} = mB (\cos 60^\circ - \cos 90^\circ)$$

$$= mB \left(\frac{1}{2} - 0 \right) = \frac{1}{2} mB$$

$$= \frac{1}{2} \times 6 \times 0.44 \text{ J} = 1.32 \text{ J}$$

- (ii) $\theta_1 = 60^\circ, \theta_2 = 180^\circ$

$$\therefore \text{work done} = mB (\cos 60^\circ - \cos 180^\circ)$$

$$= mB \left(\frac{1}{2} - (-1) \right) = \frac{3}{2} mB$$

$$= \frac{3}{2} \times 6 \times 0.44 \text{ J} = 3.96 \text{ J}$$

[Also seept calculations done through changes
in potential energy.]

(b)

$$\text{Torque} = |\vec{m} \times \vec{B}| = mB \sin\theta$$

For $\theta = 180^\circ$, we have

$$\text{Torque} = 6 \times 0.44 \sin 180^\circ = 0$$

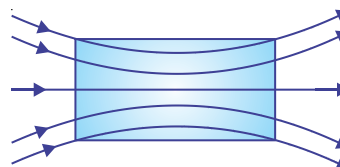
[If the student straight away writes that the torque is zero since magnetic moment and magnetic field are anti parallel in this orientation, award full 1 mark]

14. (a) Expression for Ampere's circuital law ½ mark
 Derivation of magnetic field inside the ring 1 mark
 (d) Identification of the material ½ mark
 Drawing the modification of the field pattern 1 mark
 (a) From Ampere's circuital law, we have,

$$\oint \vec{B} d\vec{l} = \mu_0 \mu_r I_{\text{enclosed}}$$

For the field inside the ring, we can write

$$\oint \vec{B} d\vec{l} = \oint B dl = B \cdot 2\pi r$$



(r = radius of the ring) using equation (i)

$$\therefore B \cdot 2\pi r = \mu_0 \mu_r \cdot (2\pi r n) I$$

$$\therefore B = \mu_0 \mu_r \cdot n I$$

[Award these $\left(\frac{1}{2} + \frac{1}{2}\right)$ marks even if the result is written without giving the derivation]

(b) The material is paramagnetic.

The field pattern gets modified as shown in the figure below.

15. (a) Diagram ½ mark
 Polarisation by reflection 1 mark,
 (b) Justification 1 mark
 Writing yes/no ½ mark

- (a) The diagram, showing polarisation by reflection is as shown. [Here the reflected and refracted rays are at right angle to each other.]

$$\therefore r = \left(\frac{\pi}{2} - i_B \right)$$

$$\therefore \mu = \left(\frac{\sin i_B}{\sin r} = \tan i_B \right)$$

Thus light gets totally polarised by reflection when it is incident at angle i_B (Brewster's angle), where $i_B = \tan^{-1} \mu$

- (b) The angle of incidence, of the ray, on striking the face AC is $i = 60^\circ$ (as from figure)
Also, relative refractive index of glass, with respect of the surrounding water, is

$$\mu_r = \frac{3/2}{4/3} = \frac{9}{8}$$

$$\text{Also } \sin i = \sin 60^\circ = \frac{\sqrt{3}}{2} = \frac{1.732}{2} \\ = 0.866$$

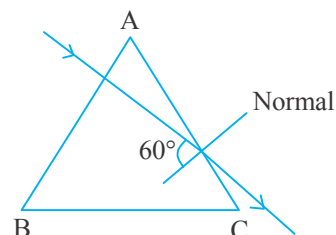
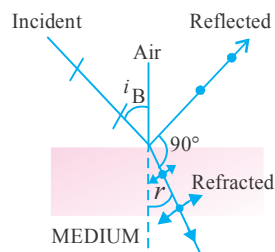
For total internal reflection, the required critical angle, in this case, is given by

$$\sin i_c = \frac{1}{\mu} = \frac{8}{9} \approx 0.89$$

$$\therefore i < i_c$$

Hence the ray would not suffer total internal reflection on striking the face AC

[The students-may just write the two conditions



needed for total internal reflection without analysis of the given case, student may be awarded ($\frac{1}{2} + \frac{1}{2}$) mark in such a case.]

16. (a) Finding the (modified) ratio of the maximum and minimum intensities

2 marks

- (b) Fringes obtained with white light 1 mark

- (a) After the introduction of the glass sheet (say, on the second slit), we have

$$\frac{I_2}{I_1} = 50\% = \frac{1}{2}$$

\therefore Ratio of the amplitudes

$$= \frac{a_2}{a_1} = \sqrt{\frac{1}{2}} = \frac{1}{\sqrt{2}}$$

- (b) The central fringe remains white.

$$\text{Hence } \frac{I_{\max}}{I_{\min}} = \left(\frac{a_1 + a_2}{a_1 - a_2} \right)^2$$

$$= \left(\frac{1 + \frac{1}{\sqrt{2}}}{1 - \frac{1}{\sqrt{2}}} \right)^2$$

$$= \left(\frac{\sqrt{2} + 1}{\sqrt{2} - 1} \right)^2$$

- (b) The central fringe remains white.

No clear fringe pattern is seen after a few (coloured) fringes on either side of the central fringe.

[Note : For part (a) of this question,



The student may

- (i) Just draw the diagram for the Young's double slit experiment.

Or (ii) Just state that the introduction of the glass sheet would introduce an additional phase difference and the position of the central fringe would shift.

For all such answers, the student may be awarded the full (2) marks for this part of this question.]

17. Lens maker's formula $\frac{1}{2}$ mark

Formula for 'combination of lenses' $\frac{1}{2}$ mark

Obtaining the expression for $\frac{1}{2}$ marks

Let μ denote the refractive index of the liquid.

When the image of the needle coincides with the lens itself; its distance from the lens, equals the relevant focal length.

With liquid layer present, the given set up, is equivalent to a combination of the given (convex) lens and a concavo plane / piano concave 'liquid lens'.

$$\text{We have } \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\text{and } \frac{1}{f} = \left(\frac{1}{f_1} + \frac{1}{f_2} \right)$$

as per the given data, we then have

$$\frac{1}{f_2} = \frac{1}{y} = (1.5 - 1) \left(\frac{1}{R} - \frac{1}{(-R)} \right)$$

$$= \frac{1}{R}$$

$$\therefore \frac{1}{x} = (\mu_l - 1) \left(-\frac{1}{R} \right) + \frac{1}{y} = \frac{-\mu_l}{y} + \frac{2}{y}$$

$$\therefore \frac{\mu_l}{x} = \frac{2}{y} - \frac{1}{y} = \left(\frac{2x - y}{xy} \right)$$

$$\text{or } \mu_l = \left(\frac{2x - y}{x} \right)$$

18. (a) Statement of Bohr's postulate ½ mark

Explanation in terms of de Broglie hypothesis

- (b) Finding the energy in the $n = 4$ level 1 mark

Estimating the frequency of the photon ½ mark

- (a) Bohr's postulate, for stable orbits, states

The electron, in an atom revolves around the nucleus only in those orbits for which its angular momentum is an integral multiple

of $\frac{h}{2\pi}$ (h = Planck's constant),”

[Also accept $mvr = n \cdot \frac{h}{2\pi}$ ($n = 1, 2, 3, \dots$)

As per de Broglie's hypothesis

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

For a stable orbit, we must have circumference

of the orbit $= n\lambda$ ($n = 1, 2, 3, \dots$)

$$\therefore 2\pi r = n \cdot \lambda$$

$$\text{or } mvr = \frac{nh}{2\pi}$$

Thus de-Broglie showed that formation of stationary pattern for integral 'n' gives rise to stability of the atom.

This is nothing but the Bohr's postulate

$$(b) \text{ Energy in the } n = 4 \text{ level} = \frac{-E_0}{4^2} = -\frac{E_0}{16}$$

\therefore Energy required to take the electron from

$$\text{the ground state, to the } n = 4 \text{ level} = \left(-\frac{E_0}{16}\right) - (-E_0)$$

$$= \frac{-1 + 16}{16}$$

$$= \frac{15}{16} E_0$$

$$= \frac{15}{16} \times 13.6 \times 1.6 \times 10^{-19} \text{ J}$$

Let the frequency of the photon be ν , we have

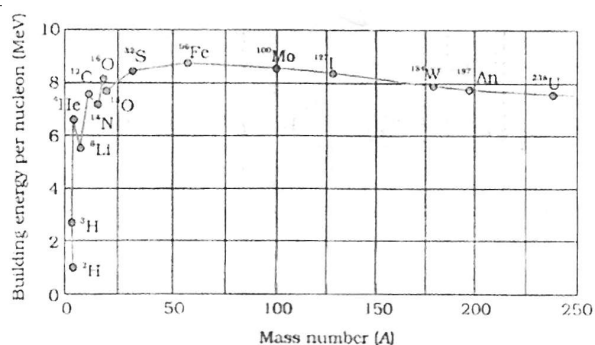
$$h\nu = \frac{15}{16} \times 13.6 \times 1.6 \times 10^{-19}$$

$$\therefore \nu = \frac{15 \times 13.6 \times 1.6 \times 10^{-19}}{16 \times 6.63 \times 10^{-34}} \text{ Hz}$$

$$= 3.1 \times 10^{15} \text{ Hz}$$

(Also accept $3 \times 10^{15} \text{ Hz}$)

19. (a) Drawing the plot 1 mark
 Explaining the process of
 Nuclear fission and Nuclear fusion $\frac{1}{2}/\frac{1}{2}$ mark
- (c) Finding the required time
- (a) The plot of (B.F / nucleon) verses mass number is as shown.



[Note: Also accept the diagram that just shows the general shape of the graph.]

From the plot we note that

- (i) During nuclear Fission

A heavy nucleus in the larger mass region ($A > 200$) breaks into two middle level nuclei, resulting in an increase in B.E/ nucleon. This results in a release of energy.

- (ii) During nuclear fusion

Light nuclei in the lower mass region ($A < 20$) fuse to form a nucleus having higher B.E/ nucleon. Hence Energy gets released.

[Alternatively: As per the plot: During nuclear Fission as well as nuclear fusion, the final value of B.E/ nucleon is more than its initial value. Hence energy gets released in both these processes.]

- (b) We have

$$3.125\% = \frac{3.125}{100} = \frac{1}{32} = \frac{1}{2^5}$$

Half life = 10 years

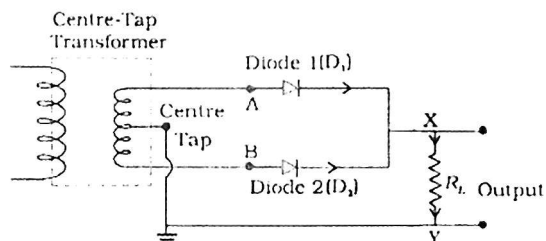
\therefore Required time = 5×10 years
= 50 Years

20. (a) Drawing the labeled circuit diagram 1 mark

Explanation of working

1 mark

(a) The labeled circuit diagram, for the required circuit is as shown.



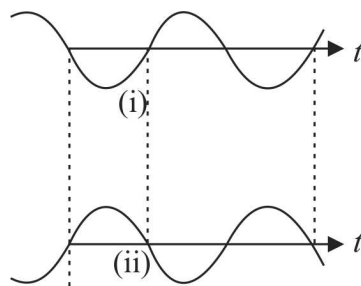
The working of this circuit is as follows:

- (i) During one half cycle(of the input ac) diode D_1 alone gets forward biased and conducts. During the other half cycle, it is D_2 (alone) that conducts.

Because of the use of the center tapped transformer the current through the load flows in the same direction in both the half cycles.

Hence we get a unidirectional/ direct current through the load, when the input is alternating current,

[Alternatively: The student may just use the following diagrams to explain the working.]



SECTION E

24. (a) Definition of electric flux 1 mark

Stating scalar/ vector ½ mark

Gauss's Theorem ½ mark

Derivation of the expression for electric flux

- (b) Explanation of change in electric flux

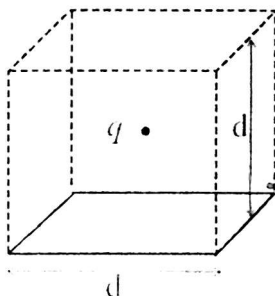
- (a) Electric flux through a given surface is defined as the dot product of electric field and area vector over that surface.

$$\text{Alternatively } \phi = \int_s \vec{E} \cdot d\vec{S}$$

Also accept

Electric flux, through a surface equals the surface integral of the electric field over that surface.

