NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIALS

PHT100 ENGINEERING PHYSICS

VISION OF THE INSTITUTION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION OF THE INSTITUTION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Mechanical Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing internationally competitive Mechanical Engineers with social responsibility & sustainable employability through viable strategies as well as competent exposure oriented quality education.

DEPARTMENT MISSION

1. Imparting high impact education by providing conductive teaching learning environment.
2. Fostering effective modes of continuous learning process with moral & ethical values.
3. Enhancing leadership qualities with social commitment, professional attitude, unity, team spirit & communication skill.
4. Introducing the present scenario in research & development through collaborative efforts blended with industry & institution.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates shall have strong practical & technical exposures in the field of Mechanical Engineering & will contribute to the society through innovation & enterprise.

PEO2: Graduates will have the demonstrated ability to analyze, formulate & solve design engineering / thermal engineering / materials & manufacturing / design issues & real life problems.

PEO3: Graduates will be capable of pursuing Mechanical Engineering profession with good communication skills, leadership qualities, team spirit & communication skills.

PEO4: Graduates will sustain an appetite for continuous learning by pursuing higher education & research in the allied areas of technology.

PROGRAM OUTCOMES (POS)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and teamwork**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the

engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO1: graduates able to apply principles of engineering, basic sciences & analytics including multi variant calculus & higher order partial differential equations..

PSO2: Graduates able to perform modeling, analyzing, designing & simulating physical systems, components & processes.

PSO3: Graduates able to work professionally on mechanical systems, thermal systems & production systems.

PHT 100	ENGINEERING PHYSICS A (FOR CIRCUIT BRANCHES)	CATEGORY	L	T	P	CREDIT	YEAR OF INTRODUCTION
		BSC	3	1	0	4	2019

Preamble: The aim of the Engineering Physics Program is to offer students a solid background in the fundamentals of Physics and to impart that knowledge in engineering disciplines. The program is designed to develop scientific attitudes and enable the students to correlate the concepts of Physics with the core programmes

Prerequisite: Higher secondary level Physics, Mathematical course on vector calculus, differential equations and linear algebra

Course Outcomes: After the completion of the course the student will be able to

CO 1	Compute the quantitative aspects of waves and oscillations in engineering systems.
CO 2	Apply the interaction of light with matter through interference, diffraction and identify these phenomena in different natural optical processes and optical instruments.
CO 3	Analyze the behaviour of matter in the atomic and subatomic level through the principles of quantum mechanics to perceive the microscopic processes in electronic devices.
CO 4	Classify the properties of magnetic materials and apply vector calculus to static magnetic fields and use Maxwell's equations to diverse engineering problems
CO 5	Analyze the principles behind various superconducting applications, explain the working of solid state lighting devices and fibre optic communication system

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2						1	2			1
CO 2	3	2						1	2			1
CO 3	3	2						1	2			1
CO 4	3	1						1	2			1
CO 5	3	1						1	2			1

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination (Marks)
	Test 1 (Marks)	Test 2 (Marks)	
Remember	15	15	30
Understand	25	25	50
Apply	10	10	20

Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE marks	ESE marks	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the effect of damping force on oscillators.
2. Distinguish between transverse and longitudinal waves.
3. (a) Derive an expression for the fundamental frequency of transverse vibration in a stretched string.

   (b) Calculate the fundamental frequency of a string of length 2 m weighing 6 g kept stretched by a load of 600 kg.

Course Outcome 2 (CO2):

1. Explain colours in thin films.
2. Distinguish between Fresnel and Fraunhofer diffraction.
3. (a) Explain the formation of Newton's rings and obtain the expression for radii of bright and dark rings in reflected system. Also explain how it is used to determine the wavelength of a monochromatic source of light.

   (b) A liquid of refractive index μ is introduced between the lens and glass plate.

What happens to the fringe system? Justify your answer.

Course Outcome 3 (CO3):

1. Give the physical significance of wave function ?
2. What are excitons ?
3. (a) Solve Schrodinger equation for a particle in a one dimensional box and obtain its energy eigen values and normalised wave functions.

   (b) Calculate the first three energy values of an electron in a one dimensional box of width 1 A^0 in electron volt.

Course Outcome 4 (CO4):

1. Compare displacement current and conduction current.
2. Mention any four properties of ferro magnetic materials.
3. (a) Starting from Maxwell's equations, derive the free space electromagnetic wave equation and show that velocity of electromagnetic wave is $1/(\mu_o \varepsilon_o)^{½}$

   (b) An electromagnetic wave is described by $E = 100 \exp 8\pi i [10^{14} t - (10^{6} z / 3)]$ V/m. Find the direction of propagation of the wave,speed of the wave and magnetic flux density in the wave.

Course Outcome 5 (CO5):

1. Explain the working of a solar cell.
2. Distinguish between Type I and Type II super conductors.
3. (a) Define numerical aperture and derive an expression for it.

   (b) Explain the working of intensity modulated fibre optic sensor.

Model Question paper

QP CODE: PAGES:3

Reg No:_______________

Name :_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIRST SEMESTER B.TECH DEGREE EXAMINATION, MONTH & YEAR

Course Code: PHT 100

Course Name: Engineering Physics A

Max. Marks: 100 **Duration: 3 Hours**

PART A

Answer all Questions. Each question carries 3 Marks

1. Compare electrical and mechanical oscillators
2. Distinguish between longitudinal and transverse waves
3. Write a short note on antireflection coating.
4. Diffraction of light is not as evident in daily experience as that of sound waves. Give reason.
5. State and explain Heisenberg's Uncertainty principle. With the help of it explain natural line broadening.
6. Explain surface to volume ratio of nanomaterials.
7. State Faraday's laws of electromagnetic induction.
8. Compare displacement current and conduction current
9. List four important applications of superconductors.
10. Give the working principle of LED. (10x3=30)

PART B

Answer any one full question from each module. Each question carries 14 Marks

Module 1

11. (a) Derive the differential equation of damped harmonic oscillator and deduce its solution. Discuss the cases of over damped, critically damped and under damped cases. (10)

(b) The frequency of a tuning fork is 500 Hz and its Q factor is 7×10^{4}. Find the relaxation time. Also calculate the time after which its energy becomes 1/10 of its initial undamped value. (4)

12. (a) Derive an expression for the velocity of propagation of a transverse wave in a stretched string. Deduce laws of transverse vibrations. (10)

(b) The equation of transverse vibration of a stretched string is given by y =0.00327 sin (72.1x- 2.72t)m, in which the numerical constants are in S.I units. Evaluate (i) Amplitude (ii) Wavelength
(iii) Frequency and (iv)Velocity of the wave. (4)

Module 2

13.(a)Explain the formation of Newton's rings and show that the radius of dark ring is proportional to the square root of natural numbers. How can we use Newton's rings experiment to determine the refractive index of a liquid. (10)

(b) Two pieces of plane glass are placed together with a piece of paper between two at one end. Find the angle of the wedge in seconds if the film is viewed with a monochromatic light of wavelength 4800Å. Given β = 0.0555 cm. (4)

14. (a) Explain the diffraction due to a plane transmission grating. Obtain the grating equation. (10)

(b) A grating has 6000 lines per cm. Find the angular separation of the two yellow lines of mercury of wavelengths 577 nm and 579 nm in the second order. (4)

Module 3

15.(a) Derive time dependent and independent Schrodinger equations. (10)

(b) An electron is confined to one dimensional potential box of length 2Å. Calculate the energies corresponding to the first and second quantum states in eV. (4)

16.(a) Classify nanomaterials based on dimensionality of quantum confinement and explain the following nanostructures. (i) nano sheets (ii) nano wires (iii) quantum dots. (10)

(b) Find the de Broglie wavelength of electron whose kinetic energy is 15 eV. (4)

Module 4

17.(a) State Poynting's Theorem. Calculate the value of Poynting vector at the surface of the sun if the power radiated by the sun is 3.8×10^{26} W and its radius is 7×10^{8} m. (5

(b) Distinguish between paramagnetic, diamagnetic and ferromagnetic materials. (9)

18.(a) Starting from Maxwell's Equations, derive electromagnetic wave equations in free space. (10)

(b) If the magnitude of **H** in a plane wave is 1 A/m, find the magnitude of **E** in free space. (4)

Module 5

19.(a) Show that superconductors are perfect diamagnets. Distinguish between Type I and Type II superconductors with suitable examples. (10)

(b) Write a short note on high temperature superconductors. (4)

20.(a) Define numerical aperture of an optic fibre and derive an expression for the NA of a step index fibre with a neat diagram. (10)

(b) Calculate the numerical aperture and acceptance angle of a fibre with a core refractive index of 1.54 and a cladding refractive index of 1.50 when the fibre is inside water of refractive index 1.33. (4) (14x5=70)

Syllabus

ENGINEERING PHYSICS A
(FOR CIRCUIT BRANCHES)

Module 1

Oscillations and Waves

Harmonic oscillations, Damped harmonic motion-Derivation of differential equation and its solution, Over damped, Critically damped and Under damped Cases, Quality factor-Expression, Forced oscillations-Differential Equation-Derivation of expressions for amplitude and phase of forced oscillations, Amplitude Resonance-Expression for Resonant frequency, Quality factor and Sharpness of Resonance, Electrical analogy of mechanical oscillators

Wave motion- Derivation of one dimensional wave equation and its solution, Three dimensional wave equation and its solution (no derivation), Distinction between transverse and longitudinal waves, Transverse vibration in a stretched string, Statement of laws of vibration

Module 2

Wave Optics

Interference of light-Principle of superposition of waves, Theory of thin films - Cosine law (Reflected system), Derivation of the conditions of constructive and destructive Interference, Interference due to wedge shaped films -Determination of thickness and test for optical planeness, Newton's rings - Measurement of wavelength and refractive index, Antireflection coatings

Diffraction of light, Fresnel and Fraunhofer classes of diffraction, Diffraction grating-Grating equation, Rayleigh criterion for limit of resolution, Resolving and Dispersive power of a grating with expression (no derivation)

Module 3

Quantum Mechanics & Nanotechnology

Introduction for the need of Quantum mechanics, Wave nature of Particles, Uncertainty principle, Applications-Absence of electrons inside a nucleus and Natural line broadening mechanism, Formulation of time dependent and independent Schrodinger wave equations-Physical meaning of wave function, Particle in a one dimensional box- Derivation for normalised wave function and energy eigen values, Quantum Mechanical Tunnelling (Qualitative)

Introduction to nanoscience and technology, Increase in surface to volume ratio for nanomaterials, Quantum confinement in one dimension, two dimension and three dimension-Nano sheets, Nano wires and Quantum dots, Properties of nanomaterials-mechanical, electrical and optical, Applications of nanotechnology (qualitative ideas)

Module 4

Magnetism & Electro Magnetic Theory

Magnetic field and Magnetic flux density, Gauss's law for Magnetic flux density, Ampere's Circuital law, Faraday's law in terms of EMF produced by changing magnetic flux, Magnetic permeability and susceptibility, Classification of magnetic materials-para, dia and ferromagnetic materials

Fundamentals of vector calculus, concept of divergence, gradient and curl along with physical significance, Line, Surface and Volume integrals, Gauss divergence theorem & Stokes' theorem, Equation of continuity, Derivation of Maxwell's equations in vacuum, Comparison of displacement current with conduction current. Electromagnetic waves, Velocity of Electromagnetic waves in free space, Flow of energy and Poynting's vector (no derivation)

Module 5

Superconductivity & Photonics

Superconducting phenomena, Meissner effect and perfect diamagnetism, Types of superconductors- Type I and Type II, BCS Theory (Qualitative), High temperature superconductors-Applications of super conductivity

Introduction to photonics-Photonic devices-Light Emitting Diode, Photo detectors -Junction and PIN photodiodes, Solar cells-I-V Characteristics, Optic fibre-Principle of propagation of light, Types of fibres-Step index and Graded index fibres, Numerical aperture –Derivation, Fibre optic communication system (block diagram), Industrial, Medical and Technological applications of optical fibre, Fibre optic sensors-Intensity Modulated and Phase modulated sensors.

Text Books

1. M.N.Avadhanulu, P.G.Kshirsagar,TVS Arun Murthy "A Text book of Engineering Physics", S.Chand &Co., Revised Edition 2019

2. H.K.Malik , A.K. Singh, "Engineering Physics" McGraw Hill Education, Second Edition 2017

Reference Books

1. Arthur Beiser, "Concepts of Modern Physics ", Tata McGraw Hill Publications, 6th Edition 2003
2. D.K. Bhattacharya, Poonam Tandon, "Engineering Physics", Oxford University Press, 2015
3. Md.N.Khan & S.Panigrahi "Principles of Engineering Physics 1&2", Cambridge University Press, 2016
4. Aruldhas G., "Engineering Physics", PHI Pvt. Ltd., 2015
5. Ajoy Ghatak, "Optics", Mc Graw Hill Education, Sixth Edition, 2017
6. T. Pradeep, "Nano:The Essentials'', McGraw Hill India Ltd, 2007
7. Halliday, Resnick, Walker, "Fundamentals of Physics'', John Wiley & Sons.Inc, 2001
8. David J Griffiths, "Introduction to Electrodynamics'', Addison-Wesley publishing, 3rd Edition, 1999
9. Premlet B., "Advanced Engineering Physics", Phasor Books,10th edition,2017
10. I. Dominic and. A. Nahari, "A Text Book of Engineering physics", Owl Books Publishers, Revised edition, 2016

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Oscillations and Waves (9 hours)**	
1.1	Harmonic oscillations, Damped harmonic motion-Derivation of differential equation and its solution, Over damped, Critically damped and Under damped Cases, Quality factor-Expression	2 hrs
1.2	Forced oscillations-Differential Equation-Derivation of expressions for amplitude and phase of forced oscillations, Amplitude Resonance-Expression for Resonant frequency, Quality factor and Sharpness of Resonance, Electrical analogy of mechanical oscillators	3hrs
1.3	Wave motion- Derivation of one dimensional wave equation and its solution, Three dimensional wave equation and its solution (no derivation)	2 hrs
1.4	Distinction between transverse and longitudinal waves. Transverse vibration in a stretched string, Statement of laws of vibration	2 hrs
2	**Wave Optics (9 hours)**	
2.1	Interference of light-Principle of superposition of waves, Theory of thin films - Cosine law (Reflected system), Derivation of the conditions of constructive and destructive Interference	2 hrs
2.2	Interference due to wedge shaped films -Determination of thickness and test for optical planeness, Newton's rings - Measurement of wavelength and refractive index, Antireflection coatings	
2.3	Diffraction of light, Fresnel and Fraunhofer classes of diffraction, Diffraction grating-Grating equation	2 hrs
2.4	Rayleigh criterion for limit of resolution, Resolving and Dispersive power of a grating with expression (no derivation)	1 hr
3	**Quantum Mechanics &Nanotechnology (9hours)**	
3.1	Introduction for the need of Quantum mechanics, Wave nature of Particles, Uncertainty principle, Applications-Absence of electrons inside a nucleus and Natural line broadening mechanism	2 hrs
3.2	Formulation of time dependent and independent Schrodinger wave equations-Physical Meaning of wave function, Particle in a one dimensional box- Derivation for normalised wave function and energy eigen values, Quantum Mechanical Tunnelling (Qualitative)	4 hrs
3.3	Introduction to nanoscience and technology, Increase in surface to volume ratio for nanomaterials, Quantum confinement in one dimension, two dimension and three dimension-Nano sheets, Nano wires and Quantum dots	2 hrs
3.4	Properties of nanomaterials-mechanical, electrical and optical Applications of nanotechnology (qualitative ideas)	1 hr
4	**Magnetism & Electro Magnetic Theory (9 hours)**	
4.1	Magnetic field and Magnetic flux density, Gauss's law for Magnetic flux	2 hrs

	density, Ampere's Circuital law, Faraday's law in terms of EMF produced by changing magnetic flux	
4.2	Explanation for Magnetic permeability and susceptibility Classification of magnetic materials- para, dia and ferromagnetic materials	1 hr
4.3	Fundamentals of vector calculus, concept of divergence, gradient and curl along with physical significance, Line, Surface and Volume integrals, Gauss divergence theorem & Stokes' theorem	2 hrs
4.4	Equation of continuity, Derivation of Maxwell's equations in vacuum, Comparison of displacement current with conduction current. Electromagnetic waves, Velocity of Electromagnetic waves in free space, Flow of energy and Poynting's vector (no derivation)	4 hrs
5	**Superconductivity &Photonics (9hours)**	
5.1	Super conducting Phenomena, Meissner effect and perfect diamagnetism, Types of superconductors-Type I and Type II	2 hrs
5.2	BCS Theory (Qualitative), High temperature superconductors, Applications of super conductivity	2 hrs
5.3	Introduction to photonics-Photonic devices-Light Emitting Diode, Photo detectors -Junction and PIN photodiodes, Solar cells-I-V Characteristics	2 hrs
5.4	Optic fibre-Principle of propagation of light, Types of fibres-Step index and Graded index fibres, Numerical aperture –Derivation, Fibre optic communication system (block diagram), Industrial, Medical and Technological applications of optical fibre, Fibre optic sensors-Intensity Modulated and Phase modulated sensors	3 hrs

QUESTION BANK

Module – I

Q.No	Questions	CO	KL
1	What do you mean by oscillation?	CO1	K1
2	Explain angular frequency?	CO1	K2
3	Define damped oscillation and forced oscillation	CO1	K2
4	Derive the differential equation of SHM	CO1	K3
5	Derive forced harmonic oscillation	CO1	K3
6	What do you mean by resonance and sharpness of resonance ?	CO1	K1
7	Compare electrical and mechanical oscillation	CO1	K2
8	A transverse wave on a stretched string is described by	CO1	K4

	Y(x,y)=4.0sin(25t+0.016x+π\3) where x and y are in CM and t is in second obtain a) speed b) amplitude c) frequency d) intial phase of origin		
9	State the transverse vibrations of a stretched string	CO1	K2
10	A piece of wire 50 cm long is stretched by a load of 2.5kg and has a mass of 1.44kg.Find the frequency of the second harmonic?	CO1	K4
11	Calculate the speed of transverse wave in a string of cross sectional area1mm^2 under tension of 1kg wt density of wire =10.5*10^3kg/m^3	CO1	K4

Module – II

Q.No	Questions	CO	KL
1	State the conditions for sustained interference	CO2	K2
2	Explain the term coherent source of light	CO2	K1
3	What is diffraction grating?	CO2	K1
4	Derive the relation for n^th diameter ring of newton's ring .Why rings are closer for higher order?	CO2	K3
5	State Rayleigh criterion for resolving power	CO2	K1
6	State the difference between diffraction and interference	CO2	K1
7	Explain fraunhoffer diffraction through a single slit	CO2	K1
8	What is interference and derive the equation for interference on a thin flim ?	CO2	K1
9	Derive the equation for wedge shaped film and explain it	CO2	K2
10	Differentiate between frensel and fraunhofer diffraction	CO2	K3
11	Explain newton's ring and derive its equation	CO2	K1

Module – III

Q.No	Questions	CO	KL
1	Derive mathematical expression for wave nature of the particle	CO3	K3
2	Write about absence of electrons in a nucleus	CO3	K1
3	Derive mathematical expression Schrodinger time independent wave equation	CO3	K3
4	Derive mathematical expression Schrodinger time dependent wave equation	CO3	K3
5	Define quantum mechanical tunneling	CO3	K3
6	What is the physical meaning of wave equation	CO3	K1
7	Derive mathematical expression for normalized wave equation	CO3	K3
8	Derive mathematical equation for energy eigen values	CO3	K3
9	How does optical and electrical property of the nanomaterial differs from the normal materials	CO3	K3
10	Support the statement that "nanomaterials have vital role in electronic industry "	CO3	K3
11	Does nanomaterials have significant role in medical industries? If yes explain briefly	CO3	K4

Module – IV

Q.No	Questions	CO	KL
1	A proton is moving at 12% of the speed of light in the direction which is 20 degrees up from west. It passes through the earth's magnetic field which points due north with a strength of 0.5 x 10^{-4} T. What is the resultant force on the proton? What will the radius of curvature of its path be?	CO4	K3
2	A wire loop is bent into the shape of a square with each side of length 4.5 cm. The loop is placed horizontally on a tabletop with two of the sides oriented north/south and two of the sides oriented east/west. A battery is connected so that a current of 24 mA is produced around the loop; the current flows in the clockwise direction looking from the top. What is the force produced by the earth's magnetic field on each	CO4	K3

	section of current-carrying wire? What is the overall torque on the loop? What would the torque be if the same length of wire were bent into a circle instead of a square (assuming the same current)?		
3	Derive a mathematical expression for magnetic field "B" on a current carrying hollow cylinder and also state the law which relates to current and magnetic field.	CO4	K5
4	How do you differ paramagnetic and diamagnetic material in physical and chemical aspects?	CO4	K2
5	Derive mathematical expression for Maxwell's equations in vacuum	CO4	K2
6	Find the curl of the vector field F =(XYZ ,ZY, XZ) and state whether is it conservative or not	CO4	K4
7	Verify Stokes theorem for the field F =(X^2, X/2, Z^2) on the ellipse S = {(x, y, z) : $4x^2 + y^2 < 4$, z = 0}	CO4	K4
8	Find the divergence and the curl of F = {2xyz, −xy, $-z^2$}	CO4	K3
9	Compare displacement current and conduction current	CO4	K2
10	Define poynting vector	CO4	K3
11	Derive mathematical expression for equation of continuity	CO4	K3

Module – V

Q.No	Questions	CO	KL
1	How do you support the statement that "photonics are used in our daily life".	CO5	K3
2	Explain about BCS theory	CO5	K2
3	Explain about intensity modulated sensors	CO5	K1
4	How does high temperature superconductors can be stated as sensitive and consistent material in medical field.	CO5	K5
5	How critical magnetic field does differs in type –I and type –II semiconductors.	CO5	K3

6	Explain the properties of superconductor with their application	CO5	K3
7	How does superconductivity material is applicable in electronics	CO5	K4
8	Define LED and its working principle with the help of an diagram	CO5	K2
9	a) Calculate the critical angle when the core refractive index is 2.35 and relative refractive index is 5%. b) Find the numerical aperture of an optical fiber having a core refractive index of 3.25 and a cladding refractive index of 0.80	CO5	K5
10	Derive mathematical expression for numerical aperture	CO5	K3
11	Explain about the method of transforming information with the help of pulses of IR lights.	CO5	K3

Module - I

chapter - I

Oscillations

Harmonic Motion.

The displacement of the particle executing oscillatory motion that can be expressed in terms of sine or cosine functions are known as Harmonic motion. The simplest type of harmonic motion is called Simple Harmonic motion (SHM)

Periodic Motion

A motion which repeats itself after regular intervals of time is called periodic motion

Eg:- Oscillations of simple pendulum

motion of Earth around Sun etc..

Oscillatory Motion

A motion in which a particle moves to and fro about a fixed point and repeats the motion after a regular intervals of time is called oscillatory motion

Eg:- Oscillations of simple pendulum and loaded spring

Simple Harmonic Motion

A particle is said to execute simple harmonic motion if it moves to and fro periodically along a path such that the restoring force acting on it is proportional to its displacement from a fixed point and is always directed towards that point

Differential equation for SHM

Consider a particle of mass m executing SHM along a straight line

Then $F \propto$ displacement

$$F \propto -x$$

$$F = -kx$$

where k is the proportionality const as spring constant. The -ve sign indicates that the restoring force acts against displacement

ie $F = -kx$

$$ma = -kx \qquad \left\{ a = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} \right.$$

$$m\frac{d^2x}{dt^2} = -kx$$

$$m\frac{d^2x}{dt^2} + kx = 0 \Rightarrow \text{differential eqn for SHM}$$

OR

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

$$\frac{d^2x}{dt^2} + \omega^2 x = 0 \quad -①$$

Multiplying above eqn by $2\frac{dx}{dt}$

$$2\frac{dx}{dt}\frac{d^2x}{dt^2} + 2\frac{dx}{dt}\omega^2 x = 0 \quad -②$$

Then eqn ② can be written as

$$\frac{d}{dt}\left(\left(\frac{dx}{dt}\right)^2 + \omega^2 x^2\right) = 0$$

Now integrating $\left(\frac{dx}{dt}\right)^2 + \omega^2 x^2 = c \quad -③$

where c is a constant of integration

To find c

The velocity of the particle at the external position is zero. If 'a' is the maximum amplitude (maximum displacement), Then

$$\frac{dx}{dt} = 0 \text{ at } x = a$$

Substitute this in eqn ③

$$c = \omega^2 a^2$$

Then put $c = \omega^2 a^2$ in eqn ③

$$\left(\frac{dx}{dt}\right)^2 + \omega^2 x^2 = \omega^2 a^2$$

$$\left(\frac{dx}{dt}\right)^2 = \omega^2 a^2 - \omega^2 x^2$$

$$\left(\frac{dx}{dt}\right)^2 = \omega^2 (a^2 - x^2)$$

$$\frac{dx}{dt} = \omega \sqrt{(a^2 - x^2)} \quad — ④$$

$\frac{dx}{dt}$ ie Velocity $V = \omega\sqrt{a^2 - x^2}$ — ⑤

from eqn ④ $\frac{dx}{dt} = \omega\sqrt{a^2 - x^2}$

$$\frac{dx}{\sqrt{a^2 - x^2}} = \omega dt$$

Then integrating $\sin^{-1}\left(\frac{x}{a}\right) = \omega t + \phi$

where ϕ is const of integration

i.e, $\frac{x}{a} = \sin(\omega t + \phi$ or $x = a\sin(\omega t + \phi)$ — ⑥

x is the displacement of the particle at any instant t and $(\omega t + \phi)$ is the phase of oscillation at any instant

⇒ Now, the initial phase $\phi = \delta + \pi/2$

The $x = a \sin\left(\omega t + \delta + \pi/2\right)$

$$x = a \cos(\omega t + \delta) \quad — ⑦$$

also represent SHM

if t is increased by $2\pi/\omega$

$$x = a \sin\left(\omega\left(t + \frac{2\pi}{\omega}\right) + \phi\right)$$

$$= a \sin(\omega t + 2\pi + \phi) = a \sin(\omega t + \phi)$$

∴ The eqn repeats itself after a time $\frac{2\pi}{\omega}$, $4\pi/\omega$ etc

Hence $\frac{2\pi}{\omega}$ is called the perior or $T = \frac{2\pi}{\omega}$

$$\omega = \sqrt{\frac{K}{m}} \quad \text{or} \quad T = 2\pi\sqrt{K/m}$$

Damped Harmonic Oscillation

in Free oscillations total energy of the system remains constant.

The decrease in amplitude of an oscillation caused by dissipative forces is called Damping.

{ in Real situations the total energy is dispipated to its surroundings and the amplitude decays to zero }

Damped Harmonic Oscillator.

Damped Harmonic Oscillator particle in a medium Oscillate, when a particle and a damping force acts in the particle and gradually decrease the ampilitude, such an oscillator is called damped Harmonic oscillator and the corresponding motion is called Damped Harmonic Oscillation.

Differential Equation of Damped Harmonic Oscillator

Consider a particle executing damped harmonic oscillation in a medium. The forces acting on it are

i) Restoring force $= -kx$

ii) Damping Force $= -b\frac{dx}{dt}$ where b is called damping constant.

Then $F = f_1 + f_2$

$$m\frac{d^2x}{dt^2} = -kx - b\frac{dx}{dt}$$

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0.$$

$$m\left\{\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x\right\} = 0$$

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$

Put $\frac{b}{m} = 2\gamma$, where γ is damping ~~constant~~ coefficient

$\frac{k}{m} = \omega_0^2$, where ω_0 is the natural angular frequency of the oscillation in the absence of damping force

Then $\frac{d^2x}{dt^2} + 2\gamma \frac{dx}{dt} + \omega_0^2 x = 0$ — ②

This is the differential equation of damped harmonic oscillator.

Solution of the equation

Assume the solution of the form $x = Ae^{\alpha t}$

Then differentiating $\frac{dx}{dt} = A\alpha e^{x} = \alpha x$

$$\frac{d^2x}{dt^2} = \alpha^2 A e^{\alpha t} = \alpha^2 x$$

Substitute the values in eqn ②

$$\alpha^2 x + 2\gamma \alpha x + \omega_0^2 x = 0$$

$$\alpha^2 + 2\gamma\alpha + \omega_0^2 = 0$$

The roots of the eqn $\alpha = \frac{-2\gamma \pm \sqrt{4\gamma^2 - 4\omega_0^2}}{2}$

Then $x = Ae^{(-\gamma \pm \sqrt{\gamma^2 - \omega_0^2})t}$

ie, the solutions. $x_1 = A_1 e^{(-\gamma + \sqrt{\gamma^2 - \omega_0^2})t}$ &

$$x_2 = A_2 e^{(-\gamma - \sqrt{\gamma^2 - \omega_0^2})t}$$

where A_1 & A_2 are constants which depends on the initial values of position and velocity the value of 'γ' determines the behavior of the system.

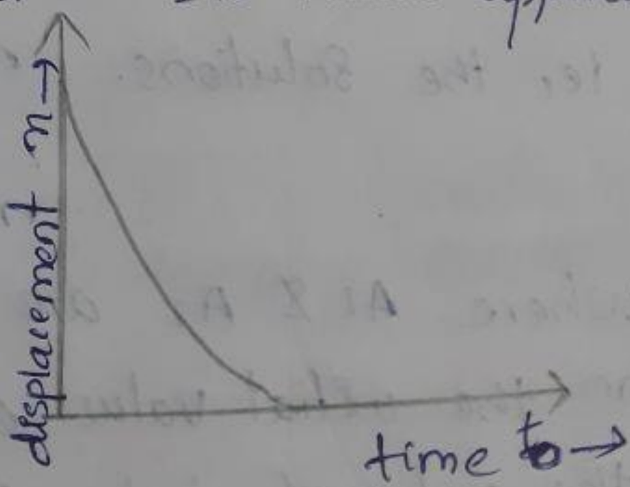
The generate solution is

$$x = A_1 e^{(-r+\sqrt{r^2-\omega_0^2})t} + A_2 e^{(-r-\sqrt{r^2-\omega^2})t} \quad \text{—③}$$

case I Over damped case ($r > \omega_0$)

If the damping is so high such that $r > \omega_0$ then $\sqrt{r^2-\omega_0^2}$ is a real quantity and $\sqrt{r^2-\omega^2}$ is less than r. Thus $(-r+\sqrt{r^2-\omega_0^2})t$ & $(-r-\sqrt{r^2-\omega_0^2})t$ are both $-ve$. So the displacement (x) decays exponentially to zero without any oscillation. This motion is called over damped or dead Beat or Aperiodic

Aperiodic - The particle when once displaced returns to equilibrium position slowly without performing any oscillation. Its main application is in Dead beat



Case ② - Critically damped ($r = \omega_0$).

Applying the condition in eqn ③

Then $\sqrt{r^2 - \omega_0^2} = 0$ or general soln will be

$$x = A_1 e^{-rt} + A_2 e^{-rt} = (A_1 + A_2) e^{-rt}$$

let $A_1 + A_2 = c$, Then $x = ce^{-rt}$

In this eqn there is only one constant and hence does not form the solution by the second order differential equation.

$$\therefore \sqrt{r^2 - \omega_0^2} = h$$

Then eqn ③ becomes

$$x = A_1 e^{-rt+ht} + A_2 e^{-rt-ht}$$

$$= A_1 e^{-rt} e^{ht} + A_2 e^{-rt} e^{-ht}$$

$$= e^{-rt}(A_1 e^{ht} + A_2 e^{-ht})$$

$$= e^{-rt}\left\{A_1\left(1 + ht + \frac{(ht)^2}{2} + \dots\right) + A_2\left(1 - ht + \frac{(ht)^2}{2} \dots\right)\right\}$$

Negleting higher process of h due to its small magnitude

$$x = e^{-rt}\{A_1 + A_1 ht + A_2 - A_2 ht\}$$

$$= e^{-rt}\{(A_1 + A_2) + (A_1 - A_2) ht\}$$

Put $A_1 + A_2 = P$ & $(A_1 - A_2)h = \phi$

Then $x = e^{-rt}\{P + \phi t\}$ — (4)

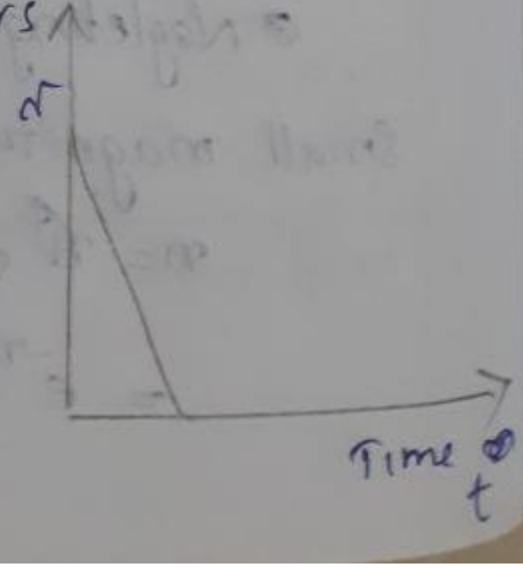
From the above eqn initially as t increases $P+\phi t$ increase and the displacement also increase out as the time ~~~~ increases the exponential form increases more than $(P+Qt)$ term. Then the displacement decreases from maximum value to zero quickly. The motion neighther damped nor oscillatory ∴ This motion is called ~~~~ critically damped or Just oscillatory. ~~This motion is calle~~ Here the particle aquires the position of equlibrium very rapidly

Applications :- pointer type instruments like galvanometer where the pointer moves at once to have a correct position and stay at this position without any ~~~~ oscillation.