It is a scalar quantity



Constructing a cube of side 'd' so that charge 'q' gets placed within of this cube (Gaussian surface)

According to Gauss's law the Electric flux

$$\phi = \frac{\text{Charge enclosed}}{\epsilon_0}$$

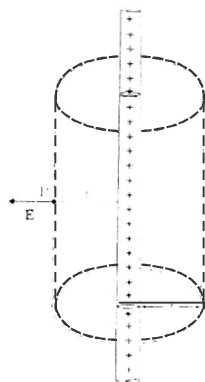
This is the total flux through all the six faces of the cube. Hence electric flux through the square

- (b) If the charge is moved to a distance d and the side of the square is doubled the cube will be constructed to have a side $2d$ but the total charge enclosed in it will remain the same. Hence the total flux through the cube and therefore the flux through the square will remain the same as before.

[Deduct 1 mark if the student just writes No change /not affected without giving any explanation.]

OR

- (a) Derivation of the expression for electric field E
 (b) Graph to show the required variation of the electric field
 (c) Calculation of work done
 (a)



To calculate the electric field, imagine a cylindrical Gaussian surface, since the field is everywhere radial, flux through two ends of the. Cylindrical Gaussian surface is zero.

= Flux through the curved cylindrical part of the surface.

$$= E \times 2\pi r l$$

Applying Gauss's Law

$$\text{Flux } \phi = \frac{q_{\text{enclosed}}}{\epsilon_0}$$

Total charge enclosed

$$= \text{Linear charge density} \times l$$

$$= \lambda l$$

$$\therefore \phi = \frac{\lambda L}{\epsilon_0} \quad \dots\dots\dots(\text{ii})$$

Using Equations (i) & ii

$$E \times 2 \pi r l = \frac{\lambda l}{\epsilon_0}$$

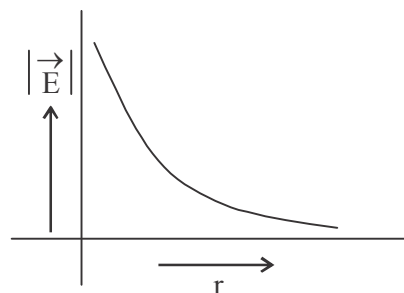
$$\Rightarrow E = \frac{\lambda}{2\pi\epsilon_0 r}$$

In vector notation

$$\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r} \hat{n}$$

(where \hat{n} is a unit vector normal to the charge)

(b) The required graph is as shown:



(a) Work done in moving the charge ' q '

Through a small displacement ' qr '.

$$dW = \vec{E} \cdot d\vec{r}$$

$$dW = q\vec{E} \cdot d\vec{r}$$

$$= qEdr\cos 0$$

$$dW = q \times \frac{\lambda}{2\pi\epsilon_0 r} dr$$

Work done in moving the given charge from r_1 to $r_2 (r_2 > r_1)$

$$W = \int_{r_1}^{r_2} dW = \int_{r_1}^{r_2} \frac{\lambda q dr}{2\pi\epsilon_0 r}$$

$$W = \frac{\lambda q}{2\pi\epsilon_0} [\log_e r_2 - \log_e r_1]$$

$$W = \frac{\lambda q}{2\pi\epsilon_0} \left[\log_e \frac{r_2}{r_1} \right]$$

26. (a) Principle of ac generator working

Labeled diagram

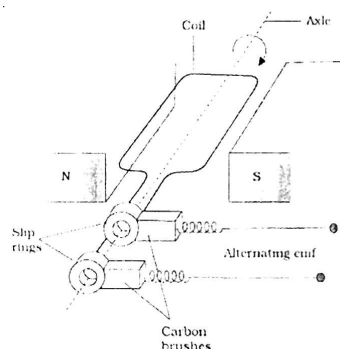
Derivation of the expression for induced emf

- (b) Calculation of potential difference

- (a) The AC Generator works on the principle of electromagnetic induction.

when the magnetic flux through a coil changes, an emf is induced in it.

As the coil rotates in magnetic field the effective area of the loop, (i.e. $A \cos \theta$) exposed to the magnetic field keeps on changing, hence magnetic flux changes and an emf is induced.



When a coil is rotated with a constant angular speed ' ω ', the angle ' θ ' between the magnetic field vector \vec{B} and the area vector \vec{A} , of the coil at any instant ' t ' equals ωt ;
(assuming $\theta = 0^\circ$ at $t = 0$)

As a result, the effective area of the coil exposed to the magnetic field changes with time ; The flux at any instant ' t ' is given by

$$\phi_B = NBA \cos \theta = NBA \cos \omega t$$

$$\therefore \text{The induced emf } e = -N \frac{d\phi}{dt}$$

$$= -NBA \frac{d}{dt}(\cos \omega t)$$

$$e = NBA \omega \sin \omega t$$

(b) Potential difference developed between the ends of the wings ' $e = Blv$

$$\begin{aligned} \text{Given Velocity } v &= 900 \text{ km/hour} \\ &= 250 \text{ m/s} \end{aligned}$$

$$\text{wing span' } (l) = 20 \text{ m}$$

Vertical component of Earth's magnetic field

$$\begin{aligned} B_v &= B_H \tan \delta \\ &= 5 \times 10^{-4} (\tan 30^\circ) \text{ tesla} \end{aligned}$$

$$\begin{aligned} \therefore \text{Potential difference} \\ &= 5 \times 10^{-4} (\tan 30^\circ) \times 20 \times 250 \end{aligned}$$

$$= \frac{5 \times 20 \times 250 \times 10^{-4}}{\sqrt{3}} \text{ V}$$

$$= 1.44 \text{ volt}$$

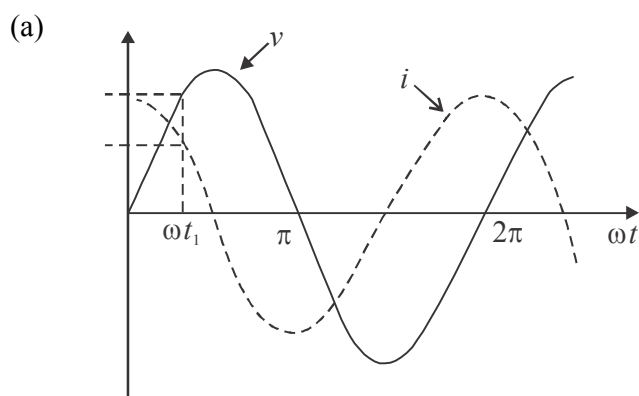


Or

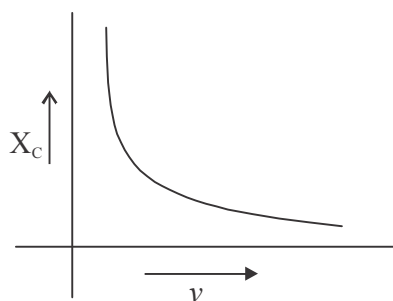
- (a) Identification of the device X
Expression for reactance
- (b) Graphs of voltage and current with time
Variation of reactance with frequency
(Graphical variation)
- (d) Phasor Diagram
- (a) X : capacitor

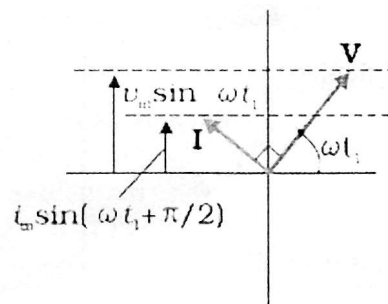
1 + 1

$$\text{Reactance } X_c = \frac{1}{\varepsilon_c} = \frac{1}{2\pi u C}$$

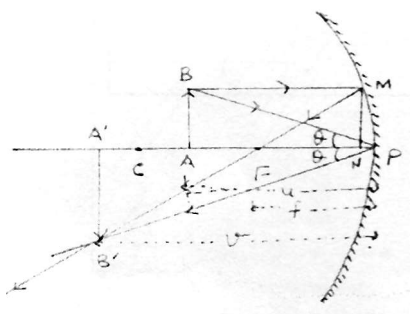


- (c) Reactance of the capacitor varies in inverse proportion to the frequency i.e., $X_c \propto \frac{1}{u}$





26. (a) Ray diagram to show the required image formation 1 mark
- (b) Derivation of mirror formula
Expression for linear magnification
- (c) Two advantages of a reflecting telescope over a refracting telescope
- (a)



- (b) In the above figure
 ΔBAP and $\Delta B'A'P$ are similar

$$\Rightarrow \frac{BA}{B'A'} = \frac{NF}{NF'}$$

Similarly, ΔMNF and $\Delta B'A'P$ are similar

For the given figure, as per the sign convention,

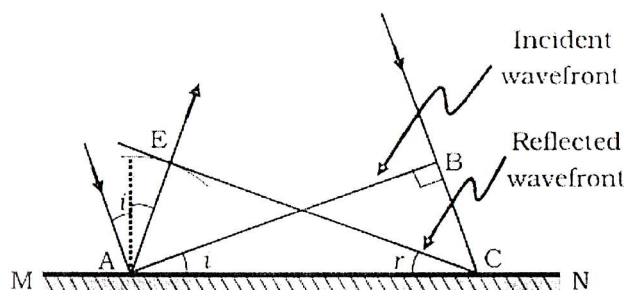
- (b) Advantages of reflecting telescope over refracting telescope
- (i) Mechanical support is easier
- (ii) Magnifying power is large

- (iii) Resolving power is large
- (iv) Spherical aberration is reduced
- (v) Free from chromatic aberration (any two)

OR

- (a) Definition of wave front
Verification of laws of reflection
- (b) Explanation of laws of reflection central maxima
- (c) Explanation of the bright spot in the shadow of the obstacle

- (a) The wave front may be defined as a surface of constant phase.
(Alternatively: The wave front is the loci of all points that are in the same phase)



Let speed of the wave in the medium be ' u '

Let the time taken by the wave front, to advance from point B to point C is ' τ '

Let CE represent the reflected wave front

Distance $AE = u\tau = BC$

$\triangle AEC$ and $\triangle ABC$ are congruent

$\angle BAC = \angle ECA$

$\Rightarrow \angle i = \angle r$

- (b) Size of central maxima reduces to half,

(Size of central maxima =)

Intensity increases,

This is because the amount of light, entering the slit, has increased and the area, over which it falls, decreases.

(Also accept if the student just writes that the intensity becomes four fold)

(c) This is because of diffraction of light.

Light gets diffracted by the tiny circular obstacle and reaches the centre of the shadow of the obstacle.

[Alternatively:

There is as a maxima, at the centre of the obstacle, in the diffraction pattern produced by it.]



Sample Question Paper
Class XII –Physics
(Applicable for March 2019 Examination)

Time Allowed: 3 Hours

Maximum Marks: 70

General Instructions

1. All questions are compulsory. There are 27 questions in all.
2. This question paper has four sections: Section A, Section B, Section C and Section D
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, 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.

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m}^{-2}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}_2\text{N}^{-1}\text{m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{mass of neutron} = 1.675 \times 10^{-27} \text{ kg}$$

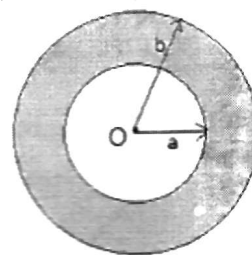
$$\text{mass of proton} = 1.673 \times 10^{-27} \text{ kg}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$

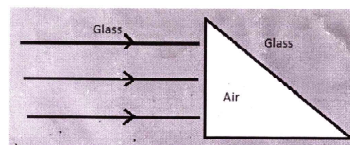
$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

Section A

- 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)

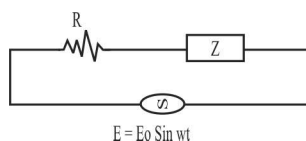


- Give an example of a material each for which temperature coefficient of resistivity is (i) positive, (ii) negative.
- State the factors on which the refractive index of a material medium for a given wavelength depends.
- Sketch the emergent wavefront.
- In the wave picture of light, intensity of light is determined by square of the amplitude of wave. What determines the intensity of light in the photon picture of light?

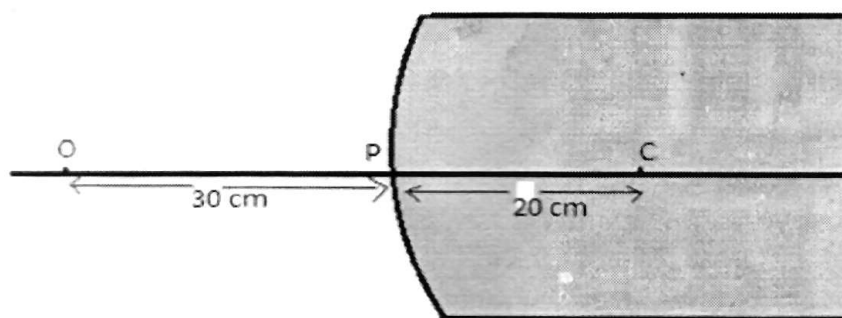


Section B

- (a) An alternating voltage $E = E_0 \sin \omega t$ 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 $I = I_0 \sin (\omega t + \pi/4)$.