⇒ Automobile shock absorbers

⇒ Door close mechanisms

⇒ Re coil mechanism in guns.



case ③ under damped case ($\gamma < \omega_0$)

Here $\sqrt{\gamma^2 - \omega^2}$ is imaginary

$$\sqrt{\gamma^2 - \omega^2} = i\omega = i\sqrt{\omega_0^2 - \gamma^2}$$

Then eqn ③ will be

$$x = A_1 e^{(-\gamma + i\omega)t} + A_2 e^{(-\gamma - i\omega t)t}$$

$$x = e^{-\gamma t}\left(A_1 e^{i\omega t} + A_2 e^{-i\omega t}\right)$$

$$= e^{-\gamma t}\left\{A_1(\cos\omega t + i\sin\omega t) + A_2(\cos\omega t - i\sin\omega t)\right\}$$

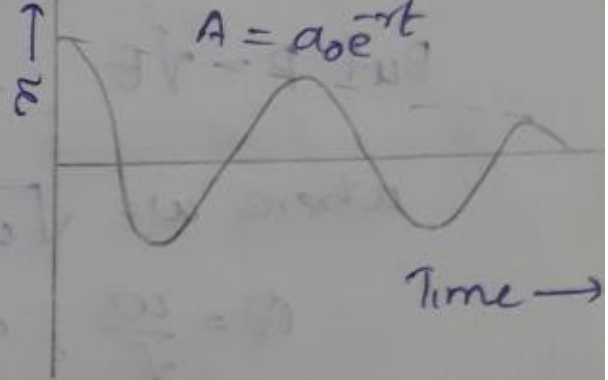
$$x = e^{-\gamma t}\left\{A_1 + A_2(\cos\omega t) + i(A_1 - A_2)\sin\omega t\right\}$$

put $A_1 + A_2 = a_0 \sin\phi$ & $i(A_1 - A_2) = A_0 \cos\phi$

ie $x = A_0 e^{-\gamma t}(\sin\phi \cos\omega t + \sin\omega t \cos\phi)$

$$x = a_0 e^{-\gamma t} \sin(\omega t + \phi) \quad -⑤$$

eqn ⑤ shows that motion is oscillatory. The amplitude $a_0 e^{-\gamma t}$ is not a constant but decreases with time



Applications

⇒ Ballistic Galvanometer

effect of damping

1. The amplitude of oscillation decreases exponentially with time.

2. The frequency of osillation of a damped oscillator is less than the frequency of damped oscillations.

Quality Factor

Quality factor is defined as 2π times the ratio of energy stored to the energy loss per period.

$$Q = 2\pi \frac{\text{energy stored}}{\text{energy loss per period}}$$

$$= \frac{2\pi E}{PT}$$

$$\left\{ Q = \frac{2\pi E}{-\frac{dE}{dt} \times t} = 2\pi \frac{E}{PT} \right.$$

P = power dissipation $= -\frac{dE}{dt}$

But $P = \gamma E$ $\therefore Q = \frac{2\pi E}{\gamma E T} \Rightarrow \frac{2\pi}{\gamma T} = \frac{2\pi}{\gamma \left(\frac{2\pi}{\omega}\right.}$

where $\omega = \sqrt{\omega_0^2 - \gamma^2}$

$Q = \frac{\omega}{\gamma}$, $\gamma = \frac{b}{2m}$, b is damping const

Then $Q = \frac{2\omega m}{b}$ & Q is dimensionless

Forced or Driven Harmonic Oscillations

If an external periodic force is applied on a damped harmonic oscillator, the oscillatory system is called driven or Forced Harmonic oscillator.

or

An oscillator which is forced to oscillate with a frequency other than its natural frequency is known as forced or driven harmonic oscillator

The forces acting on a forced oscillator are

1) Restoring force $-kx$

2 The damping Force $-bV$

3 External driving periodic force $F_0 \sin \omega_f t$, where F_0 is amplitude

$$\therefore F = F_1 + F_2 + F_3$$

$$ma = -kx - bbV + F_0 \sin \omega_f t$$

$$m\frac{d^2x}{dt^2} = -kx - bV + F_0 \sin \omega_f t \quad \text{—} \; ①$$

$$\frac{d^2x}{dt^2} + \frac{kx}{m} + \frac{b}{m} V = f_0 \sin \omega_f t \quad \text{—} \; ②$$

but $V = \frac{dx}{dt}$

Then eqn ② becomes

$$\frac{d^2x}{dt^2} + \frac{k}{m}x + \frac{b}{m}\frac{dx}{dt} = f_0 \sin\omega_f t \quad —③$$

where $\sqrt{k/m} = \omega_0$, The natural frequency of the body and $\frac{b}{m} = 2\alpha$, the damping constant for unit mass & $\frac{f_0}{m} = f_0$

Then $\frac{d^2x}{dt^2} + 2\alpha\frac{dx}{dt} + \omega_0^2 x = f_0 \sin\omega_f t \quad —④$

above eqn represent differential eqn for Forced harmonic oscillator.

Solution.

$$x = A\sin(\omega_f t - \theta) \quad — ⑤$$

$$\frac{dx}{dt} = A\omega_f \cos(\omega_f t - \theta)$$

$$\frac{d^2x}{dt^2} = -A\omega_f^2 \sin(\omega_f t - \theta)$$

Sub this in eqn ④

$$-A\omega_f^2 \sin(\omega_f t - \theta) + 2\alpha A\omega_f \cos(\omega_f t - \theta) + \omega_0^2 A\sin(\omega_f t - \theta)$$
$$= f_0 \sin(\omega_f t - \theta + \theta)$$

(In RHS, we added & substracted θ)

ie, $-A\omega_f^2 \sin(\omega_f t - \theta) + 2\gamma A\omega_f \cos(\omega_f t - \theta) +$
$\omega_0^2 A \sin(\omega_f t - \theta) = f_0 \left(\sin(\omega_f t - \theta) \cos\theta + \cos(\omega_f t - \theta) \sin\theta \right)$

Taking like terms we get

$$(-A\omega_f^2 - f_0 \cos\theta + \omega_0^2 A) \sin(\omega_f t - \theta) + (2\gamma A\omega_f - f_0 \sin\theta) \cos(\omega_f t - \theta) = 0 \quad -(7)$$

To find A

equating the coefficients of $\sin(\omega_f t - \theta)$ & $\cos(\omega_f t - \theta)$, which are zero seperating

$$\therefore -A\omega_f^2 - f_0 \cos\theta + \omega_0^2 A = 0$$

$$-A\omega_f^2 + \omega_0^2 A = f_0 \cos\theta \quad -(8)$$

$$2\gamma A\omega_f - f_0 \sin\theta = 0$$

$$2\gamma A\omega_f = f_0 \sin\theta \quad -(9)$$

Squaring and adding (8) & 9 we get

$$(-A\omega_f^2 + \omega_0^2 A)^2 + 4\gamma^2 A^2 \omega_f^2 = f_0$$

$$A^2 \left\{ (\omega_0^2 - \omega_f^2)^2 + 4\gamma^2 \omega_f^2 \right\} = f_0^2$$

$$A = \frac{F_0}{\sqrt{(\omega_0^2 - \omega_f^2) + 4\gamma^2 \omega_f^2}} \quad -(10)$$

which is the amplitude of force oscillation.

Phase difference

Dividing eqn ⑨ by ⑧

$$\tan\theta = \frac{2\gamma A\omega_f}{A(\omega_0^2-\omega_f^2)} = \frac{2\gamma\omega_f}{\omega_0^2-\omega_f^2} \quad \text{—— (11)}$$

This gives the phase difference b/w forced oscillation & applied force

Sub for A in eqn ⑤

$$x = \frac{f_0}{\sqrt{(\omega_0^2-\omega_f^2)+4\gamma\omega_f^2}} \sin(\omega_f t-\theta) \quad \text{—— (12)}$$

Above eqn shows that the system vibrate with the frequency of the applied periodic force and having a phase difference of θ

Case I Low driving frequency $\omega_f < \omega_0$

$$A = \frac{f_0}{\sqrt{(\omega_0^2-\omega_f^2)+4r^2\omega_f^2}}$$

negleting ω_f^2, since ω_f is less than ω_0

$$A = \frac{f_0}{\omega_0^2} = \frac{f_0/m}{k/m} = f_0/k$$

Amplitude ~~do~~ not depend on mass of oscillating body

Case II ($\omega_f = \omega_0$) Resonance

Resonance is a phenomenon that occurs when a vibrating system or external force drives another system to oscillate with greater amplitude at a specific frequency

Here $\omega_f = \omega_0$

$$\therefore A = \frac{f_0}{2r\omega_f} \quad \& \quad \tan\theta = \frac{2r\omega_f}{\omega_0^2 - \omega_f^2} = \infty$$

or $\theta = \frac{\pi}{2}$

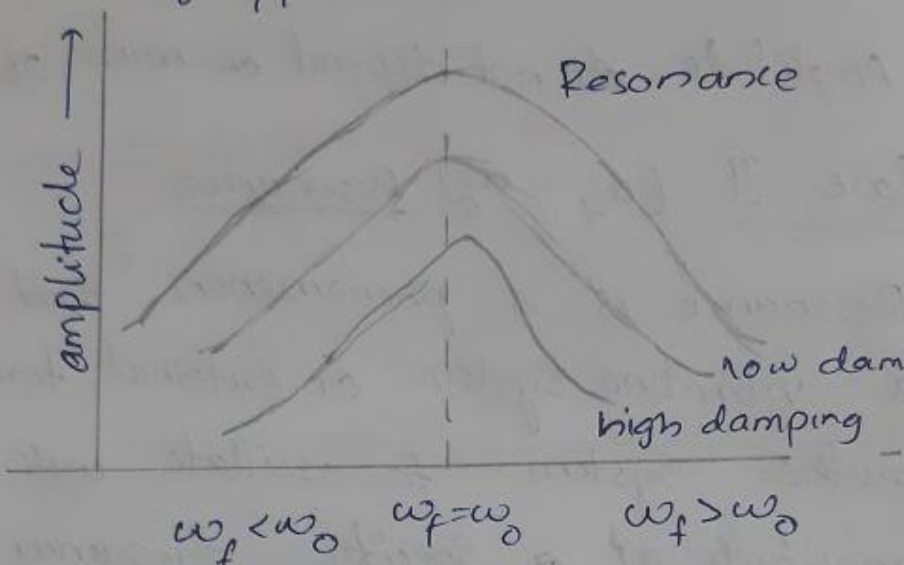
Case III High Driving Frequency $\omega_f > \omega_0$

$$A = \frac{f_0}{\sqrt{(\omega_0^2 - \omega_f^2) + 4r^2\omega_f}}$$

when $\omega_f > \omega_0$

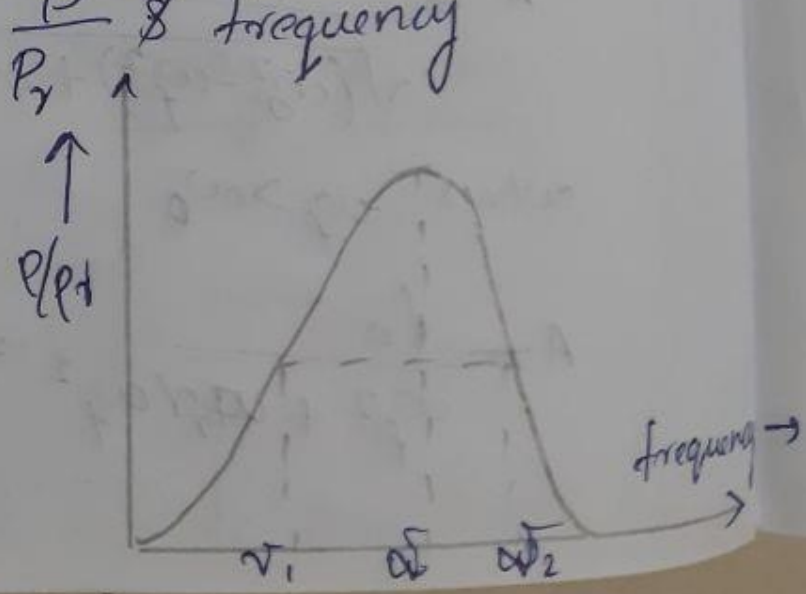
$$A \approx \frac{f_0}{\omega_f^2 + 4r\omega_f^2} = \frac{f_0}{\omega_f^2} \text{ for low damping}$$

Variation Of Amplitude A with frequency ω_f of applied force



Sharpness Of Resonance

The rate of change (Fall) of amplitude with the change of frequency of the applied periodic force on eighther side of resonant frequeny is known as sharpness of resonance let P_r is the power absorbed at resonance, P is the power absorbed at any frequeny ν a graph is drawn between $\frac{P}{P_r}$ & frequency



LCR Circuit as Electrical analogue of Mechanical Oscillator.

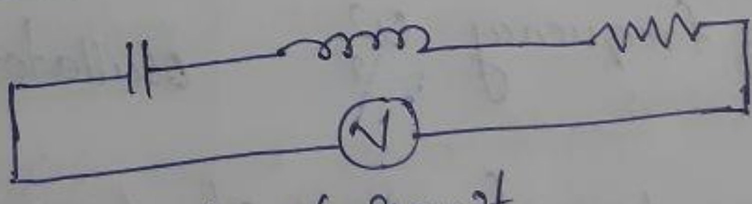
Oscillations in an LC Circuit.

A pure LC circuit is an electrical analogue if the simple pendulum. In the case of simple pendulum energy alternates between the ~~practical~~ potential and kinetic energy. In cases of LC circuit energy is alternately shared in the capacitor as electric feild and in inductor as magnetic feild.

In LC circuit frequency of oscillation

$$n = \frac{1}{2\pi\sqrt{LC}}$$

Forced Oscillation in A Series LCR Circuit



$$V = V_0 \sin \omega t$$

Applying kirchoff's Voltage law to the circuit

$$V_L + IR + V_C = V_0 \sin \omega t$$

$$L\frac{di}{dt} + IR + \frac{Q}{C} = V_0 \sin \omega t$$

$$L\frac{d^2q}{dt^2} + iR + \frac{q}{c} = V_0 \sin\omega t$$

$$\text{ie, } \frac{d^2q}{dt^2} + \frac{R}{L}\frac{dq}{dt} + \frac{q}{c} = \frac{V_0 \sin\omega t}{L}$$

This is the differential equation in case of Forced Oscillation..

Mechanical Oscillator	Electrical Oscillator
Displacement x	charge q
Velocity $\frac{dx}{dt}$	Current $\frac{dq}{dt}$
mass m	Inductance L
damping coefficient γ	Resonance R
Force amplitude F_0	voltage amplitude V_0
Driving frequency ω_f	oscillator frequency ω_0

The angular frequency of damped oscillations in LCR circuit is given by

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Waves

Wave Motion.

wave is a form of disturbance which propagate through space. It transfers energy from one ~~given~~ region of space to another region without transfering matter along with.

Mechanical Waves

Waves which require a medium for their propagation are known as mechanical waves.

Electromagnetic Waves

waves which do not require a medium for their propagation are known as E.M waves

Progressive Waves

A wave which travel onward with the transfer of energy across any medium is known as progressive wave it is ~~known~~ moving continuously along the same direction.

Stationary Wave.

The progressive waves travelling through the same medium in opposite direction form a stationary or standing wave. stationary wave do not transfer energy from one place to another. The crest & trough and zone of compression & rarefraction merely appear and dissapear in fixed positions.

wavelength

⇒ The distance b/w two consecutive crusts or troughs is called wavelength by transverse wave

or

⇒ wavelength is also defined as the distance travelled by the wave during the time a particle of the medium complete n one vibration about its mean position. It is denoted by λ

ie, $v = \lambda \nu$ or $\lambda = \frac{v}{\nu}$

Transverse Wave Motion

when the particle of the medium vibrate about their mean position in a direction perpendicular to the direction of propagation of a wave, it is called a transverse wave

eg:- Light wave, waves produced in a string under tension

Longitudinal wave motion

when the particle of the medium vibrate about their mean position parallel to the direction of the propagation of waves it is called a longitudinal wave.

Eg:- Sound waves etc.

The distance b/w two consecutive compressions or rarefractions is called wavelength of longitudinal wave.

General equation of wave Motion.

one dimensional waves

waves travelling along a line or axis is known as one dimensional wave.

Eg:- waves through a string or through a spring

Consider a wave pulse moves in a direction with a velocity v after a time t the pulse has moved a distance vt.

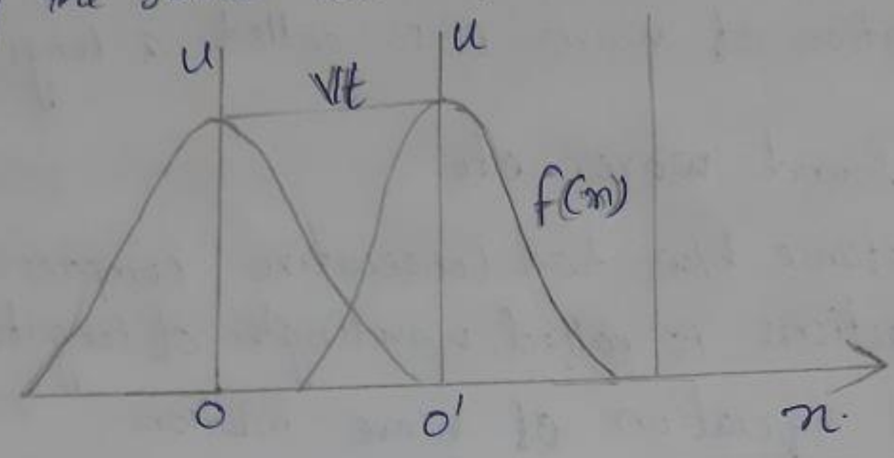
let $u(x,t)$ be transverse displacement at x, which is a fn of x & t

$$\text{ie, } \quad u(x,t) = f(x,t)$$

$$\text{At } x=0, \; u(x,0) = f(x,0)$$

when F describes the shape of wave function. after a time t the pulse travelled a distance

Vt since the shape of the wave doesnot change as it travels the wave form must be represented by the same wave function.



Then $x' = x - vt$

or $u(x,t) = f(x - vt)$

if the pulse moving in opposite direction

$$u(x,t) = f(x + vt)$$

Sinusoidal waves

Consider a transverse wave having a sinusodal shape as $t=0$ i.e.,

$u(x,0) = f(x,0) = a \sin \omega t = a \sin \frac{2\pi}{\lambda}$

If the wave travels with a velocity v in the direction of x axis

$$u(x,t) = a \sin \frac{2\pi}{\lambda}(x - vt)$$

$\frac{2\pi}{\lambda}(x - vt)$ is called phase of wave at time t

ange
ented

$$u = a \sin \frac{2\pi}{\lambda}(x - vt)$$

$$= a \sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{\lambda}vt\right)$$

$$u = \sin(kx - \omega t)$$

Particle Velocity And wave Velocity

particle velocity is the velocity of the particle of the motion undergoing SHM when a harmonic wave travels through it

$$v_p = \frac{dy}{dt}$$

wave velocity:

wave Velocity is the velocity of the wave moving in a direction for a wave frequency with a perpendicular ~~force~~ phase.

Differentiating, ~~dx~~ vd dx − vdt = 0

$$\text{or } v = \frac{dx}{dt}$$

General wave Equation

1D wave equation

The equation of wave motion is given by

$$u = f(x - vt) \quad \text{--- (1)}$$

$$u = a \sin \frac{2\pi}{\lambda}(x - vt)$$

$$= a \sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{\lambda}vt\right)$$

$$u = \sin(kx - \omega t)$$

Particle Velocity And wave Velocity

particle velocity is the velocity of the particle of the motion undergoing SHM when a harmonic wave travels through it

$$v_p = \frac{dy}{dt}$$

wave velocity:-

wave Velocity is the velocity of the wave moving in a direction for a wave frequency with a perpendiculus phase.

Differentiating, $d x - v dt = 0$

$$\text{or } v = \frac{dx}{dt}$$

General wave Equation

1D wave equation

The equation of wave motion is given by

$$u = f(x - vt) \quad \text{—} (1)$$

Differentiating eqn ① WRT x twice

$$\frac{du}{dx} = f'(x - vt) \quad -②$$

$$\frac{d^2u}{dx^2} = f''(x - vt) \quad -③$$

differentiating eqn ① W.R.T t twice

$$\frac{du}{dt} - f'(x - vt).v \quad -④$$

$$\frac{d^2u}{dt^2} = v^2 f''(x - vt) \quad -⑤$$

sub eqn ③ in ⑤ we get

$$\frac{d^2u}{dt^2} = v^2 \frac{d^2u}{dx^2} \text{ or } \frac{d^2u}{dx^2} = \frac{1}{v} \frac{du^2}{dt^2} \quad -⑥$$

This is called 1D differential eqn of wave motion

From eqn ② & ④ $\frac{du}{dt} = v \frac{du}{dx}$

$\frac{du}{dt} \Rightarrow$ particle velocity

$V \Rightarrow$ wave velocity & $\frac{du}{dx} \Rightarrow$ slope of my wave

ie, particle velocity = wave velocity × slope of my wave

<u>Solution</u>

solution in the form $\frac{d^2u}{dx^2} = \frac{1}{V^2} \frac{d^2u}{dt^2} \quad -①$

$$u(x,t) = X(x)T(t) \quad -②$$

$X(x)$ is a fn of x & $T(t)$ is a fn of t

Differentiating ① twice WRT x & WRT t and substitute in eqn ②

$$\frac{du}{dx} = \frac{dX}{dx} T \quad \& \quad \frac{du}{dt} = X \frac{dT}{dt}$$

$$\frac{d^2u}{dx^2} = \frac{d^2X}{dx^2} T \qquad \frac{d^2u}{dt^2} = X \frac{d^2T}{dt^2}$$

$$\text{ie} \quad T\frac{d^2X}{dx^2} = \frac{X}{V^2} \frac{d^2T}{dt^2} \quad — ③$$

diving eqn ③ by XT

$$\frac{1}{X} \frac{d^2X}{dx^2} = \frac{1}{V^2} \frac{1}{T} \frac{d^2T}{dt^2} \quad - ④$$

$$\frac{1}{X} \frac{d^2x}{dx^2} = -k^2 \quad \& \quad \frac{d^2X}{dx^2} = -k^2x \quad — ⑤$$

Similiarly $\frac{d^2T}{dt^2} = k^2V^2T$ —⑥

eqn ⑤ & ⑥ are 2nd order differential equations & their solutions can be written in terms of exponential forms

ie, $X(x) = Ce^{\pm ikx}$ — ⑦

$T(t) = Ce^{\pm i\omega t}$ — ⑧

combining these, $u(x,t) = Ce^{(ikx \pm i\omega t)}$ or

$$u(x,t) = Ce^{i(kx \pm \omega t)}$$

C is a constant & can be found by initial condition.

3 Dimensional wave Equation

In 3 Dimension the wave eqn can be written as

$$\frac{d^2u}{dx^2} + \frac{d^2u}{dy^2} + \frac{d^2u}{dz^2} = \frac{1}{V^2}\frac{d^2u}{dt^2} \text{ or}$$

$$\nabla^2 u = \frac{1}{V^2}\frac{d^2u}{dt^2} \quad \text{— (7)}$$

where ∇^2 is the laplacian operator defined by $\nabla = \frac{d^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}$

Eqn (7) represents the diff eqn for a wave propagating in any 3D space

Soln

The solution of 3D wave eqn can be

$$u(x,y,z,t) = ae^{i(\vec{k}\cdot\vec{r} \pm \omega t + \phi)}$$

where a & k are constants & they are the amplitude and phase of the wave respectively

$\vec{k} = k_x\hat{i} + k_y\hat{j} + k_z\hat{k}$ is a Vector along the direction propagation and is called propagation Vector

$$|\vec{k}| \sqrt{k_x^2 + k_y^2 + k_z^2} \ \&$$

as

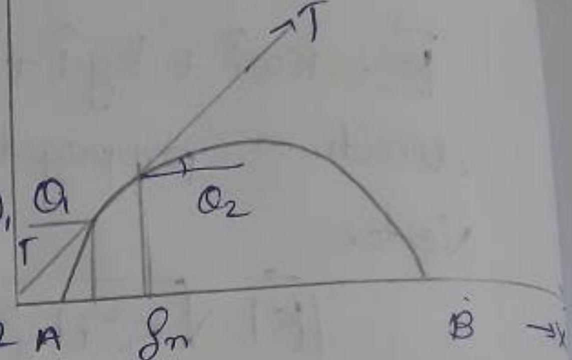
$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

Transverse Wave in a stretched string

consider a string of length l, stretched b/w two points A & B by a tension. Let it be plucked at the centre and let free. It vibrates transversely. These vibrations are simple harmonic. Let the normal position of the string correspond to x axis & the displacement be along y axis the force acting to bring any element of the string back to equilibrium position is the component of tension acting right angle to it. Consider a small element of length δx. The tangents at P & Q make angle θ_1 & θ_2 with the horizontal resolving the tension along x axis & y axis net force on PQ acting on x & y directions are

$f_x = T\cos\theta_2 - T\cos\theta_1$

$f_y = T\sin\theta_2 - T\sin\theta_1$



For small oscillation θ_1 & θ_2 are small

$$\cos\theta_1 = \cos\theta_2 = 1$$

also $\sin\theta_1 = \tan\theta_1$ & $\sin\theta_2 = \tan\theta_2$

Then $f(x) = 0$

$$f_y = T\tan\theta_2 - T\tan\theta_1$$

so net force acting on element δx in the displaced position is along y-axis

$$f_y = T(\tan\theta_2 - \tan\theta_1)$$

$$T\,\delta\tan\theta$$

$$T\,\delta\frac{dy}{dx}$$

If m is mass per unit length of string, mass of element $\delta x = m\,\delta x$

acceleration $= \frac{d^2y}{dx^2}$

$$m\,\delta x \frac{d^2y}{dt^2} = T\,\delta\frac{dy}{dx}$$

$$m\frac{d^2y}{dt^2} = T\frac{\delta}{\delta x}\frac{dy}{dx}$$

$$\frac{m}{T}\frac{d^2y}{dt^2} = \frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dt^2} = \frac{m}{T}\frac{d^2y}{dt^2}$$

This is the differential eqn of a vibrating string comparing this eqn by standard wave eqn

$$\frac{d^2y}{dx^2} = \frac{1}{V^2}\frac{d^2y}{dt^2}$$

$$\frac{1}{V^2} = \frac{m}{E}$$

$V^2 = \frac{T}{m}$ or $V = \sqrt{T/m}$ ⇒ Velocity of transverse wave on a stretched string

$V = \nu\lambda$

$\nu = \frac{V}{\lambda}$ or $\nu = \frac{1}{\lambda}\sqrt{T/m}$ ⇒ Frequency of transverse wave devloped in a stretched string.

Inter ference

Module ②

Interference

The re modification of light energy due to the Superposition of the light waves of the same amplitude same frequency and of constant phase difference is called interference

OR

The phenomenon of interference of light is due to the Superposition of two or more light waves by the same amplitude, same frequency and of constant phase difference

Superposition principle

According to Superposition principle when two or more waves meets in a region, the resultant displacement in the region is the Vector Sum of the individual displacements ie, $y_1 = a_1 \sin \omega t$ & $y_2 = a_2 \sin(\omega t + \delta)$

The resultant displacement $y = y_1 + y_2$

Resultant amplitude

$$A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\delta$$

when $\delta = 0, 2\pi, 4\pi \cdots 2n\pi$

$$A^2 = (a_1 + a_2)^2 \Rightarrow A = a_1 + a_2 \Rightarrow \text{Manimum}$$

when $\delta = \pi, 3\pi, 5\pi \cdots (2n+1)\pi$

$$A^2 = (a_1 - a_2)^2 \Rightarrow A = a_1 - a_2 \Rightarrow \text{Manimum}$$

Condition For constructive interference (For maxima)

⇒ when crest of one wave meets with crest of another or trough of one meets with trough of other then the resultant amplitude to manimum ⇒ constructive interference

Condition ⇒

Phase difference = $2n\pi$, $n = 0, 1, 2 \cdots$

path difference = $n\lambda$, $n = 0, 1, 2 \cdots$

λ path difference = 2π

Condition for destructive interference (for minima)

when crest of one wave meets with trough of another, then, the resultant intensity and amplitude is maximum → Destructive interference

Condition :- phase difference $(2n+1)\pi$, $n = 0, 1, 2 ..$

path difference - $(2n+1)\frac{\lambda}{2}$, $n = 0, 1, 2 ...$

Condition for permanent interferance pattern

→ Source must be coherent

→ Light waves from one source shoul superimpose at the same time and at the same place

→ Two sources should be very close to each other

Coherance

The source of light is said to be coherant, when the light waves emerging from the source must have same amplitude, same frequency and constant phase difference

Eg:- Two slits illuminated by a monochromatic screen

→ A source of light and its rejected light image

→ Two refracted images of same source

Two Types of Interference.

Interference is divided into two types depending on the mode of production of interference pattern

① **Interference produced by the division of wavefront**

The incident wavefront is divided into two points by ~~rejection~~ reflection, refraction, diffraction and total internal reflection. Now these two divided points of turns unequal distance through the medium and then they combine together to produce interferance pattern.

Eg:- Young's double slit Experiment.

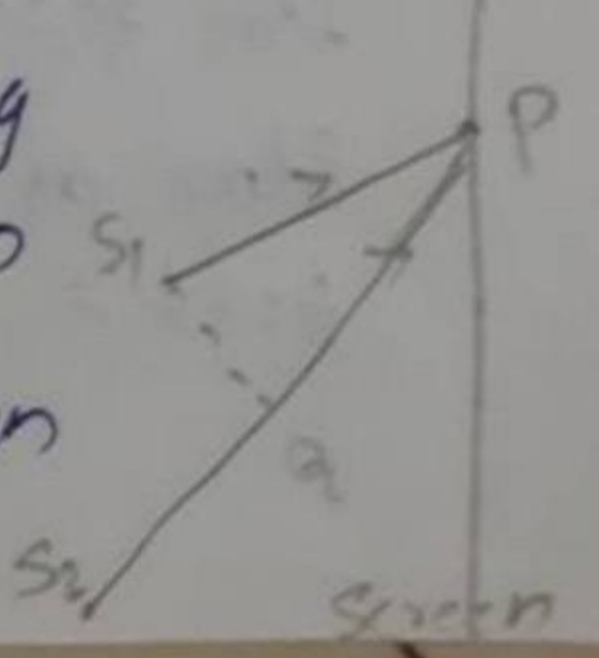
Interferance produced by the division of Amplitude

The amplitude or intensity of the incident light is divided into two parts by parallel reflection or refraction. These two divided parts of wavefront travel unequal distances through the medium and then they combine together to produce interferance pattern.