- State whether the element in the black box is a capacitor or inductor.
 - Draw the corresponding phasor diagram and find the impedance in terms of R .
- The magnetic field in a plane electromagnetic wave is given by: $B_y = 12 \times 10^{-8} \sin (1.20 \times 10^7 z + 3.60 \times 10^{15} t)$ T. Calculate the
 - Energy density associated with the Electromagnetic wave
 - Speed. of the wave
 - A spherical convex surface of radius of curvature 20 cm, made of glass ($\mu = 1.5$) 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.



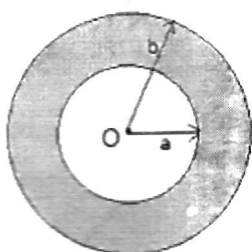
9. Name the optoelectronic device used for detecting optical signals and mention the biasing in which it is operated. Draw its I- V characteristics.
11. A monochromatic light source of power 5mW emits 8×10^{13} photons per second. This light ejects photoelectrons from a metal surface. The stopping potential for this set up is 2V. Calculate the work function of the metal. (2)
12. The following table shows some measurements of the decay rate of a radionuclide sample. Find the disintegration constant. (2)

Time (min)	$\ln R(\text{Bq})$
36	5.08
100	3.29
164	1.52
218	1.00

Section C

13. (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?

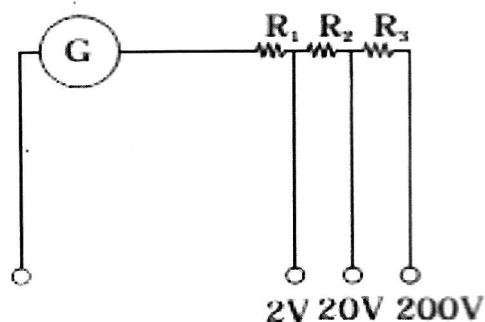
14. A point charge $+Q$ is placed at the centre O of an uncharged hollow spherical conductor of inner radius ' a ' and outer radius ' b '. Find the following:
- The magnitude and sign of the charge induced on the inner and outer surface of the conducting shell.
 - The magnitude of electric field vector at a distance (i) $r = \frac{a}{2}$, and (ii) $r = 2b$, from the centre of the shell.



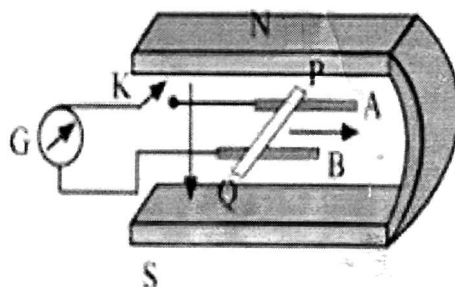
15. The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following:
- The magnitude of the electric field within them,
 - The drift speed of electrons through them, and
 - The current density within them.

Wire no.	Length	Diameter	Potential Difference
1	L	$3d$	V
2	$2L$	d	V
3	$3L$	$2d$	$2V$

16. 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 R_1 , R_2 and R_3 that have to be used.



17. 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 .
- 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.
 - 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.
 - What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?

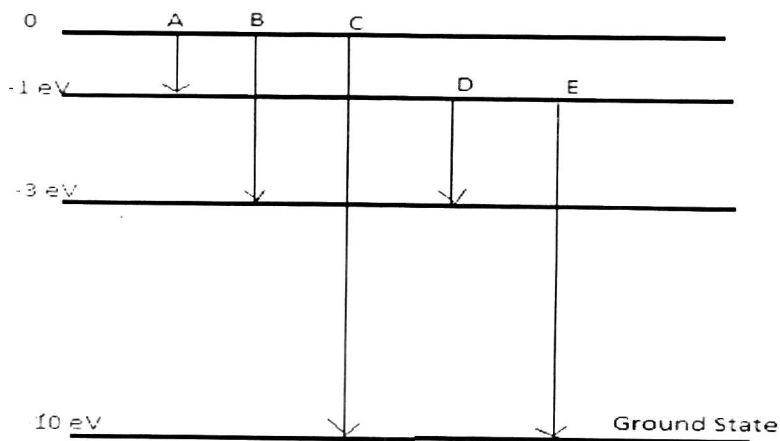


18. With the help of a diagram, explain the principle of a device which changes a low voltage into a high voltage but does not violate the law of conservation of energy. Give any one reason why the device may not be 100% efficient.

19. 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?
20. What do you understand by the statement 'Light from the sun is unpolarised'. Explain how does sunlight gets polarized by the process of scattering?
21. 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.

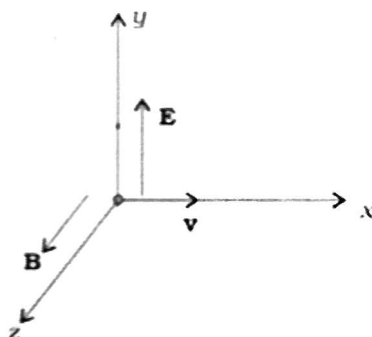
OR

- (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?

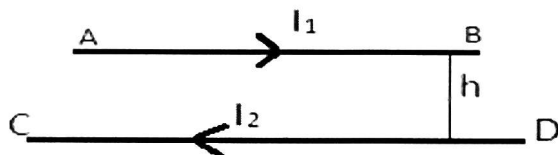


23. The energy levels of an atom of element X are shown in the diagram. Which one of the level transitions will result in the emission of photons of wavelength 620 nm? Support your answer with mathematical calculations.
24. Draw a graph showing the variation of binding energy per nucleon versus the mass number A. Explain with the help of this graph, the release of energy in the process of nuclear fission and fusion.

25. 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.
25. (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 T and mass ' m ' carries a steady current I_1 ; free to move in vertical plane is in equilibrium at a height of ' h ' over another parallel long wire CD carrying a steady current I_2 , 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.



- (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 (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.

26. (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?



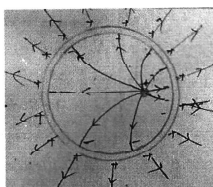
Class XII Physics
Sample Question Paper
(Applicable of March 2019 Examination)
(Marking Scheme)

Time Allowed : 3 Hours

Maximum Marks : 70

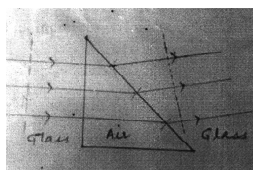
Section A

1. Inside
Outside



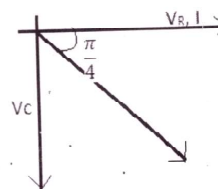
2. (i) Cu (metals, alloys)
(ii) Si (semiconductor)
3. Factors are:
(i) Magnetic permeability of the medium
(ii) Electric permittivity of the medium

4. Diagram



5. In photon picture, intensity is determined by the number of photons crossing per unit time.

6. As the current leads the voltage by $\frac{\pi}{4}$, the element used in black box is a 'capacitor'. ($1/2$)
(ii) Phasor diagram



7. (i) Energy density $\mu = \frac{B^2}{\mu_0}$,

(ii) Speed = $\frac{\omega}{k}$

speed = 3×10^8 m/s.

8. correct sign convention
 $1.0/v - 1.5/-30 = (1.0 - 1.5) / 20$
 $v = -13.3 \text{ cm}$
9. Photodiode ($\frac{1}{2}$) Reverse biasing ($\frac{1}{2}$)
 I-V characteristics NCERT page no. 487. (1)
11. $P = 5 \times 10^{-3} \text{ W}$
 $E = \frac{P}{n} = 6.25 \times 10^{-19} \text{ J}$ ($\frac{1}{2}$)
 $E = 3.9 \text{ eV}$ ($\frac{1}{2}$)
 $W_0 = E - eV_0$ ($\frac{1}{2}$)
 $= (3.9 - 2) \text{ eV}_0$
 $W_0 = 1.9 \text{ eV}.$ ($\frac{1}{2}$)
12. $R = R_0 e^{-\lambda t}$
 $\ln R = \ln R_0 - \lambda t$ ($\frac{1}{2}$)
 $\ln R = -\lambda t + \ln R_0$
 slope of $\ln R$ v/s. t is ' $-\lambda$ ' ($\frac{1}{2}$)
 $-\lambda = \frac{0 - 1.52}{210 - 254}$ ($\frac{1}{2}$)
 $-\lambda = 0.038 \text{ min ute}^{-1}$ ($\frac{1}{2}$)
13. (a) $C = 5 \times 10^{-9} \text{ F}$, $U = 25 \text{ J}$
 $U = Q^2/2C$ ($\frac{1}{2}$)
 $Q^2 = 2 U C = 2 \times 25 \times 5 \times 10^{-9}$
 $Q = 5 \times 10^{-4} \text{ C}$ ($\frac{1}{2}$)
 $Q = n e$ ($\frac{1}{2}$)
 $n = \frac{Q}{e} = 3.125 \times 10^{15} \text{ electrons}.$ ($\frac{1}{2}$)



- (b) Without changing charge on the plates, we can make C half. $C = \frac{\epsilon_0 A}{d}$, i.e. double the plate separation or inserting dielectric of dielectric of a value such that C becomes. (1)
14. (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, (1)
 Expression for electric field for radius, (1)
15. (i) $E_1 = \frac{V}{L}$, $E_2 = \frac{V}{2L}$, $E_3 = \frac{2V}{3L}$ (½)
 $E_2 < E_3 < E_1$ (½)
- (ii) $V_d \propto E$ (½)
 $V_{d2} < V_{d3} < V_{d1}$ (½)
- (iii) $I = nAe V_d / J = \sigma E$ (½)
 $J = n e V_d$
 $J_2 < J_3 < J_1$. (½)
16. NCERT Exemplar Q4.21 R1, R2, R3 (each 1 mark)
17. NCERT pg no. 301 Q6.14 (1 mark each part)
18. 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. $IPVP = IsVs$ (½)
19. $\beta = \lambda.D/d$ (½)
 $5^{th} \text{ bright} = 5\beta_1 = 5\lambda D/d = 5 \times 480 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 16 \times 10^{-4} \text{ m}$ (1)
 $5^{th} \text{ bright} = 5\beta_2 = 5\lambda D/d = 5 \times 600 \times 10^{-9} \times 2 / 3 \times 10^{-3} = 20 \times 10^{-4} \text{ m}$ (1)
 distance between two 5th bright fringes = $(20 - 16) \times 10^{-4} = 4 \times 10^{-4} \text{ m}$ (½)

20. '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)

21. (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:

$$K = eV \quad (½)$$

$$K = \frac{p^2}{2m}, \quad p = \sqrt{(2mk)}$$

(ii) $p = \sqrt{(2meV)}$

the de- Broglie wavelength λ of the electron is :

$$\lambda = \frac{h}{p}$$

For same KE, $\lambda \propto \frac{1}{\sqrt{m}}$

- (ii) For same KE, $\lambda \propto \frac{1}{\sqrt{m}}$

As mass of proton is greater than that of electron, $\therefore \lambda_p < \lambda_e$. (½)

22. $E = hc / \lambda = 6.6 \times 10^{-34} \times 3 \times 10^8 / 620 \times 10^{-9}$ (1)

$= 3.2 \times 10^{-19} \text{ J}$ (½)

$= 3.2 \times 10^{-19} / 1.6 \times 10^{-19} = 2 \text{ eV}$ (½)

This corresponds to the-transition "D" (1)

23. NCERT figure 13.1 on page no. 444 (1)

Fission (1), Fusion (1)

24. (i) Modulation Index $= A_m / A_c = 20/40 = 0.5$ (½ + ½)

The side bands are. (2000 + 20) KHz

$= 2020 \text{ KHz and } (2000 - 20) \text{ KHz}$

$$= 1980 \text{ KHz} \quad (\frac{1}{2} + \frac{1}{2})$$

Amplitude versus ω for amplitude modulated signal: page number 525 NCERT
part (ii) Figure 15.9, $A_c = 40$ volts, $\mu A_c/2 = 10$ volts. (1)