Eg:- Newtons ~~⊕~~ Experiment

conditions for Constructive & distructive interferance

S_1 & S_2 two coherant sources ~~r~~esting waves of wavelength. Consider a point P on a screen the path difference between the point p is $S_2P - S_1P = S_2Q$



For constructive interferance at p, ~~[illegible]~~ i.e to produce a bright point at p, the path difference between the curves reaching p ~~[illegible]~~ must be even ~~[illegible]~~ or an integral multiple of wavelength λ

ie, $S_2Q = 0, \lambda, 2\lambda \ldots$

or $\boxed{S_2Q = n\lambda}$

⇒ For destructive interference at p, the path difference between the waves ~~[illegible]~~ meeting p must be an odd multiple of $\lambda/2$

ie, $S_2Q = \lambda/2, 3\lambda/2, 5\lambda/2 \ldots$

$= (n+1/2)\lambda$

$\boxed{S_2Q = (2n+1)\frac{\lambda}{2}}$ $n = 0, 1, 2, 3 \ldots$

Interferance of light ~~produced~~ reflected from plane parallel thin film

when a beam of light falls on a thin transparent film a part of light is reflected from one top surface of the film and a part of light is reflected from the lower surface of the film. These two reflected rays interfere if the incident light is white, the film appears beautifully coloured. This is why a film of oil on the surface of cover or a soap bubble appears coloured in sunlight.

Diffraction

It is the phenomenon of bending of light round the edges of an obstack or encroachment of light into the geomatrical shadow of the obstacle

Fresnel diffraction

Statement: The diffraction pattern created by the waves with which is passing through an aperture or around an object, when viewed from relatively close to the object

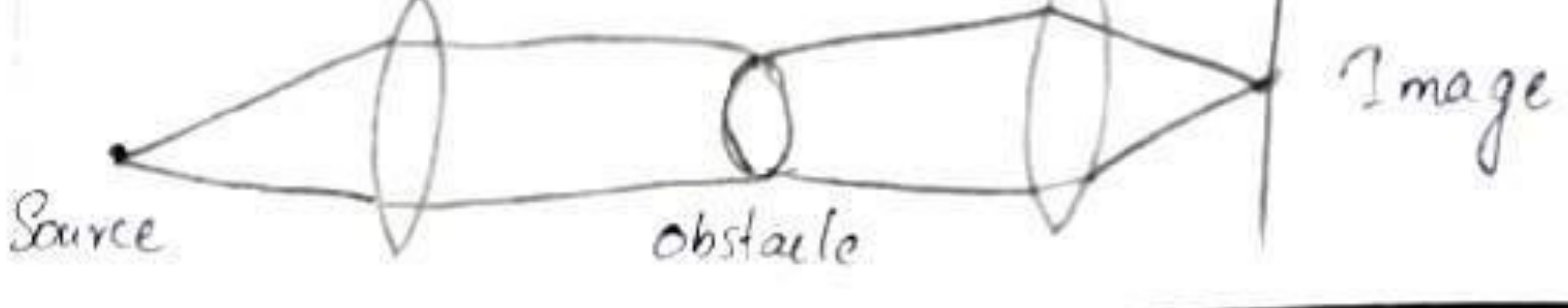
OR

The diffraction of light, when the source (light) and screen are at finite distance from the obstacle

- The wavefront falling on the obstacle is spherical or cylindrical
- Lens are not used

Fraunhofer diffraction

The diffraction causes due to source of light which is at infinite distance from the obstacle



→ The wave-front falling on the obstacle are plane

→ Convex lens are used (converging lens)

Fraunhofar diffraction at a single slit

A plane wave-front of monochomatic light of wavelength (λ) passes through the slit AB with width a. Huggens principle states that each point on the wavefront behaves like a secondary waves. so slit AB is an source of point The centre of the 2/10 known as 'O'.

The waves proceeding from sources are straight and parallel to the OP focused on the point 'p'. They rays are covering equal path and same phase without any path difference and resolves the point p and these leads to maximum brightness due to constructive reinforcement of waves. Thus Bright band is occured at the point P. known as zero order central maximum.

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A point on the screen which is just above the point with an angle θ, an line AM is drawn perpendicularly and beyond this point the waves have same paths

BM is the path difference between two

So $Bm = a \sin\theta$ —— ①

(consider triangle ABM $\sin\theta = \frac{BM}{AB}$)

$BM = \lambda$ (wavelength of light)

① → $\lambda = a \sin\theta$ —— ②

The total distance between the slits is a. so by considering the midpoint 'O' AO and BO is $a/2$ where it is half of "a" (total distance)

$\therefore AO = B = a/2$ —③

The waves proceeding from O and B are traveling along ON and BM reaches the point the point (due to lens)

From the equation. no ②

$$n\lambda = (a+b)\sin\theta$$

If $n-1 \rightarrow$ First order principle maxima

$n=2 \rightarrow$ Second order principle maxima

$n=4 \rightarrow$ Third order principle maxima

There are N lines /unit length of grating [illegible]

There N slits are,

$$N(a+b) = 1 \rightarrow \text{unit length}$$

$$a+b = 1/N \quad -③$$

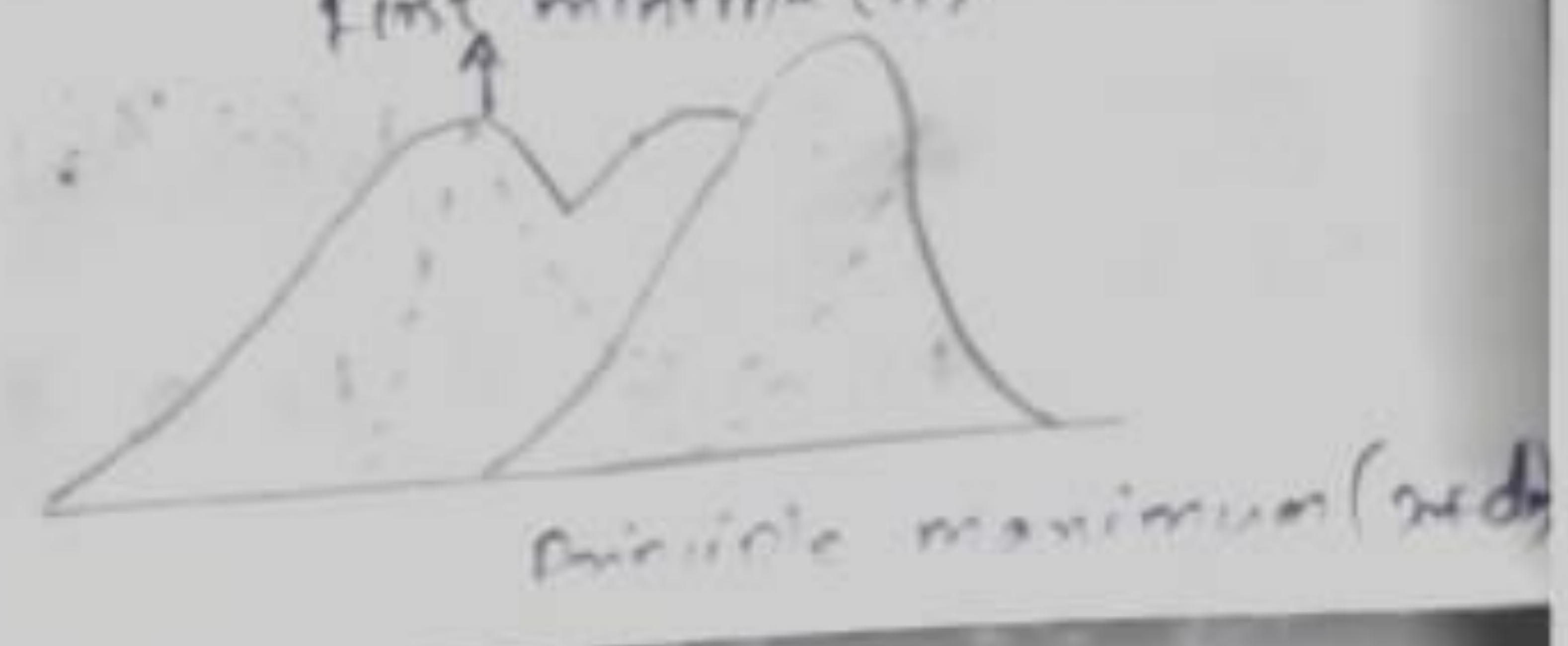
Sub eqn ③ in ② $\rightarrow$

$$\frac{1}{N}\sin\theta = n\lambda$$

$$\text{or } \boxed{\sin\theta = nN\lambda} \rightarrow \text{Grating law or Equation}$$

Ray leigh's Creterion For Resolution of Spectral lines

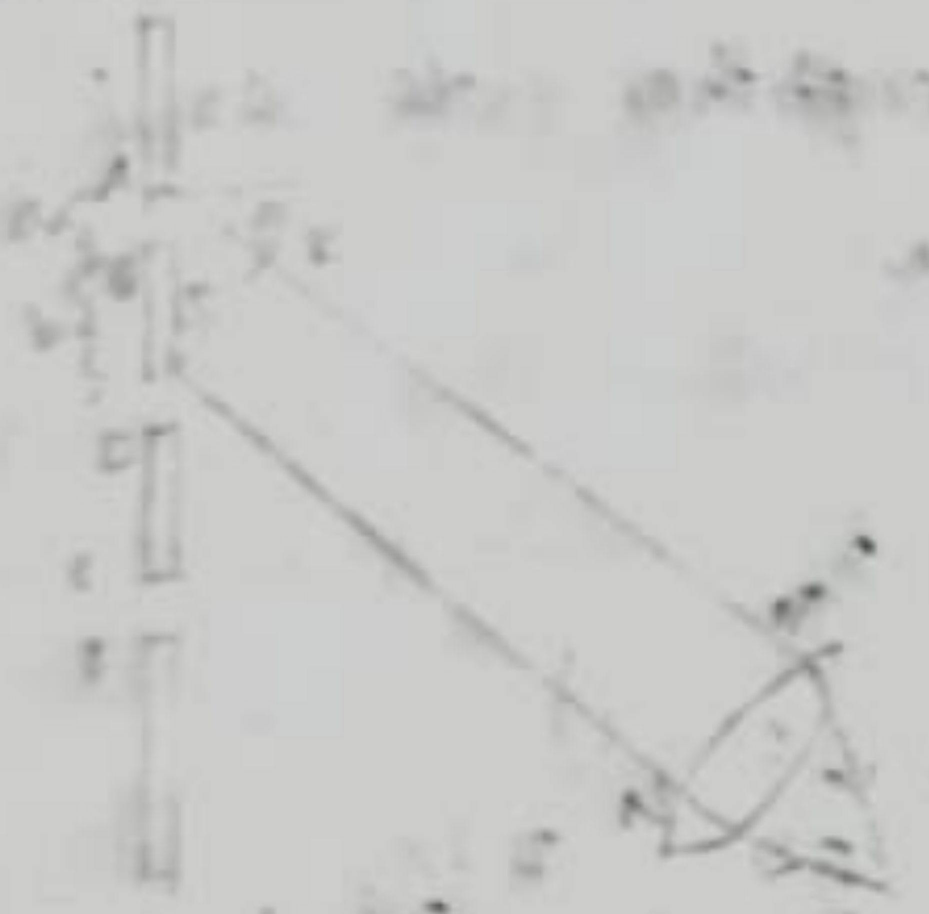
It states that when one principle maximum falls on the other first minimum, [illegible] same order then both the waves will be visible seperately



Diffraction Grating by slits.

Two waves from the corresponding points A & C of adjacent slits. Let λ be the wavelength and θ be the angle of diffraction with the normal to the grating. They travel along Am and CN & AK perpendicular to the line Am path.

path difference is AK



ΔACK

$\sin\theta = \frac{AK}{AC}$

$\therefore AK = AC\sin\theta$

$AK = a+b\sin\theta$ —(1) $[AC = a+b]$

Where AK is the path difference (represented by nλ)

$\therefore n\lambda = (a+b)\sin\theta$ —(2) (when two waves interference constructive)

The waves of wavelength λ originate from different corresponding points with diffracted angle θ reinforce and give a bright line at

Resolving Power Of Gratting

Resolving power of grating is defined as the measure of its ability to spatially seperate two wavelengths.

- In Grating there are N slit and path difference when they reach a point on the screen. the path difference between the waves from adjacent slits is changed by λ/N_1. If grating has two halves then the path difference is $\lambda/2$

According Rayleigh's criterion for Resolution Two seperate lines are just resolved when the principle maximum of n^{th} order for $\lambda + d\lambda$ falls on the first minimum of the same order for λ. Then the angle difference is same

n^{th} Order principle maximum for $\lambda + d\lambda$ is

$$(a+b)\sin\theta = n(\lambda + d\lambda) \quad -(1)$$

$(a+b)$ = grating constant

n^{th} Order minima

$$a+b \sin\theta = n\lambda + \lambda/N_1 \quad -(2)$$

$N_1 \rightarrow$ Total no of slits

Substitute ② in ①

$n(\lambda + d\lambda) = n\lambda + \lambda/N_1$

$n\lambda + n\,d\lambda = n\lambda + \lambda/N_1$ — ③

By simplifying above equation

$n\lambda + n d\lambda = n\lambda + \lambda/N_1$

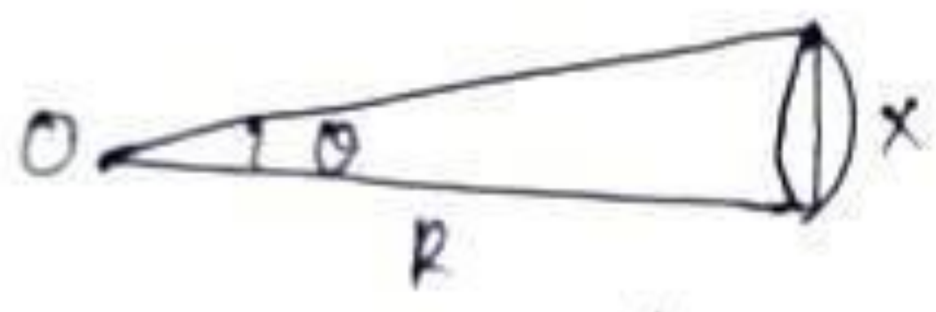
$N_1 n d\lambda = \lambda$

$$\boxed{N_1 N = \lambda/d\lambda}$$ → Resolving power of grating

when we use lens the above eqn can be written as $\theta_N = 1.22\lambda/D$

The condition for Rayleigh's criterion for minimum angle of resolution using a lens with daimeter 'D' at a wave length λ is given by

$$\theta_{mini} = \frac{1.22\lambda}{N}$$



Dispresive power of a grating

It is known as the ratio of change in angle of diffraction to the corresponding cange in wavelength let λ and $\lambda + d\lambda$ with angles θ and $\theta + d\theta$

The dispresive power of grating is $d\theta / d\lambda$

∴ n^{th} maxima for a wave length λ

$$(a+b)\sin\theta = n\lambda \quad -(1)$$

differentiating both sides

$$a+b \cos\theta \, d\theta = n d\lambda$$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\cos\theta}$$

$$\frac{1}{a+b} = N$$

so $\boxed{\frac{d\theta}{d\lambda} = \frac{Nn}{\cos\theta}}$ dispresive power Formula

NANOSCIENCE

Nanoscience is the study of and application of structure and materials that have dimensions at the nanoscience level. Nanoscience is the study of nanomaterials and their properties, and the understanding of how these materials, at the molecular level, provide naved properties and physical, chemical and biological phenomena that have been successfully used in innovative way in a range of industries.

Feyman's 1959 talk is often cited as a source of inspiration for Nanoscience but it was only published as a scientific paper in 1992

NanoTechnology.

Nano science is the science and technology of object at the nanoscale level, the properties of which differ significantly from that of their constituent material at the macroscopic or even microscopic scale. It is a multidisciplinary field that encompasses understanding and control of matter at about 1- 100 nm, leading to development of innovative and revolutionary applications.

Difference b/w Nanotechnology & Nanoscience

Nanoscience and Nanotechnology are the study & application of extremely small things, The materials with nanometre dimensions. Nanoscience is where atomic physics converges with the physics & chemistry of complex systems. Nano~~science~~ technology is the science and technology of objects at the nanoscale level, the properties of which differ significantly from that of their constituent material at the macroscopic or even microscopic scale. When we're talking about a scale an order of magnitude of size, or length. Nanoscience is the study of structures and materials on the nanoscale.

Nanotechnology is a multidisciplinary field that encompasses understanding and control of matter at about 1-100 nm, leading to development Innovative and Revolutionary applications. It encompasses nanoscale science, engineering and technology In addition to modeling and mompits f^n of matter on an atomic, molecular & supermolecular scale. Nano science is about the phenomena that occurs in systems with nanometre dimension & it involves understanding the fundamental ~~intra~~ interactions of physical systems confined to nanoscale dimensions and their properties.

INCREASE IN SURFACE AREA TO VOLUME RATIO

when size of the particle ↓ses the ratio of surface area to volume ↑es

"The ratio of surface area to Volume (SAVR) plays an vital role in nanoscience and nanotechnology. The ratio is the amount of surface area per unit volume of an object".

Cube :-

consider a cube with a side length of 10,

volume of the cube is $10^3 = 10 \times 10 \times 10 \, (a^3) \Rightarrow$

where 'a' is the side of an cube:

area is $10 \times 10 = 100 \, (a^2)$, cube has 6 sides.

Total surface area $= 6(10 \times 10)$
$= 6 \times 10^2$
$= 600.$

Surface Volume Ratio :-

$$\frac{\text{Surface area}}{\text{Volume}} = \frac{600}{10^3} = 0.6.$$

⇒ when the same cube with side 'a' is 5

volume is $a^3 = 5 \times 5 \times 5 = 125$

area $= 5 \times 5 = 25$

cube has 6 faces $= 6 \times a^2 = 6 \times 25 = 150$

So SAVR (Surface area to the volume ratio) is,

$$\frac{\text{Surface area}}{\text{Volume}} = \frac{150}{125} = 1.25.$$

So it is proved that when size ↓es the surface area to the vol. ratio ↑ses. So it is proved that nanomaterials has more (enhanced) 'SAVR' than the micro or macro molecules.

⇒ Solve

If side of a cube has length of 1

volume $= 1^3 = 1$

area $= 1^2$

$$\frac{\text{area}}{\text{vol}} = \frac{1}{1} = 1$$

⇒ Solve

Derive an eqn when side of cube is 's'

If 's' is the side

volume of the cube $= s^3$

Surface area of cube $= 6s^2 \; (6 \times s^2)$

Ratio of surface area to volume $= \frac{6s^2}{s^3} = 6/s.$

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Quantam Confinement
The change in electronic and optical properties of the material when its size is reduced (10nm or less than 10nm) is considered as Quantam Confinement.

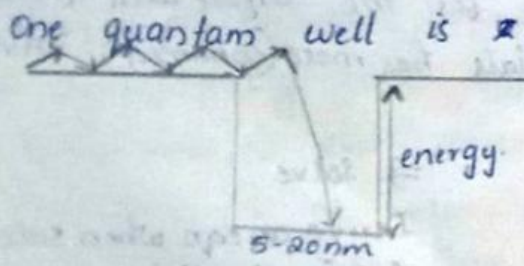
Quantam Confinement In One Dimension

⇒ Quantam Confinement
The optical property & electrical property changes when the material sampled is of sufficiently small size (10nm or less than 10nm)
When the length of a semiconductor is reduced to the same order of the exciton radius to a few nanometer, quantam ~~mechanical~~ confinement effect occurs & the exciton properties are modified. These types of quantam confinement structures are quantam well (QW) Quantam wire (QR) & Quantam dot (QD)

⇒ Exciton.
It is an bound state of an e^- & e^- hole can empty electron state in a valence bonds, which is free to move through a nanometallic crystal.

⇒ Exciton radius.
It is the distance b/w e^--hole pair

→ Quantam Well.
It is a ~~well~~ thin layer which can confine particles (quasi) (e^- or holes) in the dimension $\perp^{er}$ to the layer surface, whereas the moment of particles in other dimension is not restricted. The thickness of one quantam well is 5-20 nm.



One dimensional Quantam Confinement
The optical & electrical property of the material sample changes & forms/obtained in a one dimensional (1D) such materials are known as 1D quantam confinement.
Electrons confined in one dimensional (1D) quantam well (thin film) e^-s can easily move in 2-D, so one dimensional is quantifies.

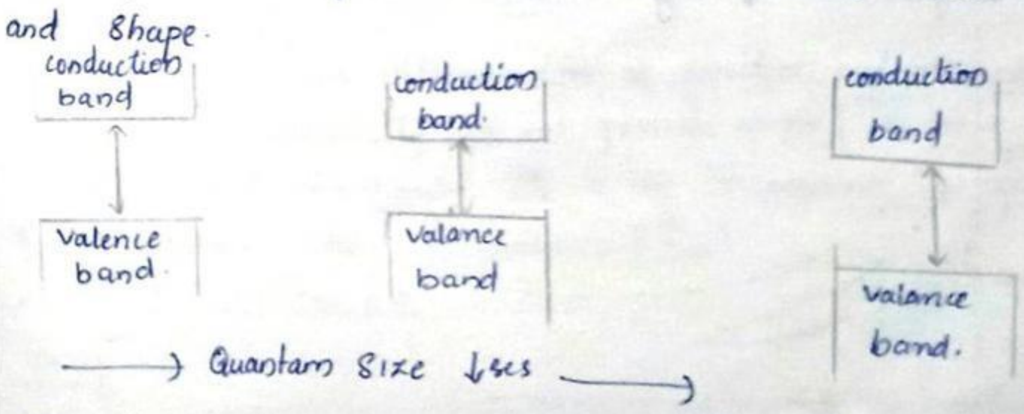
e^-s confines in 2-D quantam wires, e^-s can easily move in 1-D, so 2-D is confined.
e^-s confined in 3-D, quantam Dots (QD) so 3-D is quantized.

Nanosheet
A 2-D nanostructure with thickness (1 to 100nm)
eg:- graphens
Example :- ① silicon nanosheets:- are being used to prototype future generation (transfers) (5nm)
② Carbon nanosheets:- A graphene alternate, used as electrodes in super capacitors.

Nanowire
A nanostructure with the diameter of the order of nanometer (10^{-9}nm) ratio of length to width is greater than 1000 it's mainly used for transistor (MOSFET)

25/1/21 Quantam Wire.
A formation of confined 2-Dimension system by making a thin wire of the selected semiconductor.
Trapped excitons is in 2-D quantam confinement but it is force to move in 1-D only ~~the~~ along the wire

Quantam Dots:-
A semiconductor nanocrystalline materials with diameter usually at 2-10nm, It can produce distinctive colours determined by the size and shape.



Due to quantam confinement the electrons comes back to the valance band & ↓ses ~~so~~ energy (light)
According to quantam mechanics energy of photons relates to the wavelength (colour) of photons. This means emitted colour

depends on band gap. Various size of quantam dots results in differ colouring small size emits blue colour light but larger band gap where as bigger size will emits real colour light with small band gap (Tv screens - LED TVs)

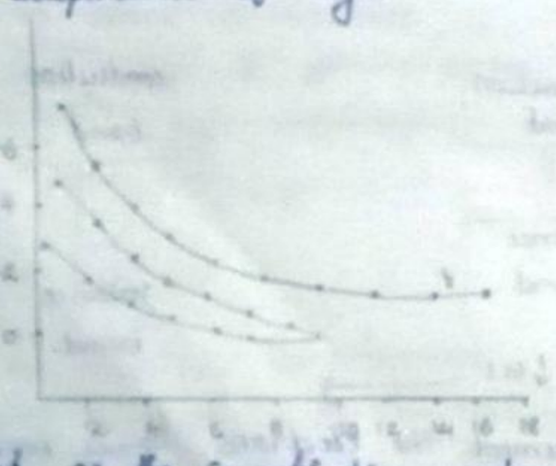
Optical Properties

Nanocrystalline systems have interesting optical properties. Depending on the particles size, same substance shows different colours. Gold nanospheres of 100nm appears orange in colour while that of 50nm size appears green. In the case of nanosized semiconductor particles quantum effects came into played and optical properties can be varied merely by controlling it's size. This particles can be made to emit or absorb specific wavelength of light by varying its size. The linear and non-linear properties of such materials can be tuned in the same way. Nanomaterials such as tungstic oxide gel is explored for large electronic display devices

Magnetic properties

The strength of a magnet is measured in terms of coercivity and saturation magnetization values. These values increases with a decrease in grainsize and with increase in specific surface area (surface area per unit volume). Therefore nanomaterials present good properties in this field.

In small particles a large fraction of the atom reside at the surface. These atoms have lower co-ordination numbers than the interior atoms. The magnetic moment in determined by the local co-ordination number. Fig 4 shows the calculated dependence of magnetic moment on the nearest co-ordination number



It is clear that as the co-ordination number decreases the magnetic moment increases in short, small particles are more magnetic than bulk materials.

Even nanoparticles of nonmagnetic solids are found to be magnetic ie, at small sizes, the clusters become spontaneously magnetic

Mechanical properties

most metals are made up of small crystalline grains. The boundaries b/w the grains slow down or arrest the propogation of defects when the material is stressed, thus giving its strength if the grains are nanoscale in size the interface area is greatly increasing, which increase its strength. For eg: nanocrystalline (substance) nickel is as strong as hardened steel. Because of the nanosize, many of their mechanical properties such as hardness, elastic modulus, fracture toughness, scratch resistance and fatigue strength are modified

Some observation on the mechanical behaviour of nanostructured materials are :

1) 30-50% lower elastic moduli than conventional materials.
2) 2-7 times higher hardness.
3) Super plastic behaviour in brittle ceramics.

The experimental behaviour of hardness measurements show different behaviour namely positive slope, zero slope, and negative slope depending on the grain size, when it is less than 20nm. Thus the hardness, strength and deformation behaviour of nanocrystalline materials is unique and not well understood.

Super plasticity in another phenomenon that has been found to occur in nanocrystalline materials at some what lower temperature and higher strain rates

Heisenberg's Uncertainity Principle

It states that it is impossible to determine position (x) and the momentum (P) of a particle with absolute precision

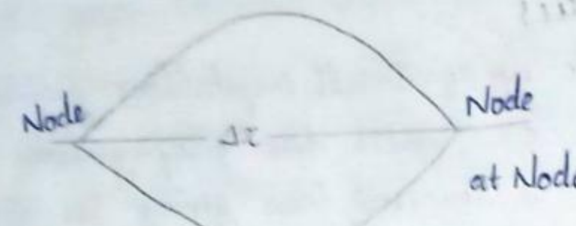
Statement

In any simultaneous determination of position and momentum of the particle, the product of uncertainity Δx (or possible error) in the x-co-ordinate of a particle in motion and uncertainity ΔP_x in the x-component of momentum is of the order of or greater than $\hbar = (1.054 \times 10^{-34} Js)$

$$\Delta x \, \Delta P_x \geq \hbar$$

Proof →

consider a particle (wave packet) moving in x-axis. The envelope of the wave packet moves with a velocity equal to particle velocity. when the wave packet extends Δx (finite distance), the two points at which the amplitude of the wave packet becomes zero and it will be repeated successively



at Node- amplitude = Zero

Nodes means the points at which amplitude becomes Zero. Due to wave nature of the particle position of the particle will have minimum error equal to distance (Δx)

The amplitude of the wave packet is,

$$R = 2A \cos\left[\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x\right] \quad \text{——— (1)}$$

At node amplitude is zero.

$$\text{So,} \quad 0 = 2A \cos\left[\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x\right] \quad \text{——— (2)}$$

Since $2A \neq 0$ (taking $2A$ to LHS)

$$\cos\left[\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x\right] = 0 \quad \text{——— (3)}$$

$$\left[\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x\right] = 0$$

when cos is $(2n+1)\frac{\pi}{2}$ ie, $\frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2} \ldots$ ——— (4)

we know there are two nodes so the position are also two.

$\therefore$ positions of two nodes are two ie,

1st position $$\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x_1 = (2n+1)\frac{\pi}{2} \quad \text{——— (5)}$$

2nd position $$\frac{\Delta\omega}{2}t - \frac{\Delta k}{2}x_2 = (2n+1)\frac{\pi}{2} + \pi$$

$$= (2n+3)\pi/2 \quad \text{——— (6)}$$

On simplyfying (5) and (6) (subtraction)

$$\frac{\Delta k}{2}(x_2 - x_1) = \pi \quad \text{——— (7)}$$

$$\Delta k (x_2 - x_1) = 2\pi$$

$$x_2 - x_1 = \frac{2\pi}{\Delta K} \quad \text{——— (8)}$$

or

$$\Delta x = \frac{2\pi}{\Delta K} \quad \text{——— (9)}$$

This is the fundamental error in the measurement of the position of the particles.

$$K = \frac{2\pi}{\lambda} \quad \text{——— (10)}$$

$$\lambda = h/P_x \quad \text{——— (11)}$$

where $h \rightarrow$ plancks constant

$\Delta P_x \rightarrow$ momentum of the particle in x-axis

Since, $k = \frac{2\pi}{\lambda}$

Sub eqn (11) in eqn (10)

$$k = \frac{2\pi}{h/P_x} \; ; \; k = \frac{2\pi P_x}{h}$$

$$\text{ie,} \quad \Delta k = 2\pi\left(\frac{\Delta P_x}{h}\right) \quad \text{——— (12)}$$

from eqn no 9 $\Delta x = \frac{2\pi}{\Delta K}$

Sub eqn (12) in eqn (9)

$$\Delta x = \frac{2\pi}{2\pi \frac{\Delta P_x}{h}} = \frac{h}{\Delta P_x}$$

$$\Delta x = \frac{h}{\Delta P_x}$$

According to Superposition of waves.

$$\Delta x = \frac{1}{\Delta K} \quad \text{or} \quad \Delta K = \frac{1}{\Delta x}$$

$$\frac{1}{\Delta x} = \frac{2\pi \Delta P_x}{h} \quad (\text{from eqn 12})$$

$$\frac{1}{\Delta x \Delta P_x} = \frac{2\pi}{h}$$

$$\Delta x \Delta P_x = \frac{h}{2\pi} \qquad \frac{h}{2\pi} = \hbar$$

$$\Delta x \Delta P_x = \hbar$$

Thus, $$\Delta x \Delta P_x \geq \hbar$$

Que. A microscope using photons is employed to locate an e^- in an atom $0.2Å$. what is the uncertainity in the momentum of the e^- located in this solution. Given $\Delta x = 0.2Å = 2\times10^{-11} m$ $\Delta P = ?$

ans. Since we know that the Uncertainity principle

$$\Delta x \, \Delta P_x = \frac{h}{2\pi}$$

$$\Delta P_x = \frac{h}{2\pi \Delta x}$$

$$\Delta P_x = \frac{6.626\times10^{-34}}{2\pi \times 2\times10^{-11} m}$$

$$= 5.27\times10^{-24} \, kgm/s$$

Que. Show that the uncertainity in the location of the particle is equal to the debroglie wavelength the uncertainity in its velocity is equal to its velocity.

ans. Solution, Given $\Delta x = \lambda$

Since we know that by uncertainity principle

$$\Delta x \, \Delta P_x = \frac{h}{2\pi \Delta x}$$

$$\Delta P_x = \frac{h}{2\pi \Delta x}$$

$$\Delta x \, \Delta P_x = \hbar$$

$$\lambda \, \Delta P = \hbar$$

$$\Delta P = \frac{\hbar}{\lambda}$$

we have $\frac{\hbar}{\lambda} = P$ ie $\Delta P = P$

$\Delta P = P$

$m \Delta V_x = m V_x$

$\frac{m}{m} \Delta V_x = V_x$

$$\boxed{\Delta V_x = V_x}$$

Que. A microscope ~~along~~ using photons is employed to located an e^- in an atom $5Å$. what is Uncertainity in the momentum of the e^- located in this.

ans. $\Delta x = 5Å = 5\times10^{-12} m$ $\Delta P = ?$

$$\Delta x \, \Delta P_x = \frac{h}{2\pi}$$

$$\Delta P_x = \frac{h}{\Delta x \, 2\pi}$$

$$= \frac{6.626\times10^{-34}}{5\times10^{-12} \times 2\pi}$$

$$= 2.1091\times10^{-23} \, kgm/s$$

Application Of Heisenberg's Uncertainity principle

(*) Absence of free electrons.

~~$[E^2 = p^2c^2 + m_0^2c^4]$~~

~~$\Delta x \, \Delta P_x = \frac{h}{2\pi}$~~

~~$\Delta P_x = \frac{h}{2\pi \Delta x} = \frac{6.626\times10^{-24}}{2\pi \times 1\times10^{-14}}$~~

~~$\Delta P_x = 1.054\times10^{-20} \, kgms^{-1}$~~

~~$E^2 = (1.05\times10^{-20} \times 3\times10^{8})^2 + (9.1\times10^{-31})^2 \times (3\times10^{8})^4$~~

~~$= 9.929\times10^{-24}$ joule~~

→ Absence of free electrons

According to theory of relativity energy of a particle is given by the relation

$$E^2 = p^2c^2 + m_0^2c^4$$

where P = momentum

m_0 = rest mass of the particle

According to Heisenberg's principle

$$\Delta x \, \Delta P_x = \frac{h}{2\pi}$$

The diameter of the nucleus is 10^{-14} m, so the maximum possibility of the particles is within its diameter thus the position of the particle is in 10^{-14} m.