25. (a) Condition $qE = qvB$ (1/2)

$$v = \frac{E}{B}$$

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

$$\frac{Fm}{l} = \frac{\mu_0 I_1 I_2}{2\pi h}, \text{ upwards on wire AB(2)}$$

At equilibrium Magnetic Force per unit length = mass per unit length $\times g$

$$\frac{\mu_0 I_1 I_2}{2\pi h} = \frac{m}{l} g(1)$$

OR

(a) Using the condition $mvr = \frac{nh}{2\pi}$ (1/2)

$$\text{For H-atom } n = I, V = \frac{h}{2\pi mr}$$

$$\text{Time period } T = \frac{2\pi r}{v}$$

$$\therefore T = \frac{4\pi^2 mr^2}{h}, I = \frac{Q}{T} = \frac{eh}{4\pi^2 mr^2} \quad (1/2)$$

$$M = IA \quad (1/2)$$

$$M = \left(\frac{eh}{4\pi^2 mr^2} \right) (\pi r^2) \quad (1)$$

$$M = \frac{eh}{4\pi m} \quad (1/2)$$

(b) Diagram for magnetic field lines Cu-diamagnetic (1)

Al- Paramagnetic (1)

Fe- Ferromagnetic (1)

26. (a) Diagram (2) + labelling (1/2)

(b) $m_e = 1 + 25/5 = 6$ (1/2)

$m_0 = 30 / m_e = 5$ (1/2)

$m_0 = v_0 / -u_0 v_0 = -5 u_0$

$1/f_0 = 1/v_0 - 1/u_0 f_0 = -(5/6) u_0$ (1/2)

$u_0 = 1.5 \text{ cm} , v_0 = 7.5 \text{ cm}$

$u_e = -4.17 \text{ cm}$ (1/2)

Length of the tube $= u_e + v_0 = 11.67 \text{ cm}$ (1/2)

OR

(a) Diagram (2) + labelling (1/2)

(b) $m = -f_0/f_e$ (1/2)

$f_0 = 5f_e$ (1/2)

$L = f_0 + f_e$ (1/2)

$f_e = 36/6 = 6 \text{ cm}$ (1/2)

$f_0 = 30 \text{ cm}$ (1/2)

27. (a) circuit diagram (1)

OR

Diagram (1 1/2)



Practice Paper

Class XII –Physics

Time Allowed: 3 Hours

Maximum Marks: 70

General Instructions

- (i) All questions are compulsory. There are 37 questions in all.
- (ii) This question paper has four sections A, B, C and D.
- (iii) Section A contains '20' questions of '1' mark each,
Section B contains '7' questions of '2' marks each,
Section C contains '7' questions of '3' marks each,
Section D contains '3' questions of '5' marks each,
- (iv) There is no overall choice. However internal choice is provided in some questions of each section.
- (v) You may use the following values of physical constants wherever necessary.

$$C = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ JS}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T mA}^{-1}$$

$$E_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

$$\text{mass of electron} = 9.1 \times 10^{-31} \text{ Kg}$$

$$\text{mass of Neutron} = 1.675 \times 10^{-27} \text{ Kg}$$

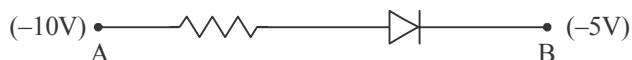
$$\text{mass of proton} = 1.673 \times 10^{-27} \text{ Kg}$$

$$\text{Avagadro's number} = 6.023 \times 10^{23} \text{ per gram mole.}$$

$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

Section : A

1. How does the energy of dipole change when it is rotated from unstable equilibrium to stable equilibrium in uniform Electric field?
2. The vertical component of Earth's magnetic field at a place is $\sqrt{3}$ times the horizontal component, what is the value of dip at that place?
3. Name the type of biasing used in diode in the following circuit diagram



4. What is the ratio of radii of the orbits corresponding to first excited state and ground state of hydrogen atom?
5. Arrange the following e.m. waves in descending order of wavelength.
(Gamma (γ ray), UV radiation, microwaves)

Or

Name the two physical quantities which are imparted by an em wave to a surface on which it falls.

6. The power factor of an a.c. circuit is 0.5. What will be the phase difference between voltage and current in this circuit?
7. What is the function of radial magnetic field in moving coil galvanometer?
8. Draw the electric field versus distance for a spherical shell of radius R and charge $Q > 0$ from centre to the $r > R$.

Or

What is the work done in moving a test charge 'q' through a distance of 1 cm along the equatorial axis of an electric dipole?

9. What is Doping in semiconductors?

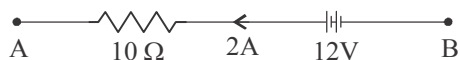
Or

Write one use of photodiode.

10. In a single slit diffraction experiment the width of slit is reduced to half of its original width. How does it affect the size of central maxima?



11. The number of turns of a solenoid is doubled keeping the other factors constant. How does the self inductance of the solenoid change?
12. A proton and an alpha particle has same de-Broglie wavelength. What will be the ratio of kinetic energies of the two.
13. In the following figure, what is the potential difference between A and B?



14. How does the angle of minimum deviation of a glass prism of refractive index 1.5 change. If it is immersed in a liquid of refractive index of 1.3?

Or

If a ray of light propagates from rare to denser medium, how does its frequency and wavelength change.

15. Name the radiations used for detecting fake currency notes?
16. Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same distance apart in air?
17. Under what condition on electron will move undeflected in the presence of crossed electric and magnetic fields?

Or

Write any two uses of eddy current.

18. A point charge $Q > 0$ is placed at 'O' as shown in Fig. what will be the value of $V_A - V_B$.



19. You are required to select a carbon resistor of resistance $47\text{ K}\Omega \pm 10\%$ from a large collection. What should be the sequence of color bands used to code it.
20. Which optical phenomenon is responsible for sparkling of diamond?

Section B

21. State Gauss's theorem in Electrostatics. A charge of $17.7 \times 10^{-4}\text{C}$ is distributed over a large sheet of area 200 m^2 . Calculate the electric field intensity at a distance 20 cm from it in air.
22. What is induced e.m.f.? Write Faraday's law of electromagnetic induction. Express it mathematically.

Or

A metallic rod of length ' l ' is rotated with angular frequency of ' ω ' with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius ' l ' about an axis passing through its centre and perpendicular to the plane of ring. A constant and uniform magnetic field ' B ' parallel to the axis is present everywhere. Deduce an expression for the emf between the centre and the metallic ring.

23. (a) Why do welders wear special glass goggles?
(b) Ultraviolet rays are used in LASIK eye surgery. Why?
24. Using Bohr's quantisation condition, show that the circumference of the electron orbit in n th orbital state in hydrogen atom is n times the de-Broglie wavelength associated with it.
25. Name the device which is used as a voltage regulator. Draw the necessary circuit diagram and explain its working.
26. A galvanometer needs 50 mV for full scale deflection of 50 divisions. Find its voltage sensitivity. What must be the galvanometer resistance if its current sensitivity is 1 Div/A .
27. The value of ground state energy of hydrogen atom is -13.6 eV .
(a) What does the negative sign signify?
(b) How much energy is required to take the electron from ground state to first excited state.

Or



Show that Nuclear density of a nucleus is independent of its mass number.

Section C

28. (a) Derive an expression for the work done in rotating an electric dipole of dipole moment p in a uniform electric field 'E' from an orientation θ_1 to θ_2 .
(b) Show that potential at a point on equatorial line of an electric dipole is zero.

Or

- (a) Obtain an expression for the energy stored in a parallel plate capacitor.
(b) A battery of 10 V is connected to a capacitor of 0.1 F. The battery is now removed and the capacitor is then connected to a second uncharged capacitor of same capacitance. Calculate the total energy stored in the system.
29. (a) What do you understand by power of a lens. Define its unit.
(b) A convex lens of focal length 25 cm is placed coaxially in contact with a concave lens of focal length 20 cm.

Determine the power and Nature of Combination.

30. On the basis of Energy band diagrams distinguish between conductors, insulators and semiconductors.
31. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work function W_1 and W_2 ($W_1 > W_2$). On what factors does the (i) slope (ii) intercept of lines depend?
32. (a) Define magnetic dipole moment. Give its S.I. unit.
(b) A circular coil of N turns and radius R carries a current I . It is unwound and rewound to make a square coil of side a having same number of turns N . Keeping the current I same, find the ratio of the magnetic moments of a square and circular coil?
33. Using Huygen's principle, prove Snell's law of refraction of a plane wave propagating from rarer to denser medium.

Or

- (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 the ray is travelling from a rarer to denser medium.
 - (b) Using this diagram, derive a relation between object distance range distance and radius of curvature of convex spherical surface.
34. (a) Write a relation between mean life and half life of a radioactive sample.
- (b) A radioactive sample contains 2.2 mg of pure ^{11}C which has half life period of 1224 seconds calculate:
- (i) No. of atoms present initially.
 - (ii) The activity when 5 μg of the sample will be left.

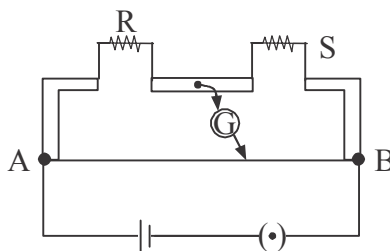
SECTION D

35. (a) Derive the relation between current density ' \vec{j} ' and potential difference V across a current carrying conductor of length ' l ', area of cross section ' A ' and the number density ' n ' of free electrons.
- (b) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area $1.0 \times 10^{-7} \text{ m}^2$ carrying a current of 1.5 A. The no. density of conduction electrons is $9 \times 10^{28} \text{ m}^{-3}$.

Or

- (a) State the principle of working of a metre bridge.
- (b) Which material is used for metre bridge wire and why.
- (c) In a metre bridge shown in diagram, the null point is found 60 cm from end A. If now a resistance of 5Ω is connected in series with S. The null point is at 50 cm. Determine the value of R and S.





36. (a) With the help of a labelled diagram, describe briefly the underlying principle and working of a step up transformer.
- (b) Write any two sources of energy loss in a transformer.
- (c) A step up transformer converts a low input voltage into a high voltage output. Is law of conservation of energy valid explain.

Or

- (a) A voltage $V = V_m \sin \omega t$ is applied to a series LCR circuit. Derive an expression for the average power dissipated over a cycle.
- (b) Under what condition (i) no power is dissipated even though the current flows through the circuit (ii) maximum power is dissipated in the circuit.
37. (a) In Young's double slit experiment, derive the condition for constructive interference and (ii) destructive interference at a point on the screen.
- (b) A beam of light consisting of two wavelengths 800 nm and 600 nm is used to obtain the interference fringes in a YDSE on a screen 1.4 m away. If the two slits are separated by 0.28 mm. Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

Or

- (a) Explain with the help of a suitable ray diagram how an unpolarised light can be polarised by reflection from a transparent medium. Deduce the necessary condition for it.
- (b) The refractive index of a medium is $\sqrt{3}$. What is the angle of refraction, if the unpolarised light is incident on it at the polarising angle of the medium.

SOLUTIONS

1. $\Delta u = PE (\cos 180^\circ - \cos 0^\circ) = -2PE$

2. $\tan \delta = \frac{V}{H} = \sqrt{3}$

$\Rightarrow \delta = \tan^{-1} \sqrt{3}$

$\therefore \delta = 60^\circ$

3. As p is connected to move negative

\therefore Diode is R.B.

4. $r \propto n^2$

$\therefore \frac{r_1}{r_0} = \frac{2^2}{1^2} = \frac{4}{1}$

5. Microwaves, UV radiation, Gamma rays

Or

Energy and pressure.

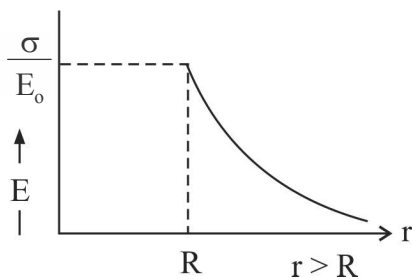
6. $\cos \phi = 0.5$

$\Rightarrow \phi = \cos^{-1} \frac{1}{2}$

$\Rightarrow \phi = 60^\circ$

7. It provide strong magnetic field so that torque actual on coil is max. *i.e.*, NIAB.

8. Zero as $V_{\text{(equitional)}} = 0$



9. Process of adding impurity in pure semiconductor in a controlled and small quantity.

Or

Detection of optical signal.

10. Double as $b \propto \frac{1}{d}$

11. $L \propto n^2$ \therefore Four times

12. $\lambda = \frac{h}{\sqrt{2mE}}$ $\therefore \frac{K.E_p}{K.E_\alpha} = \frac{m_2}{m_p} = \frac{4}{1}$

13. $V_A - V_B = -20 + 12 = -8 \text{ V}$

14. $\mu_{ge} = \frac{1.5}{1.3} = 1.15$ as μ decreases so δ_m decreases

Or

Frequency same, wavelength decreases.