$\therefore \Delta x = 10^{-14}$ m

$\Delta x \, \Delta P_x = h/2\pi$

$$\Delta P_x = \frac{h}{\Delta x \, 2\pi} = \frac{6.63 \times 10^{-34}}{2 \times 3.14 \times 1 \times 10^{-14}} = 1.05 \times 10^{-20} \text{ kg m/s}$$

For electron of minimum momentum, the minimum energy is given by

$$E_{min} = P_{min}^2 c^2 + m_0^2 c^4$$

$$= (1.055 \times 10^{-20} \times 3 \times 10^8)^2 + 9.1 \times 10^{-31} \times (3 \times 10^8)^4$$

$$= 3 \times 10^8 \sqrt{1.113 \times 10^{-40}}$$

$$= 3.1648 \times 10^{-12} \text{ J}$$

Converting into eV

$$\therefore E_{min} = \frac{3.1648 \times 10^{-12}}{1.6 \times 10^{-19}} \text{ eV} \simeq 20 \text{ MeV}$$

If free e^- exists the nucleus must have minimum energy about 20 MeV. But the minimum required K.E which a β-particle, emitted from radioactive nucleus is at 4 MeV

Quantam Mechanics

classical physics couldn't properly explain many physical phenomenon, because it deals with microscope particles. Max plank in 1900, put forward the quantam theory to explain black body radiation.

Einstein introduced the idea of light quantam or photon particle nature of radiation was stressed in these theories. But wave nature of radiation was essential to explain interference, diffraction etc. In 1924, Lows deBroglie suggested wave particle duality. In 1926, Schrodinger developed the wave particle mechanics. PAM Dirac unified wave mechanics and matrix mechanics to setup a general formation called Quantam mechanics. It deals with microscopic particles.

WAVE NATURE OF PARTICLES

In 1924, De-broglie predicted that like radiation, particle has a dual nature ie, particle and wave nature.

de-broglie hypothesis.

All moving particle is associated with a couple called matter wave or de-broglie wave and its wavelength is known as de-broglie wavelength which is given by,

$$\lambda = \frac{h}{p} \quad \text{——— (1)}$$

where $h \rightarrow$ plancks constant 6.626×10^{-34} Js

$p \rightarrow$ momentum of the particle $= mv$

According to mass-energy relation

$$E = mc^2 \quad \text{— (1)} \quad \text{particle nature}$$

we know the relation (wave-nature)

$$E = h\nu \quad \text{——— (2)}$$

equating (1) and (2)

$$mc^2 = h\nu$$

$$mc = \frac{h\nu}{c}$$

$$p = \frac{h\nu}{c}$$

but $mc = p$

we have,

$v = \nu\lambda$ or $c = \nu\lambda$

$$\therefore \frac{\nu}{c} = \frac{1}{\lambda}$$

substitute $\frac{\nu}{c} = \lambda$

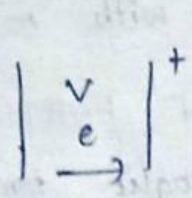
$$p = \frac{h}{\lambda}$$

$$\boxed{\lambda = \frac{h}{p}}$$

Que. Calculate the wavelength of an electron accelerated by a potential difference of V volt.

ans. Energy of electron

$E = eV$ ——— (1)



where e = change of e^-

$= 1.6 \times 10^{-19}$ J

V = applied potential difference

we have $KE = \frac{1}{2} mv^2$ ——— (2)

$\frac{1}{2} mv^2 = eV$ ——— (3)

$v^2 = \frac{2eV}{m}$

$v = \sqrt{\frac{2eV}{m}}$

h → plancks constant
m → mass of e^- 9.1×10^{-31} kg.
e → change of e^- 1.6×10^{-19} C
V → potential diff in volt.

Then momentum $P = mv$

$P = m\sqrt{\frac{2eV}{m}} = \sqrt{\frac{m^2\, 2eV}{m}} = \sqrt{2eVm}$

then $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2meV}}$ ——— (4)

Que. calculate the wavelength associated with an e^- under a potential difference of 100V.

ans. For an e^-, $\lambda = \frac{h}{\sqrt{2meV}}$

$h = 6.625 \times 10^{-34}$ Js

$m = 9.1 \times 10^{-31}$ kg.

$V = 100$V

then $\lambda = \frac{6.625 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100}} = 1.2 \times 10^{-10}$ m

Que. Estimate the de broglie wavelength of an e^- moving with a K.E of 100 eV.

ans. we have, for an electron

$KE = eV$

$\frac{1}{2} mv^2 = eV = 100$eV

$= 100 \times 1.6 \times 10^{-19}$ J

the $\lambda = \frac{h}{\sqrt{2meV}}$

$\lambda = \frac{6.625 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100}}$

$\lambda = 1.2 \times 10^{-10}$ m

(*) Calculate the de-broglie wavelength of whoose KE is 10keV.

ans. $KE = eV = 10$keV

$= 10 \times 10^{3} \times 1.6 \times 10^{-19}$ J

then $\lambda = \frac{h}{\sqrt{2meV}}$

$\lambda = \frac{6.625 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 10 \times 10^{3} \times 1.6 \times 10^{-19}}}$

$\lambda = 1.22 \times 10^{-11}$ m.

UNCERTAINITY PRINCIPLE (Heisenberg's Uncertainity principle)

It is impossible to have an accurate measurement of two conjugate variables simultaneously. ie,

it is impossible to know both the exact position and exact momentum of an object at the same time.

Let the Uncertainity in position = Δx

Uncertainity in momentum = ΔP_x

Then according to Heisenberg's Uncertainity principle

$\Delta x \, \Delta P_x \geq \frac{\hbar}{2}$ where $\hbar = \frac{h}{2\pi}$

or

$\Delta x \, \Delta P_x \geq \hbar$

Similarly Uncertainity in energy = ΔE

Uncertainity in time = Δt

then $\Delta E \, \Delta t \geq \frac{\hbar}{2}$ or

$$\Delta E \, \Delta t \geq \hbar$$

Application of Uncertainity principle

1. Abscence of electron inside the nucleus

Let the nucleus of the order of 10^{-14} m.

ie, $\Delta x \simeq 10^{-14}$ m

By uncertainity principle

$$\Delta x \cdot \Delta P_x \geq \hbar$$

$$\Delta x \cdot \Delta P_x = \hbar = \frac{h}{2\pi}$$

then, $\Delta P_x = \frac{h}{2\pi \Delta x} = \frac{6.625 \times 10^{-34}}{2\pi \times 10^{-14}}$

$$\Delta P_x = 1.10 \times 10^{-20} \text{ kgm/s}$$

This momentum contributes to the ~~necessary~~ energy of the nucleus ie,

energy of the nucleus = 1.10×10^{-20} J

energy of e^- $\simeq$ 20 meV

$\simeq 20 \times 10^6 \times 1.6 \times 10^{-19}$ J

$\simeq 8.2 \times 10^{-12}$ J

→ energy of nucleus ≠ energy of e^-

→ No electron can exist inside the nucleus.

ELECTROSTATICS

Magnetic field (B)

The force experiences by the magnet in its surroundings is known as magnetic field, It is represented as 'B'.

Applied Current $\propto$ Magnetic field.

"current always conduct in closed loop"

Magnetic flux (ϕ)

magnetic field per unit area is magnetic flux $\phi = \frac{B}{A}$

~~Divergence~~ ((E), (∇))

* when density increases permittivity decreases!

$E = \frac{\rho}{\varepsilon_0}$ Curled Dynamics (E)

$\rho \rightarrow$ density $\varepsilon_0 \rightarrow$ permittivity in Vaccum.

Magnetic flux Density.

It is the force acting per unit current, per unit length in a wire.

Magnetic flux formula.

(*) magnetic flux (Surface area)

It is defined as magnetic field per unit area $\phi_B = B \cdot A$

$\phi_B = B \cdot A \cos\theta$

consider a small surface of area dA in an surface the flux through the surface is $\phi_B = B \cdot dA$

$\therefore$ Total flux in an surface area is the sum of individual mag. flux ϕ_B

ie, $\phi_B = B_1 \cdot dA_1 + B_2 \cdot dA_2 \dots$

$\int \phi_B = \int B \cdot dA$

$d_B = B \cdot A$

$d_B = BA \cos\theta$

Guass Law in differential form.

$\nabla \cdot B = 0$ $\nabla \rightarrow$ Divergence

Curls divergence.

what is Curls divergence ?

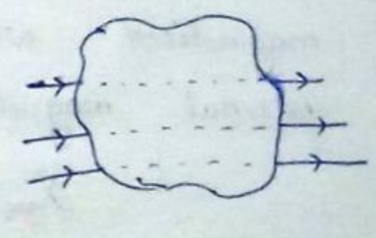
It is a theorem ~~set~~ which is related to the flux of a ~~material~~ ~~in~~ vector feel through a closed surface area of the field in volume, ~~and~~ closed. enclosed.

(*) Gauss's Law

This law states that the amount of magnetic field lines passing through an closed surface area is zero. Because no of magnetic field lines entering inside the Guassian surface is equal to the ~~the~~ no of magnetic field lines goes outside.

$\oint B \cdot ds = 0$

$\phi_B = 0$

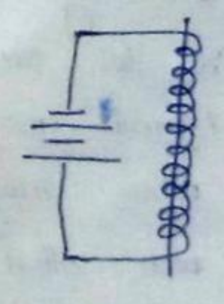


Ampere's Circuital Law.

The law states that the no of magnetic field lines in an longitudinal section is equal to the amount of current applied.

$\oint B \cdot dl \propto I$

$\oint B \cdot dl = \mu_0 I$



B x = [illegible]

B 2πr = [illegible]

B = $\frac{[illegible]}{2\pi r}$

(8) Faraday's law of magnetism (EMF)

It states that the electromotive force induced by it is the rate of change of magnetic flux to the rate of change of time

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

N = no of turns

My Magnetic permeability

The relative increase or decrease in the resultant magnetic field inside a material compared with the magnetic field when it applied.

Magnetic Susceptibility

It is the measurement of how much a material can be magnetised when the same material is kept in the external magnetic field

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

properties of Magnetism

→ Dia magnetism :- it is the prop. of a material which causes it to create a magnetic field in opposition to the external mag. field the individual atoms posses a dipole when magnetic field is applied atoms interact with each other and allign them to the direction of external magnetic field.

→ Paramagnetism :- it is property of a material which causes it to create the same direction external mag. field [illegible] permanent mag.

→ Ferromagnetism :- is [illegible] permanent magnet with [illegible] without the action of magnetic field and its [illegible] requires to [illegible]

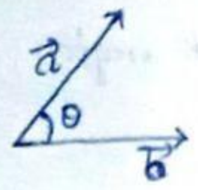
Vector Calculus.

(*) Basic principles of vector calculus

1. dot product - / scalar product

The dot product of two vector is defined as the product of magnitude and cosine angle b/w them.

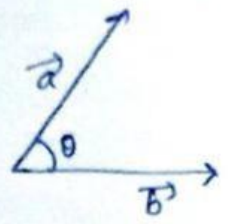
$\vec{a} \cdot \vec{b} = ab \cos\theta$



2. Cross product / Vector product

The cross product of two vectors is defined as the product of magnitude and sine angle b/w them

$\vec{a} \times \vec{b} = ab \sin\theta$

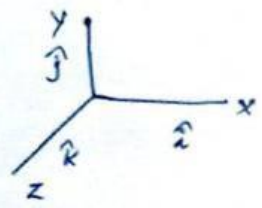


Special Cases

If there are 3-vectors $(\vec{a}, \vec{B}, \vec{C})$ where C is the resultant ~~product~~ ~~of the vectors~~ vector product of $\vec{A}$ and $\vec{B}$.

$C = (A \times B)$

$$\begin{vmatrix} i & j & k \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$



∇ operators.

$\nabla T \rightarrow$ Gradient

$\nabla \cdot a \rightarrow$ divergence

$\nabla \times a \rightarrow$ Curl

when the operator acts on a Scalar quantity it instincts to differentiate the scalar quantity the operator of ∇ on a scalar quantity results in Vector quantity.

$$\nabla = \frac{d}{dx}\hat{i} + \frac{d}{dy}\hat{j} + \frac{d}{dz}\hat{k}$$

Gradient :- An vector quantity applied on scalar quantity is,

$$\nabla = \frac{d}{dx}\hat{i} + \frac{d}{dy}\hat{j} + \frac{d}{dz}\hat{k}$$

If f is a scalar quantity & $\nabla F = \frac{dF}{dx}\hat{i} + \frac{dF}{dy}\hat{j} + \frac{dF}{dz}\hat{k}$.

Qu. Find the gradient function of F at point 1,2,3

$F = xy^2 + z^3 y$

ans $\nabla F = \frac{d(xy^2+z^3y)}{dx}\hat{i} + \frac{d(xy^2+z^3y)}{dy}\hat{j} + \frac{d(xy^2+z^3y)}{dz}\hat{k}$

$= y^2 \times 1 + z^3 y + x \times 2y + z^3 \times 1 + xy^2 + y 3z^2$ (struck through)

$= y^2 + y z^3 + 2xy + z^3 + xy^2 + 3z^2 y$ (struck through)

$= y^2 + 2xy + z^3 + 3z^2 y$

$\nabla F = y^2 + 2xy + 3z^2 y + z^3 \hat{k}$

at point (1,2,3) $= 2^2 + 2 \times 1 \times 2 + 3 \times 3^2 \times 2 + 3^3$

$= 4 + 4 + 54$

$= 4\hat{i} + 31\hat{j} + 54\hat{k}$

Basics of Divergence.

It is a scalar quantity

It is applied to the vector quantity

$$\nabla F = \frac{dF}{dx}\hat{i} + \frac{dF}{dy}\hat{j} + \frac{dF}{dz}\hat{k}$$

formula: This rule states that volume integral = Surface Integral.

$$\vec{\nabla} \cdot \vec{F} = \lim_{\Delta V \to 0} \oint \frac{F \cdot ds}{\Delta V}$$

$\vec{\nabla} \cdot \vec{F} \Delta v = \int F \cdot ds$

Que. Find the divergence of the function f at the point (1,2,1)

$\vec{F} = xy^2\hat{i} + y\hat{j} + xz\hat{k}$ (vector function)

find $\vec{\nabla}\cdot\vec{F}$

$$\nabla F = \frac{dF}{dx}\hat{i} + \frac{dF}{dy}\hat{j} + \frac{dF}{dz}\hat{k}$$

$$= y^2\hat{i} + \hat{j} + x\hat{k}$$

$$\text{at } (1,2,1) = 4\hat{i} + \hat{j} + \hat{k} = 4 + 1 + 1 = 6$$

Curl function

it is a vector quantity where it is applied to another vector quantity

Curl of $F = \vec{\nabla}\times\vec{F}$

$$\vec{F} = F_1\hat{i} + F_2\hat{j} + F_3\hat{k}$$

$$\vec{\nabla}\times\vec{F} = \begin{vmatrix} i & j & k \\ \frac{d}{dx} & \frac{d}{dy} & \frac{d}{dz} \\ F_1 & F_2 & F_3 \end{vmatrix}$$

$$\vec{\nabla}\times\vec{F} = \lim_{\Delta s\to 0} \frac{\oint F\cdot dl}{\Delta s}$$

$$\boxed{\Delta s\,\vec{\nabla}\times\vec{F} = \lim_{\Delta s\to 0}\oint F\cdot dl}$$

↓ Surface area integral ↓ Linear integral

This is known as ~~Stokes~~ Strokes theorem

Que. Volume Integrals

It is a representation of vector point function and volume (V) enclosed by a closed surface.