15. UV radiation

16. $K = \frac{F_o}{F_m} \Rightarrow F_o = KF = 81 F$

or $K = 81, F_m = F$

17. $v = \frac{E}{B}$ Or Furnace, magnetic brakes or any other

18. $V_A - V_B = \text{positive}$ as $v \propto \frac{1}{r}$

19. Yellow, violet, orange, silver.

20. Total internal reflection.

21. Total electric flux over a closed surface in a free space is $\frac{1}{E_0}$ times the net charge enclosed within the surface.

$$\sigma = \frac{Q}{A} = \frac{17.7 \times 10^{-4}}{200} = 8.85 \times 10^{-6} \text{ cm}^{-2}$$

$$E = \frac{\sigma}{2E_0} = \frac{8.85 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}} = 0.5 \times 10^6 \text{ NC}^{-1}$$

22. The emf developed in a circuit when the flux linked with that circuit changes is called induced emf.

Whenever a magnetic flux linked with the circuit. Changes on e.m.f. is induced in the circuit which is equal to the rate of change of magnetic flux and lasts as long as the change continues

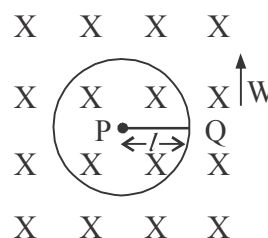
$$e = -\frac{d\phi_B}{dt}$$

Or

$$|e| = \frac{d\phi_B}{dt} = B \frac{dA}{dt}$$

$$= B \frac{\pi l^2}{T}$$

$$|e| = B \frac{\pi l^2}{2\pi/\omega} = \frac{1}{2} B \omega l^2$$



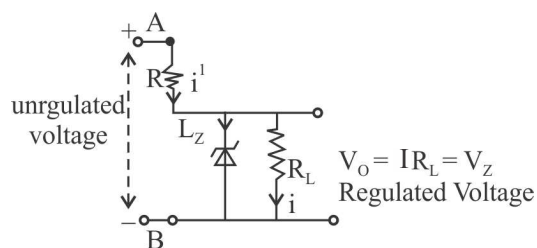
23. (a) To protect their eyes from harmful UV radiation produced by welding.
 (b) Because to its shorter wavelength there can be focussed into very narrow beams.

24. $mvr = \frac{nh}{2\pi}$ (Bohr quantisation condition)

$$\therefore 2\pi r = \frac{nh}{mv}$$

$$2\pi r = n\lambda_e \quad \left[\lambda_e = \frac{h}{mV} \right]$$

25. Zener diode



Working : If the input voltage decreases, current I and i_z decreases. The potential drop across R decreases without any change in potential across zener diode as above v_z the potential across zener diode is constant whatever the current is. Hence we get a regulated voltage in output.

$$26. \quad V_S = \frac{\theta}{V} = \frac{50}{50 \times 10^{-3}} = 10^3 \text{ div/V}$$

$$\text{as} \quad V_S = \frac{\text{Current sensitivity}(I_S)}{R}$$

$$\therefore \quad R = \frac{I_S}{V_S} = \frac{1}{10^3} = 10^{-3} \Omega.$$

27. (a) That the electron is bound to the nucleus or the force between electron and nucleus of atom is attractive.

$$E = -\frac{13.6}{n^2}$$

$$\therefore \quad \text{Energy of first excited state} = \frac{-13.6}{2^2} = -3.4 \text{ eV}$$

$$\therefore \quad \Delta E = E_2 - E_1 = -3.4 - (-13.6) = 10.2 \text{ eV.}$$

Or

$$R = R_0 A^{1/3} \dots (1)$$

$$\text{Density of nucleus} = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$$

$$= \frac{A \cdot u}{\frac{4}{3}\pi R^3} = \frac{3Au}{4\pi R_0^3 A} \quad [\text{From eqn. (1)}]$$

where $[u = 1.66 \times 10^{-27}] \text{ kg}$ and $R_0 = 1.2 f_m$

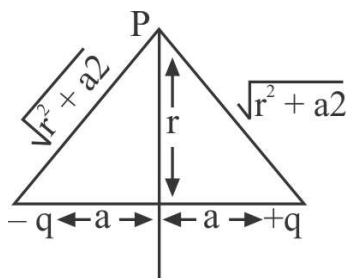
$$\therefore \quad \text{Density of nucleus} = \frac{3u}{4\pi R_0^3} = \text{constant}$$

$$\begin{aligned} 28. \quad (a) \quad W &= \int_{\theta_1}^{\theta_2} \tau d\theta \\ &= \int_{\theta_1}^{\theta_2} PE \sin\theta d\theta \quad [\text{As } \vec{\tau} = \vec{P} \times \vec{E}] \\ &= PE[-\cos\theta]_{\theta_1}^{\theta_2} \end{aligned}$$

$$W = -PE[\cos \theta_2 - \cos \theta_1]$$

$$V = V_{-q} + V_{+q}$$

$$= \frac{-q}{4\pi\epsilon_0\sqrt{r^2 + q^2}} + \frac{q}{4\pi\epsilon_0\sqrt{r^2 + q^2}} = 0$$



Or

$$(b) \quad U = W = \int_0^Q V dq$$

$$= \frac{1}{C} \int_0^Q q dq \quad \left[V = \frac{q}{C} \right]$$

$$= \frac{1}{C} \left[\frac{q^2}{2} \right]_0^Q$$

$$U = \frac{Q^2}{2C}$$

$$\text{or} \quad U = \frac{1}{2} CV^2 = \frac{1}{2} QV \quad [Q = CV]$$

$$(b) \quad V_1 = 10 \text{ V}, V_2 = 0, C_1 = C_2 = 0.1 \text{ F}$$

$$\text{Common potential} \quad V = \frac{C_1 V_1 + C_2 V_2}{C_1 + C_2}$$

$$= \frac{0.1 \times 10 + 0.1 \times 0}{0.1 + 0.1} = 5 \text{ V}$$

$$\therefore \text{ Total energy stored } U = \frac{1}{2} (C_1 + C_2) V^2 = \frac{1}{2} (0.1 + 0.1) \times 5^2$$

$$= 2.5 \text{ J}$$

29. (a) The degree of convergence and divergence of a ray is mathematically $P =$

$\frac{1}{f}$ where ' f ' is measured in metre

$$(b) \quad P_1 = \frac{100}{25} = +4D$$

$$P_2 = \frac{100}{-20} = -5D$$

$$P = P_1 + P_2 = (4 - 5)D = -1D$$

Nature of combination is concave (Diverging)

30. Fig.

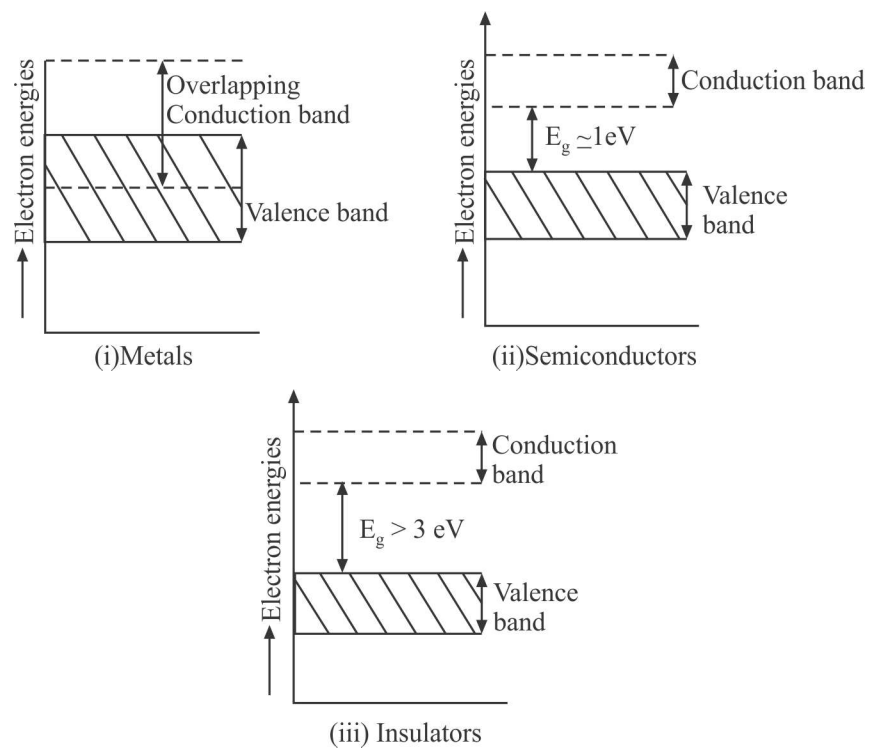
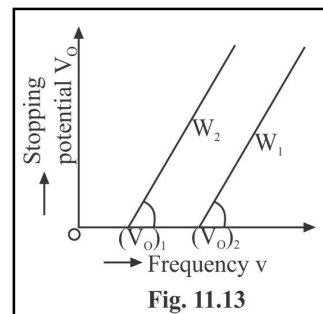


Fig. 14.60

31. A graph showing the variation of stopping potential V_0 with the frequency ν of incident radiation for two different photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$) have been shown. The graph are straight lines as shown.



- (i) Slope of the $V_0 - \nu$ lines is same for both

materials and has a value $\frac{h}{e}$, where $h =$

Planck's constant and $e =$ electron charge.

- (ii) Intercept of $V_0 - \nu$ line along ν -axis depends on the work function or the

threshold frequency ν_0 of the photosensitive material where $\nu_0 = \frac{W}{h}$.

32. (a) The magnetic moment of a given coil of 'N' no. of turns, A = Area of cross section and carrying a current I is defined as

$$m = NIA \text{ unit} = \text{Am}^2$$

- (b) Magnetic moment of circular coil of N turns and radius R carrying a current I

$$m_1 = NA_1 I = N\pi R^2 I$$

When the coil is unwound and is rewound to make another square coil of side 'a' and number of turns N, as total length of wire remains constant, we have

$$N2\pi R = N.4a$$

$$\Rightarrow a = \frac{\pi R}{2}$$

\therefore Magnetic moment of square coil for same current I

$$m_2 = NA_2 I = Na^2 I = N \left(\frac{\pi R}{2} \right)^2 I = N \frac{\pi^2 R^2}{4} I$$

$$\Rightarrow \frac{m_2}{m_1} = \frac{\pi}{4}$$

33. Consider a plane surface XY separating a rarer medium of refractive index n_1 from a denser medium of refractive index n_2 . Let c_1 and c_2 be the values of speed of light in the two media. AB is a plane wavefront incident on XY at an angle i . Let at a given instant the end A of wavefront just strikes the surface XY but the other end B has still to cover a path BC. If it takes time t , then $BC = C_1 t$

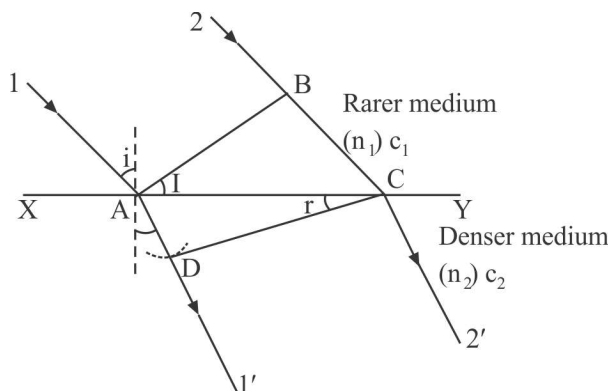


Fig. 10.15

According to Huygen's principle point A meanwhile begins to emit secondary wavelets which will cover a distance $c_2 t$ in second medium in time t . Draw a circular arc with A as centre and $c_2 t$ as radius and draw a tangent CD from point C on this arc. Then CD is the refracted wavefront, which advances in the direction of rays $1' 2'$. The refracted wavefront subtends an angle r from surface XY.

$$\text{Now in } \triangle ABC \quad \sin i = \frac{BC}{AC} = \frac{c_1 t}{AC}$$

$$\text{and in } \triangle ADC \quad \sin r = \frac{AD}{AC} = \frac{c_2 t}{AC}$$

$$\therefore \frac{\sin i}{\sin r} = \frac{c_1 t / AC}{c_2 t / AC} = \frac{c_1}{c_2} = \text{a constant} = \frac{n_2}{n_1} = n_{21}$$

which is Snell's law of refraction.

Or

Refraction formula : Consider a spherical surface XPY, convex towards

the rarer medium. As shown in Figure for a point object situated in rarer medium of refractive index n_1 , the image is formed in denser medium of refractive index n_2 at point I. If i and r be the angles of incidence and refraction respectively, then from Snell's law

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

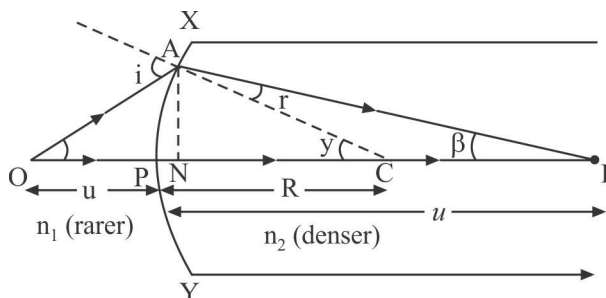


Fig. 9.96

or $n_1 \sin i = n_2 \sin r$

and for small aperture angles i and r are small and therefore $\sin i \approx i$ and $\sin r \approx r$, hence

$$n_1 i = n_2 r$$

From $\triangle OAC$, $i = \alpha + \gamma$

and from $\triangle IAC$, $\gamma = \beta + r$ or $r = \gamma - \beta$

$$\therefore n_1(\alpha + \gamma) = n_2(\gamma - \beta)$$

Again for spherical surface of small aperture angles α , β and γ are small, hence

$$\alpha = \tan \alpha = \frac{AN}{ON} = \frac{AN}{OP},$$

$$\beta = \tan \beta = \frac{AN}{IN} = \frac{AN}{PI},$$

and $\gamma = \tan \gamma = \frac{AN}{NC} = \frac{AN}{PC},$

Substituting these values of α , β and γ in (ii), we have



$$n_1 \left[\frac{AN}{OP} + \frac{AN}{PC} \right] = n_2 \left[\frac{AN}{PC} - \frac{AN}{PI} \right]$$

or
$$\frac{n_1}{OP} + \frac{n_1}{PC} = \frac{n_2}{PC} - \frac{n_2}{PI}$$

As per sign convention followed, $OP = -u$, $PC = +R$ and $PI = +v$, hence, equation (iii) becomes

$$\frac{n_1}{(-u)} + \frac{n_1}{(+R)} = \frac{n_2}{(+R)} - \frac{n_2}{(+v)}$$

or
$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

which is the relation between object distance u , image distance v and the radius R of the given spherical surface.

34. (a) Half life = $0.693 \times$ mean life

(b) (i) As 11 g of $^{11}_6\text{C}$ contains $N_A = 6.023 \times 10^{23}$ atoms, hence number of atoms present initially in $2.2 \text{ mg} = 2.2 \times 10^{-3} \text{ g}$ of sample

$$N_0 = \frac{2.2 \times 10^{-3} \times 6.023 \times 10^{23}}{11} = 1.2046 \times 10^{20}$$

(ii) Number of atoms actually present in $5 \mu\text{g} = 5 \times 10^{-6} \text{ g}$ of sample

$$N = \frac{5 \times 10^{-6} \times 6.023 \times 10^{23}}{11} = \frac{5 \times 6.023}{11} \times 10^{17}$$

and decay constant
$$\lambda = \frac{0.6931}{T_{1/2}} = \frac{0.6931}{1224} \text{ s}^{-1}$$

$$\begin{aligned} \therefore \text{Activity of the sample } R &= \lambda N = \frac{0.6931}{1224} \times \frac{5 \times 6.023}{11} \times 10^{17} \\ &= 1.55 \times 10^{14} \text{ Bq} \end{aligned}$$

35. (a) We know that in terms of drift velocity v_d of conduction electrons, the current flowing through a conductor is expressed as :

$$I = nAe v_d$$

and $v_d = \frac{eE}{m} \tau$, where E is the applied electric field and τ the relaxation time for conduction electrons.

$$\Rightarrow I = nAe \left(\frac{eE}{m} \tau \right) = \frac{nAe^2}{m} \tau E$$

If V be the potential difference across the ends of current carrying conductor of length l , then $E = \frac{V}{l}$ and hence

$$I = \frac{nAe^2}{m} \tau \frac{V}{l} = \frac{nAe^2 \tau}{ml} V$$

$$\therefore \text{Current density } j = \frac{I}{A} = \frac{ne^2 \tau}{ml} V$$

$$(b) \quad \text{Here } A = 1.0 \times 10^{-7} \text{ m}^2$$

$$I = 1.5 \text{ A}, n = 9 \times 10^{28} \text{ m}^{-3}$$

$$\text{and } e = 1.6 \times 10^{-19} \text{ C}$$

$$\therefore I = n A e v_d$$

$$\therefore \text{Average drift speed } v_d = \frac{I}{nAe} = \frac{15}{9 \times 10^{28} \times 1.0 \times 10^{-7} \times 1.6 \times 10^{-19}} \\ = 1.04 \times 10^{-3} \text{ ms}^{-1} \text{ or } 1.04 \text{ mm s}^{-1}$$

Or

(a) It is based on the principle of wheatstone bridge that when bridge is balanced then

$$\frac{P}{Q} = \frac{R}{S}$$

(b) We prefer manganin material for the metre bridge wire because its resistivity is quite high and resistivity does not change with change in temperature.

$$\frac{R}{S} = \frac{60}{(100 - 60)} = \frac{60}{40} = \frac{3}{2}$$

$$\Rightarrow R = \frac{3}{2} S$$

When a resistance of 5Ω is connected in series with S the effective resistance becomes $(S + 5)\Omega$. As now null point occurs at 50 cm, hence

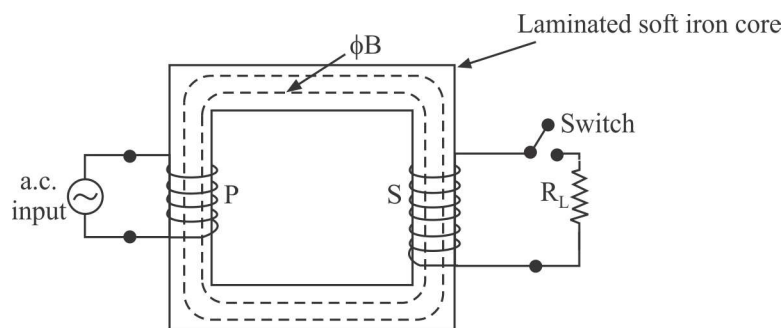


$$\frac{R}{(S+5)} = \frac{50 \text{ cm}}{(100-50) \text{ cm}} = \frac{50}{50} = 1$$

$$\Rightarrow R = S + 5$$

$$\Rightarrow S = 10 \, \Omega \text{ and } R = 15 \, \Omega$$

36. (a)



(a) Step up transformer

Principle : It is based on mutual induction working.

Theory and Working : When an alternating emf/voltage source is applied across the P coil, the input current and, hence, magnetic flux through P coil keeps on changing with time. The changing magnetic flux gets linked up with S coil through the iron core, which in turn produces induced voltage across the secondary coil. If coupling of two coils is good then all flux lines across P coil link up with S coil too. If at any time, the flux linked per unit turn of primary be ϕ_B , then

Total magnetic flux of P coil, $\phi_p = N_p \cdot \phi_B$ [where N_p = Total number of turns in P coil] and instantaneous value of induced emf in P coil, $\varepsilon_p =$

$$-\frac{d\phi_p}{dt} = -N_p \frac{d\phi_B}{dt}$$

If total number of turns in S coil be N_s , then magnetic flux of S coil, $\phi_s = N_s \cdot \phi_B$

and instantaneous value of induced emf in S coil,

$$\epsilon_s = -\frac{d\phi_s}{dt} = -N_s \frac{d\phi_B}{dt}$$

For an ideal transformer $|\epsilon_p| =$ input voltage V_p and $\epsilon_s = V_s =$ output voltage obtained across secondary coil. Then,

$$\frac{|\epsilon_s|}{|\epsilon_p|} = \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Again for an ideal transformer input power = output power

$$\therefore V_p \cdot I_p = V_s \cdot I_s$$

$$\Rightarrow \frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p} = k \text{ (the transformer ratio)}$$

For a step up transformer $V_s = kV_p$ but $I_s = \frac{I_p}{k}$. It can be shown that input and output alternating voltages are in mutually opposite phase.

However, for a practically transformer

$$\text{Efficiency } \eta = \frac{\text{output power}}{\text{input power}} = \frac{V_s \cdot I_s}{V_p \cdot I_p}$$

(c) Yes, because when V is increased in output I decreases keeping power same.

Or

Let, in general, applied voltage and current flowing in a LCR series a.c. circuit be given by

$$V = V_m \sin \omega t \text{ and } I = I_m \sin (\omega t - \phi)$$

$$\begin{aligned} \therefore \text{ Instantaneous power } P &= VI = V_m \sin \omega t \cdot I_m \sin (\omega t - \phi) \\ &= V_m I_m \sin \omega t \cdot [\sin^2 \omega t \cos \phi - \cos \omega t \sin \phi] \end{aligned}$$



$$= V_m I_m [\sin^2 \omega t \cos \phi - \frac{1}{2} \sin 2 \omega t \sin \phi]$$

∴ Average power for one complete cycle of a.c.

$$\bar{P} = V_m I_m \left[\overline{(\sin^2 \omega t) \cos \phi} - \frac{1}{2} \overline{(\sin^2 \omega t) \sin \phi} \right]$$

But we know that average value of $\sin^2 \omega t$ for a complete cycle is $\frac{1}{2}$, whereas average value of $\sin 2 \omega t$ for one complete cycle is zero. Hence,

$$\bar{P} \text{ or } P_{av} = V_m I_m \left[\frac{1}{2} \cos \phi \right] = \frac{1}{2} V_m I_m \cos \phi = V_{rms} I_{rms} \cos \phi$$

- (i) If phase difference ϕ between V and I be $\frac{\pi}{2}$ (as for a pure inductor or a pure capacitor or a series LC circuit) then $\cos \phi = \cos \frac{\pi}{2} = 0$ and hence average power dissipated is zero even though the current flows through the circuit.
- (ii) If phase difference $\phi = 0^\circ$ (as for a pure resistor or for a resonant circuit) then $\cos \phi = \cos 0^\circ = 1$ and hence average power $P_{av} = V_{rms} I_{rms}$, which is maximum power dissipated in the circuit.

37. (a)

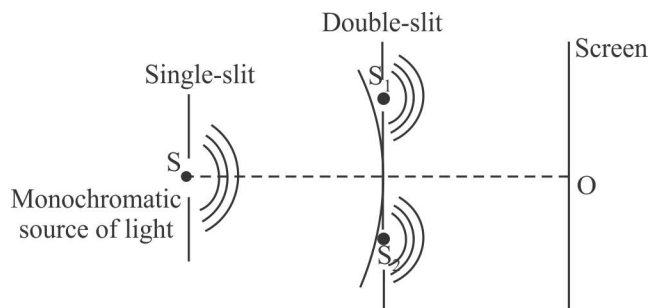


Fig. 10.17

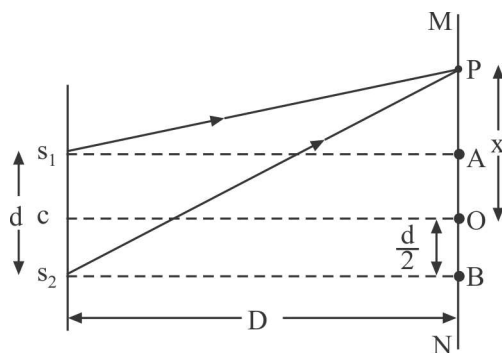


Fig. 10.18

$$(S_2P)^2 = D^2 + \left(x + \frac{d}{2}\right)^2$$

and $(S_1P)^2 = D^2 + \left(x - \frac{d}{2}\right)^2$

$$\therefore (S_2P)^2 - (S_1P)^2 = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(x - \frac{d}{2}\right)^2\right] = 2xd$$

or $(S_2P - S_1P) = \frac{2xd}{(S_2P + S_1P)}$

If x and d are very very small as compared to D , then $(S_2P + S_1P)$ may be considered as $2D$. Hence

$$[S_2P - S_1P] = \frac{2xd}{2D} = \frac{xd}{D}$$

For constructive interference, path difference must be an integer multiple of λ i.e., $\frac{xd}{D} = n\lambda$, where $n = 0, 1, 2, 3, \dots$ etc.

$$\Rightarrow x = \frac{nD\lambda}{d}$$

i.e., positions of various maxima (bright bands) will be given by :

$$x_0 = 0, \quad x_1 = \frac{D\lambda}{d},$$

$$x_2 = \frac{2D\lambda}{d}, \quad x_3 = \frac{3D\lambda}{d} \dots\dots\dots$$

For destructive interference, path difference must be an odd multiple of

$$\frac{\lambda}{2} \text{ i.e., } \frac{xd}{D} = (2n - 1) \frac{\lambda}{2}, \text{ where } n = 1, 2, 3, \dots \text{ etc.}$$

$$\Rightarrow x = \frac{(2n - 1)D\lambda}{2d}$$

i.e., positions of various minima (dark bands) will be given by :

- (b) Here $\lambda_1 = 800 \text{ nm}$, $\lambda_2 = 600 \text{ nm}$, $D = 1.4 \text{ m}$ and $d = 0.28 \text{ mm} = 2.8 \times 10^{-4} \text{ m}$.

Let at a distance 'x' from central maxima the bright fringes due to λ_1 and λ_2 coincide first time. For this to happen

$$n\lambda_1 = (n + 1)\lambda_2, \text{ where } n \text{ is an integer}$$

$$\Rightarrow \frac{n + 1}{n} = \frac{\lambda_1}{\lambda_2} = \frac{800 \text{ nm}}{600 \text{ nm}} = \frac{4}{3}$$

$$\Rightarrow n = 3$$

It means that at distance x, nth i.e., 3rd maxima for wavelength λ_1 is just coinciding with $(n + 1)^{\text{th}}$ i.e., 4th maxima for wavelength λ_2 .

$$\therefore x = \frac{nD\lambda_1}{d} = \frac{3 \times 1.4 \times 800 \times 10^{-9}}{2.8 \times 10^{-4}} = 1.2 \times 10^{-2} \text{ m or } 1.2 \text{ cm}$$

Or

Ordinary light propagating in a given direction consists of many independent waves whose planes of vibration are randomly oriented in all directions in a transverse plane. Such light is said to be unpolarised light. In an unpolarised light the electric vector takes all possible directions in the transverse plane.

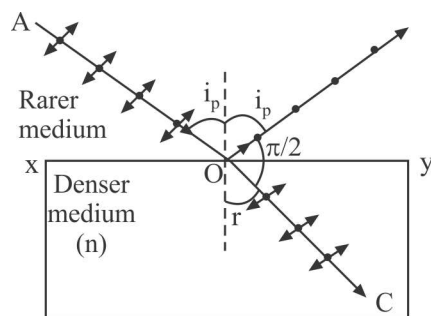


Fig. 10.24

Plane polarised light can be obtained by reflection from a ramparts surface (say a plane glass plate) when the light is incident on the surface at the polarising angle i_p .

In such a condition, the reflected light contains vibrations of electric vector perpendicular to the plane of incidence only and is, thus, completely plane polarised one.

When light is incident at the polarising angle i_p , the reflected and refracted rays make a right angle with each other i.e., $\angle r = \angle(90^\circ - i_p)$. Therefore, as per Snell's law, we have

$$n = \frac{\sin i_p}{\sin r} = \frac{\sin i_p}{\sin(90^\circ - i_p)} = \frac{\sin i_p}{\cos i_p} = \tan i_p$$

The condition $n = \tan i_p$ is referred as 'Brewster's law'.

$$\begin{aligned} \text{(b) } \mu &= \tan i_p & \Rightarrow \sqrt{3} &= \tan i_p \\ & & i_p &= \tan^{-1} \sqrt{3} \\ & & i_p &= 60^\circ \\ & & i_p + r &= 90^\circ \\ \therefore & & \angle r &= 90^\circ - 60^\circ = 30^\circ \end{aligned}$$

PRACTICE PAPER
PHYSICS

Time : 3 Hrs.

M.M.: 70

General Instructions

- (i) All questions are compulsory. There are 37 questions in all.
- (ii) This question paper has four sections A, B, C and D.
- (iii) Section A contains '20' questions of '1' mark each,
Section B contains '7' questions of '2' marks each,
Section C contains '7' questions of '3' marks each,
Section D contains '3' questions of '5' marks each,
- (iv) There is no overall choice. However internal choice have been provided in Five questions of one mark, two questions of two marks, two questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.
- (v) You may use the following values of physical constants wherever necessary.

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ JS}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T mA}^{-1}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

$$\text{mass of electron} = 9.1 \times 10^{-31} \text{ Kg}$$

$$\text{mass of Neutron} = 1.675 \times 10^{-27} \text{ Kg}$$

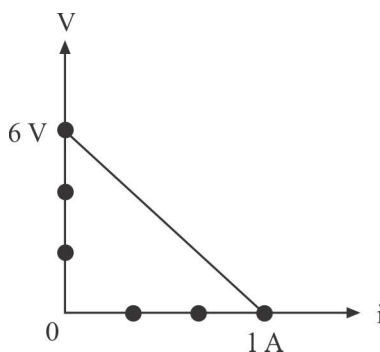
$$\text{mass of proton} = 1.673 \times 10^{-27} \text{ Kg}$$

$$\text{Avagadro's number} = 6.023 \times 10^{23} \text{ per gram mole.}$$

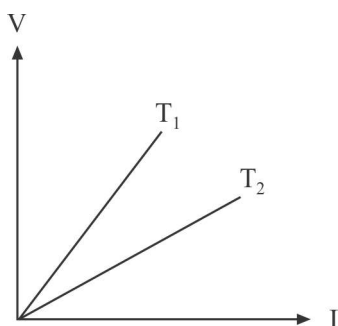
$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

SECTION A

1. What orientation of an electric dipole in uniform electric field corresponds to its (i) stable and (ii) unstable equilibrium.
2. The plot of the variation of potential difference across a combination of three identical cells in series versus current is as shown below. What is the emf of each cell?



I-V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in figure. Which of the two temperature is lower and why?



3. How will you produce EMW?
4. An equiconvex lens has refractive index 1.5. Write its focal length in terms of radius of curvature?

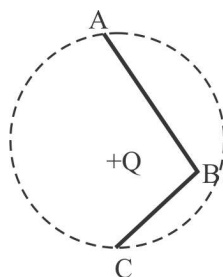
Or

How does the power of a lens, vary, if the incident red light is replaced by violet light?

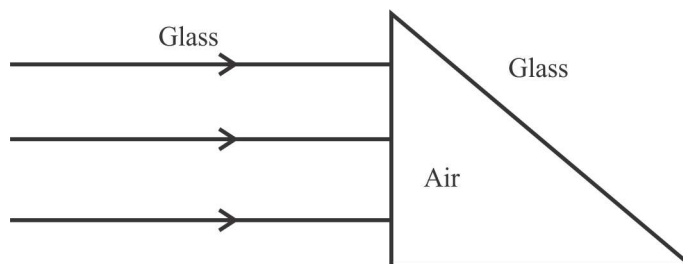
5. In the given figure, charge $+Q$ is placed at the centre of a dotted circle.



Work done in taking another charge $+q$ from A to B is W_1 and from B to C is W_2 . Which one of the following is correct : $W_1 > W_2$, $W_1 = W_2$ and $W_1 < W_2$?



6. Plot a graph showing the variation of current ' I ' versus resistance ' R ', connected to a cell of emf E and internal resistance ' r '.
7. State the factor on which the refractive index of a material medium for a given wavelength depends.
8. Sketch the emergent wavefront.



9. 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?
10. A point charge Q is placed at point O as shown in the figure. The potential difference $V_A - V_B$ is positive. Is the charge Q negative or positive?



Or

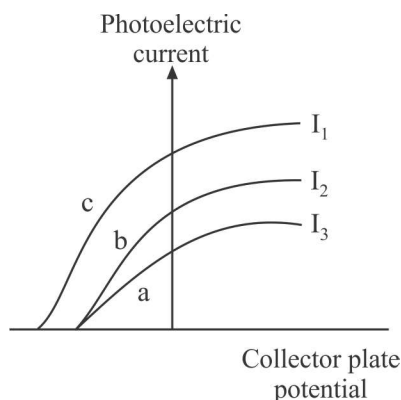
A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. What is the potential at the centre of the sphere?

11. Give an example of a material each for which temperature coefficient of resistivity is (i) positive, (ii) negative.
12. Sketch a schematic diagram depicting oscillating electric and magnetic fields of an electromagnetic wave propagating along + z-direction.
13. For the same angle of incidence, the angle of refraction in two media A and B are 25° and 30° respectively. In which one of the two media is the speed of light lesser?

Or

The refractive index of a material of concave lens is n_1 . It is immersed in a medium of refractive index n_2 . A parallel beam of light is incident on the lens. Trace the path of emergent rays when $n_1 > n_2$.

14. The figure shows a plot of three curves a , b , c show in the variation of photocurrent versus collector plate potential for three different intensities I_1 , I_2 and I_3 having frequencies ν_1 , ν_2 and ν_3 respectively incident on a photosensitive surface.



Point out the two curves for which the incident radiations have same frequency but different intensities.

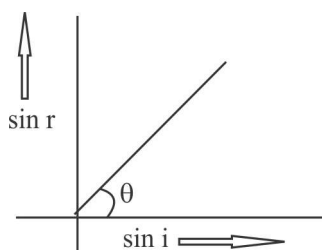
15. Two metals A and B have work functions 4 eV and 10 eV respectively. Which of the metal has higher threshold wavelength?
16. State the SI unit of the electric polarization vector?
17. Define temperature coefficient of resistivity.

18. Name the electromagnetic waves that are widely used as a diagnostic tool in medicine.

Or

Name the current which can flow even in the absence of electric charge.

19. 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.

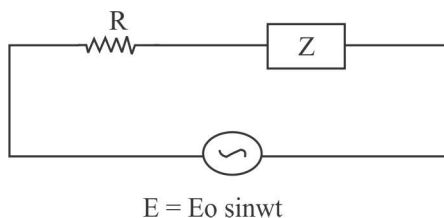


20. Two particles have equal momenta. What is the ratio of their de-Broglie wavelengths?

Or

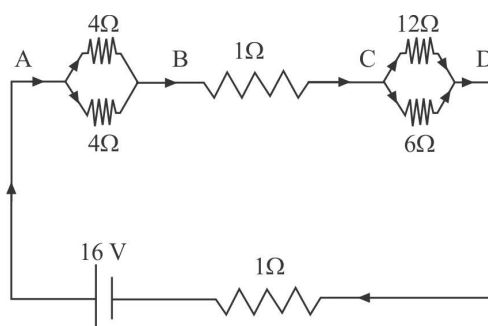
Monochromatic light of frequency 0.6×10^{14} Hz is produced by a laser. What is the energy of a photon in the light beam?

21. Six-lead-acid type of secondary cells each of emf 2V and internal resistance 0.015Ω joined in series to provide a supply to a resistance of 8.5Ω . What are the current drawn from the supply and its terminal voltage?
22. An alternating voltage $E = E_0 \sin \omega t$ 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 $I = I_0 \sin (\omega t + \pi/2)$.



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

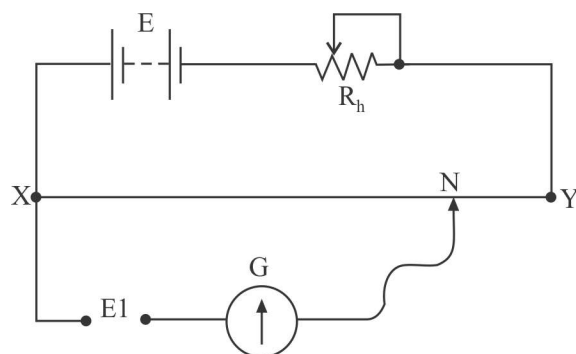
23. A network of resistors is connected to a 16 V battery with internal resistance of $1\ \Omega$, as shown in the following figure. Compute the equivalent resistance of the network.



Or

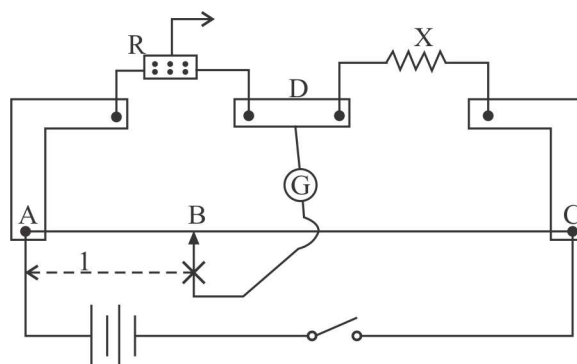
A 9V battery is connected in series with a resistor. The terminal voltage is found to be 8 V. Current through the circuit is measured as 5A. What is the internal resistance of the battery?

24. 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.

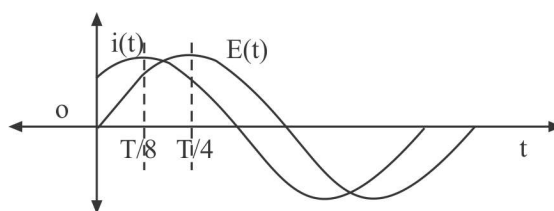


Or

Following circuit was set up in a meter bridge experiment of 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?
25. The figure shows two sinusoidal curves representing oscillating supply voltage and current in an ac circuit.



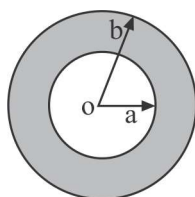
Draw a phasor diagram to represent the current and supply voltage appropriately as phasors. State the phase different between the two quantities.

26. Compare the following :
- (a) Wavelengths of the incident solar radiation absorbed by the earth's surface and the radiation re-radiated by the earth.
- (b) Tanning effect produced on the skin by UV radiation incident directly on the skin and that coming through glass window.
27. A narrow slit is illuminated by a parallel beam of monochromatic light of

wavelength λ equals to 6000 \AA 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 .

SECTION C

28. (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?
29. 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) $r = \frac{a}{2}$, and (ii) $r = 2b$, from the centre of the shell.

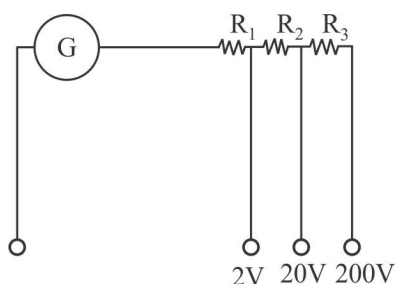


30. The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following:
- (a) The magnitude of the electric field within them,
- (b) The drift speed of electrons through them, and
- (c) The current density within them.



Wire no.	Length	Diameter	Potential difference
1	L	$3d$	V
2	$2L$	d	V
3	$3L$	$2d$	$2V$

31. 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 R_1 , R_2 and R_3 that have to be used.

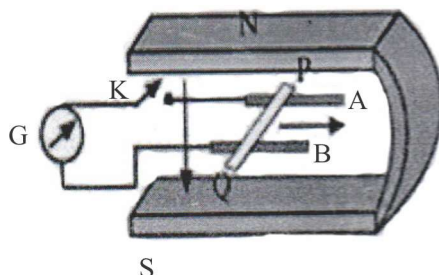


Or

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 .

- 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.
- 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.

(c) What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?



32. 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.
33. 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?

Or

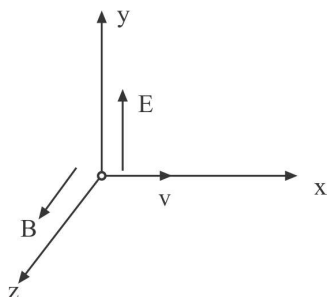
What do you understand by the statement 'Light from the sun is unpolarised'. Explain how does sunlight gets polarized by the process of scattering?

34. 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.

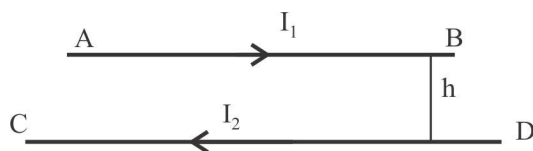
Section D

35. (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?



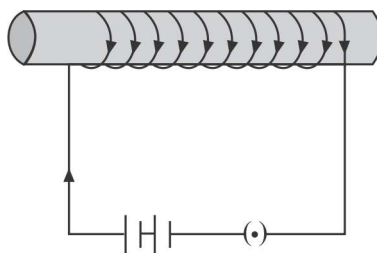


- (b) A horizontal wire AB of length ' l ' and mass ' m ' carries a steady current I_1 , free to move in vertical plane in equilibrium at a height of ' h ' over another parallel long wire CD carrying a steady current I_2 which is fixed in a horizontal plane as shown. Derive the expression for the force 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



36. (a) There are two sets of apparatus of Young's double slit experiment. In set A, the phase difference between the two waves emanatin from the slits

does not change with time, 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, The third polaroid 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 Intensity on angle of rotation.
- (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?
37. (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?
- (b) 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.

Or

- (a) Explain the processes involved in the formation of $p-n$ junction.
- (b) Draw a circuit diagram of full wave rectifier. Explain its working principle. Draw the input/output waveforms indicating clearly the functions of the two diodes used.



PRACTICE PAPER
CLASS XII
PHYSICS

Time : 3 Hrs.

M.M.: 70

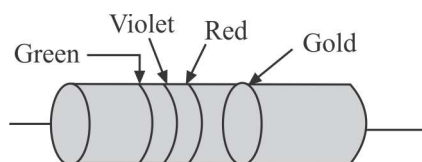
Section A

1. Draw the pattern of electric field lines, when a point charge - Q is kept near an uncharged conducting plate.

Or

Define the term 'dielectric constant' of a material.

2. Why is the electrostatic potential inside a charged conducting shell constant throughout the volume of the conductor?
3. How is the drift velocity in a conductor affected with the rise in temperature?
4. A carbon resistor is shown in the figure. Using colour code, write the value of the resistance.



5. Where on the surface of the Earth, is the vertical component of Earth's magnetic field zero?

Or

The magnetic susceptibility χ of a given material is -0.5 . Identify the magnetic material.

6. The magnetic susceptibility of magnesium at 300 K is 1.2×10^5 . At what temperature will its magnetic susceptibility become $1 : 44 \times 10^5$?
7. Write the relation for the force acting on a charged particle q moving with velocity v in the presence of a magnetic field B .
8. Define curie's point for Magnetic Material.

9. Write two observations of Rutherford Experiment.
10. Write one drawback of Bohr's model of hydrogen atom.
11. What is the speed of light in a denser medium of polarising angle 30° ?

Or

Why is convex mirror used as a side view mirror in a car?

12. A lens of large optical power bends the incident light more. Why?
13. Define the term “threshold frequency”, in the context of photoelectric emission.

Or

Plot a graph of the de-Broglie wavelength associated with a proton versus its momentum.

14. Write any two properties of photon.
15. Define packing fraction.

Or

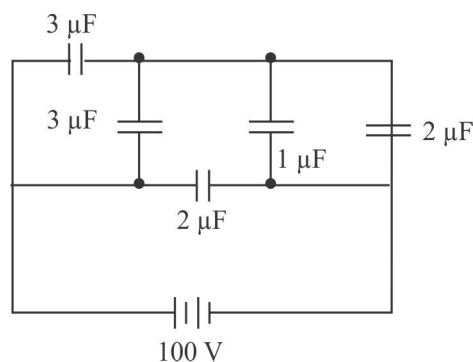
What is the unit of Decay constant?

16. Draw resistivity versus temperature graph for a semiconductor.
17. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.
18. What is the phase difference between \vec{E} and \vec{B} vector in an electromagnetic wave.
19. What is the physical significance of self inductance.
20. Define rms value of alternating current.

Section B

21. Apply Gauss's law to show that for a charged spherical shell, the electric field outside the shell is, as if the entire charge were concentrated at the centre.
22. The figure shows a network of five capacitors connected to 100 V supply. Calculate the total energy stored in the network.





23. State Kirchhoff's laws for a circuit.

Or

Establish the relation between drift velocity and current.

24. Two long straight wires carrying currents of 2A and 5A in the same direction are kept parallel, 10 cm apart from each other. Calculate the force acting between them and write its nature.
25. A charged particle q is moving in the presence of a magnetic field B which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path.
26. Calculate the radius of curvature of an equi-concave lens of refractive index 1.5, when it is kept in a medium of refractive index 1.4 to have a power of 5D?

Or

Draw the ray diagram of an astronomical telescope showing image formation in the normal adjustment position. Write the expression for its magnifying power.

27. Distinguish between nuclear fusion and nuclear fission. Give one example for each.

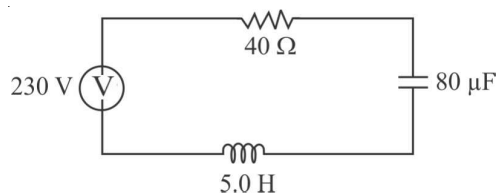
Section C

28. (a) Draw the equipotential surfaces corresponding to a uniform electric field in the z -direction.
 (b) Derive an expression for the electric potential at any point along the axial line of an electric dipole.
29. (a) Briefly explain how a galvanometer is converted into a voltmeter.
 (b) A voltmeter of a certain range is constructed by connecting a resistance of $980\ \Omega$ in series with a galvanometer. When the resistance of $470\ \Omega$ is connected in series, the range gets halved. Find the resistance of the galvanometer.

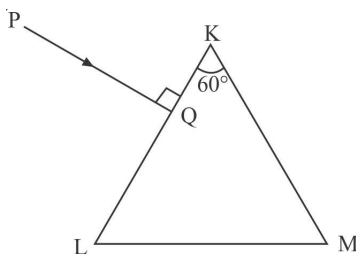
Or

Find out magnetic field at a point on the axis due to current carrying circular loop.

30. The figure shows a series LCR circuit connected to a variable frequency 230 V source.



- (a) Determine the source frequency which drives the circuit in resonance.
 (b) Calculate the impedance of the circuit and amplitude of current at resonance.
31. A triangular prism of refracting angle 60° is made of a transparent material of refractive index $\frac{2}{\sqrt{3}}$. A ray of light is incident normally on the face KL as shown in the figure. Trace the path of the ray as it passes through the prism and calculate the angle of emergence and angle of deviation.

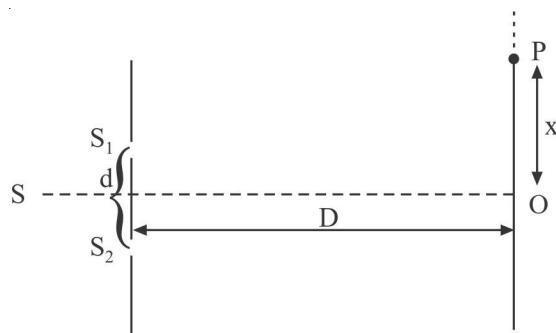


32. How is a light emitting diode fabricated? Briefly explain the basic processes involved in the emission of spontaneous radiation from it. Write two advantages of LED lamps over the incandescent low power lamps.
33. (a) Draw the energy level diagram for the line spectra representing Lyman series and Balmer series in the spectrum of hydrogen atom.
 (b) Using the Rydberg formula for the spectrum of hydrogen atom, calculate the longest and shortest wavelengths of the emission lines of the Balmer series in the spectrum of hydrogen atom. (Use the value of Rydberg constant $R = 1.1 \times 10^7 \text{ m}^{-1}$)
34. Write postulates of Bohr's atomic model of atom.
35. Derive expression for equivalent e.m.f. and equivalent resistance of n .
 (a) Series combination
 (b) Parallel combination
 of three cells with emf E_1, E_2, E_3 and internal resistance r_1, r_2, r_3 respectively.
 Or
 (a) Describe briefly, with the help of a circuit diagram, the method of measuring the internal resistance of a cell.
 (b) Give reason why a potentiometer is preferred over a voltmeter for the measurement of emf of a cell.
36. State the underlying principle of a cyclotron. Explain its working with the help of a schematic diagram. Obtain the expression for cyclotron frequency.
 (a) Why is the magnetic field radial in a moving coil galvanometer? Explain how it is achieved.
 (b) A galvanometer of resistance 'G' can be converted into a voltmeter of range $(0 - V)$ volts by connecting a resistance R in series with it. How much resistance will be required to change its range from 0 to $V/2$ volt?
 Or
 (a) A rectangular loop of N turns and area A of each turn, is kept in uniform magnetic field of intensity, B. Deduce expression for torque acting on the loop when its plane is inclined at angle θ w.r.t. magnetic field B.

- (b) A short bar magnet of magnetic moment M is turned in uniform magnetic field of intensity B from stable equilibrium to unstable equilibrium. Calculate mark done.
37. (a) Draw a labelled ray diagram of compound microscope, when final image forms at the least distance of distinct vision.
- (b) Why its objectives is of short focal length and of short aperture, compared to its eyepiece lens? Explain.
- (c) The focal length of the objective is 4 cm while that of eyepiece is 10 cm. The object is placed at a distance of 6 cm from the objective lens. Calculate the magnifying power of the compound microscope, if its final image is formed at the near point.

Or

- (a) Can the interference pattern be produced by two independent monochromatic sources of light? Explain.
- (b) The intensity at the central maximum (O) in a Young's double slit experimental set-up shown in the figure is I_0 . If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P, would equal to $\frac{I_0}{4}$.



- (c) In Young's double slit experiment, the slits are separated by 0.5 mm and screen is placed 1.0 m away from the slit. It is found that the 5th bright fringe is at a distance of 4.13 mm from the 2nd dark fringe. Find the wavelength of light used.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

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