Que. Find the volume integral of $F = 2x\hat{i} - x\hat{j} + y\hat{k}$, given bounding surface

$(x=0,\ y=0,$
$x=2,\ y=4$
$z=x^2,\ z=2)$

Ans. Solution $\iiint F\cdot dv$ dx, dy, dz

$$\int_0^2\int_0^4\int_{x^2}^{2}\left[2x\hat{i} - x\hat{j} + y\hat{k}\right] dz\,dy\,dx$$

~~$\int_0^2\left[\int_0^4 \left(\frac{2x^2}{2} - x\hat{j} + y\hat{k}\right)_{x^2}^{2} dy\right] dy\,dx$~~

$$= \int_0^2\left[\int_0^4\left(\frac{2x\hat{i}}{2} - x\hat{j}z + y\hat{k}z\right)dy\right]dx$$

~~$\left[\left(\frac{2x^2\hat{i}}{2}\right)_{x^2}^{2} - \left(\frac{x^2\hat{j}}{2}\right)_0^4 + y\hat{k}\right) dx\right]$~~

$$= \int_0^2\left[\left(\frac{2x\hat{i}}{2}\right)_{x^2}^{2} + \left(\frac{y^2\hat{k}}{2}\right)_0^4 - x\hat{j}\right) dx\Big]$$

$$= \int \frac{2x^2\hat{i}}{2}\Big)_{x^2}^{2} + \frac{y^2\hat{k}z}{2}\Big)_0^4 - \frac{x^2\hat{j}z}{2}\Big)_0^2$$

$$\frac{32}{15}\hat{i} + 3\hat{j} + 8\hat{k}$$

$$= \left(\frac{4\hat{i}}{2} - \frac{2x^2\hat{i}}{2}\right) + \left(\frac{y^2z\hat{k}}{2} - 0\right) - \left(\frac{4\hat{j}z}{2} - 0\right)$$

$$= \left(\frac{2\hat{i}}{2} - \frac{2x^2}{2}\right) + \frac{y^2\hat{k}}{2} - \frac{4\hat{j}}{2} = \frac{1}{2}\left[\ldots\right]$$

SEMICONDUCTOR

Spcl SD
define, peculiarity, Appli

Super Conductivity & Conductors:)

materials having zero resistance = super conductor.

The phenomena exactly zero resistance in a material is known as super conductive material.

(*) Critical temperature: for a normal conductor, resistance is function of temperature therefore $R = f(T)$ (as temp increase resistance also increase)
The temp at which resistance turns to zero (infinite conductivity) is called critical temp/Transistant temperature.

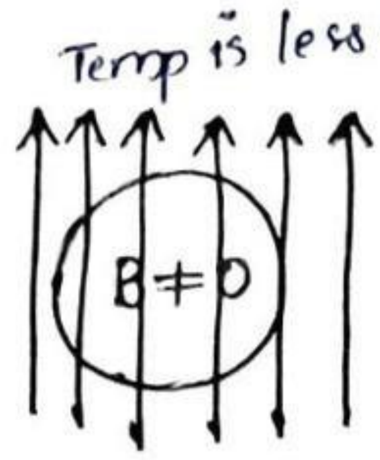
Case-1

The when temp decreases the Resistance of material is lower down (non-zero) and infinite conductivity. Such materials are known as super conductors.

(*) Above the critical temp the material will be in normal state. Super conductivity is in reversible process so that when temp is increased from the critical temp hence the resistivity also increases. Thus it is known as reversible process.

Meissner Effect

The phenomena of expulsion of magnetic field lines from superconductors is known as meissner's effect.



$$B = \mu_0 (H + M)$$

Taking H outside

$$B = H\mu_0 \left(1 + \frac{M}{H}\right) \quad \text{—— (2)}$$

we know that $\frac{M}{H} = \chi$ apply in eqn (2)

$$0 = \mu_0 H \left(1 + \frac{M}{H}\right)$$

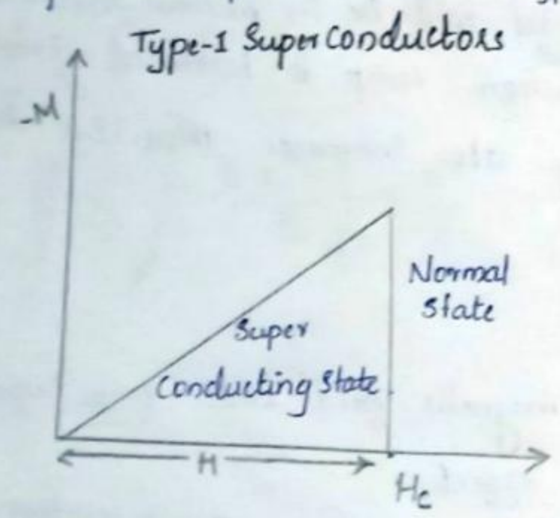
$$1 + \chi = 0$$

$$\chi = -1 \quad \text{for diamagnetic material.}$$

Type-1 Super conductors	TYPE-2 Super conductors.
(*) The materials looses its magnetisation after	(*) It lose its magnetisation gradually.
(*) It exhibits complete Meissner effect	(*) It doesn't exhibit Meissner effect.
(*) It exhibits only one critical magnetic field.	(*) It ~~is not mixed~~ exhibits diff critical magnetic field.
(*) It is not mixed state	(*) It is mixed state
(*) They are called soft super conductors	(*) They are hard super conductors.
(*) eg:- Aluminium (Al), Indium (In), Tin (Sn), Lead (Pb)	(*) eg:- Germanium (Ge), Niobium (Nb), Vanadium (Vn)

Graphical representation Type 1 and Type 2 Semiconductors

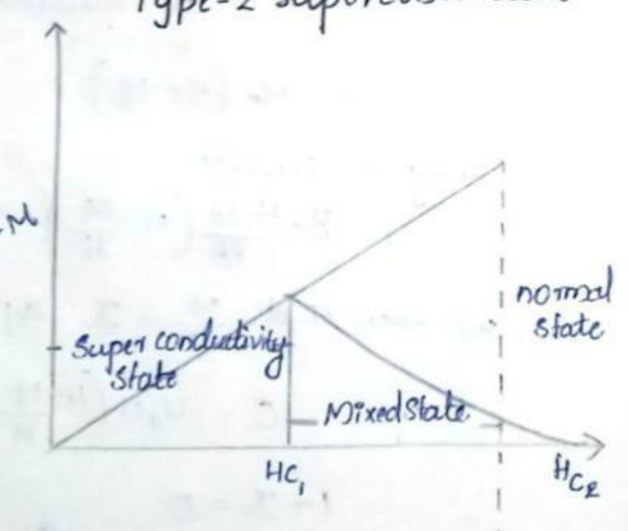
Type-1 Superconductors



$H_c \rightarrow$ Critical mag

$M \rightarrow$ magnetising field

Type-2 superconductors.



Numerical Apperture

(*) In optics numerical aperture is defined as non-dimensional number that characterises the range of angles over which the system can accept or emit light.

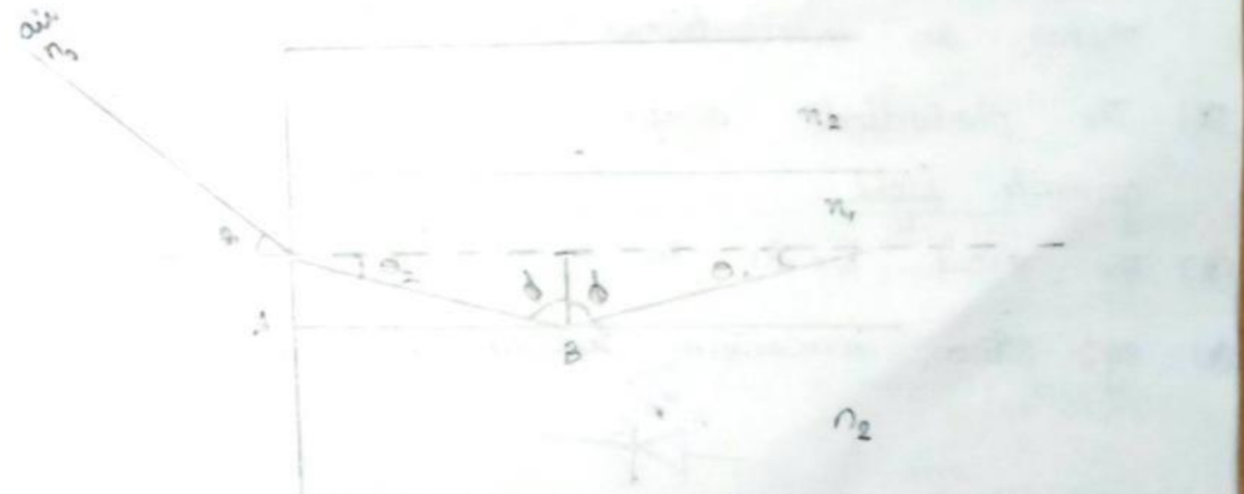
(*) It is the relation b/w acceptance angle and refractive index of 3 media involved, core, cladding, air. The light ray is incident on the fibre code. cord. (centre of the fibre) at an angle θ_1, which is less than the acceptance angle of the fibre. The ray enters from the air medium (refractive index n_0) and the fibre for refractive index (n_1) which is slightly greater than cladding refractive index The is normal to the axis, by

consider the refraction of air-core by using (Snell's law)

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

$$n_0 \sin \theta_1 = n_1 \sin \theta_2$$



LED

A p-n junction diode which operates in forward biased the e^- from the n and region and goes from p region. meet at the junction known as depletion region this e^- suppose annihilate each other in this surface just transition of e^- from the conduction band to the empty state of valence band and it releases photons.

$E_g = \frac{hc}{\lambda}$

PHOTO DIODE : The diode which produce current when light falls on it

- It is a light weight sensor which converts light energy → electrical energy
- It is a p-n junction diode where we p and we n layer makes an intentional layer called depletion layer
- The photo diode accept the light as an input source to generate light
- The diode works in reverse biased condition.
- eg:- Silicon, Germanium, Indium, Gallium

Application : Lasers, sensors

BCS Theory (Cooper pairs)

- It was developed by Bardeen and L.N. Cooper and this theory is based on cooper pairs e^-s

Consider an e^- moving in a lattice the +ve ions are attracted towards the e^-s due to coulomb force so the phonons changes its position and this type of interaction is known as e^--phonon-[illegible] interaction. Now the region of increased charge density attracts another e^- and experiences [illegible] force (+ve force) thus it leads to interact [illegible] e^-s [illegible] lattice. The interaction [illegible] and e^- develops an opposite spin then these which lead to move the pairs, this process is known as cooper pairs

Condition

As temperature increases above given temperature the [illegible] pairs decreases and high temp can destroy cooper pairs.

HCSM High temperature Super Conducting Material (HTSC)

- mixed oxide

Application of Super Conductivity

- medical, laser technology, medical [illegible]

Fibre Optics :

Optical fibre cable

- It works on Total Internal Reflection
- $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$ Snell's law
- TIR occurs when angle of incidence is greater than critical angle

∴ critical angle formula $\frac{\sin\theta_c}{\sin 90^\circ} = \frac{n_2}{n_1}$

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Step index fibre and Graded index fibre

Step Index Fibre	Graded Index Fibre
It has const refractive index	Refractive index Reduces gradually
Refractive index reduces from n_1 to n_2 suddenly	And for cladding core boundary the difference of refractive index is small.
Signals can be trans	
long distance transmission of lights	Short distance transmission of rays.
zig-zag path is followed by light ray.	Spherical or helical path is followed by light ray.

Accental Centre and Numerical appertiure.

stability and gathering of light is termed numerical appertiure.

$$NA = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}$$

$$\frac{\sin i}{\sin(90-\theta)} = \frac{n_2}{n_1}$$

$$\frac{\sin i}{\cos\theta} = \frac{n_2}{n_1}$$

Let $n = \mu$

$$\frac{\sin i}{\cos\theta} = \frac{\mu_2}{\mu_1}$$

$$\frac{\sin\theta}{\cos\theta} = \frac{\mu_2}{\mu_1} \quad (1)$$ where $\mu_2 \rightarrow$ angle of refractive index of 2nd medium, $\mu_1 \rightarrow$ 1st medium

$$\tan\theta = \frac{\mu_2}{\mu_1}$$

If $\mu_1 = 1$ $\quad \frac{\sin\theta}{\cos\theta} = \mu_2$

$\sin\theta = \mu_2\cos\theta \quad (2) = \mu_1\cos\theta$

If $\mu_2 = \mu_1$ replacing μ_2 as μ_1 the above equation

$$\sin\theta = \mu_1\cos\theta \quad (2)$$

by apply snells law

$$\frac{\sin\theta}{\sin 90^\circ} = \frac{\mu_2}{\mu_1}$$

$$\sin\theta = \frac{\mu_2}{\mu_1} \quad (3) \qquad \theta = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$$

$$\mu_2 = \mu_1\sin\theta$$

$$\sin^2\theta + \cos^2\theta = 1$$

$$\cos\theta = \sqrt{1 - \sin^2\theta}$$

$$\cos\theta = \sqrt{1 - \left(\frac{\mu_2}{\mu_1}\right)^2}$$

$$\sin\theta = \mu_1\cos\theta$$

$$\sin\theta = \mu_1\sqrt{1 - \frac{\mu_2^2}{\mu_1^2}}$$

$$\sin\theta = \frac{\mu_1}{\mu_1}\sqrt{\mu_1^2 - \mu_2^2}$$

$$\boxed{\theta = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}} \quad \text{Or} \quad \boxed{NA = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2}}$$

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$$\rho \int_V dv = \varepsilon_0 \int_S E \cdot ds$$

$D = \varepsilon_0 E$

$$\boxed{\int_S D\, ds = \int_V \rho\, dv}$$

$div\, \vec{D} = \rho$

$\nabla \vec{D} = \rho$

$\phi_e = \frac{q}{\varepsilon_0}$

$\phi_e = \vec{E}\, ds$

$q = \rho \int dv$

$\frac{\rho}{\varepsilon_0} \int_V dv = \vec{E} \int_S ds$

~~electric flux divergence in Max well equation~~

electric displacement the vector in free space

by using guass divergent theorem.

$$\int_S D ds = \int_V (\nabla \cdot \vec{D}) dv$$

$\varepsilon \rho \int_V dv = \varepsilon_0 \vec{E} \int ds$

$D = \varepsilon_0 \vec{E}$

$\rho \int_V dv = D \int_S ds$

$\int_S D\, ds = \int_V \nabla \cdot \vec{D}\, dv$

$\rho \int_V dv = \int_V \nabla \cdot \vec{D}\, dv$

$\rho = \nabla \cdot \vec{D}$

$\nabla \cdot \vec{D} = \rho$

$$\int_V \rho\, dv = \int_V (\nabla \cdot \vec{D})\, dv$$

$\rho\, dv = \nabla \cdot \vec{D}\, dv$

$$\int_V (\nabla \cdot \vec{D} - \rho)\, dv = 0$$

$\nabla \cdot \vec{D} - \rho = 0$ $\quad div\, \vec{D} = \rho$

$\nabla \cdot \vec{D} = \rho$

$div\, \vec{D} = \rho$

2). By Guass Law in Magnetism the net mag flux emerging out of a enclosed surface area is equal to zero

Integral of $\int B \cdot ds = 0$

$\int_S B\, ds = \int dv\, B\, dv$

$\int_S B \cdot ds = \nabla \cdot B$

$\therefore$ So $\nabla B = 0$

Assignment

Time independent EQUATION

MAXWELL'S CURL

According to faradays law of magnetism $e = -\frac{d\phi}{dt}$ —(1)

$e = \int \vec{E} \cdot d\vec{l}$ —(2)

$\phi = \vec{B} \cdot d\vec{s}$ —(2)

sub eqn (2) in (1)

~~$-\frac{d\phi}{dt} = \int \vec{E} \cdot d\vec{l}$~~

$$e = -\frac{d}{dt}\left(\int_S B \cdot ds\right)$$

From eqn (2) and (3)

$$\int_L \vec{E} \cdot d\vec{l} = \int_S curl\, \vec{E}\, d\vec{s}$$

So, $\int_S curl\, E \cdot ds = \int \frac{d}{dt}(\vec{B} \cdot ds) = 0$

$$\int_S \left[curl\, \vec{E} \cdot d\vec{s} + \frac{d}{dt}(\vec{B} \cdot d\vec{s})\right] = 0$$

take 'ds' commonly outside

$$\int_S \left[\left(curl\ E + \frac{dB}{dt}\right) ds\right] = 0$$

→ s is the arbitrary, equation is valid when integration is zero

$curl\ E = -\frac{dB}{dt}$

$\nabla \times E = -\frac{dB}{dt}$

According to ampere's circuital law

$\oint B \cdot dl = \mu_0 I$

where $B = \mu_0 \vec{H}$

$\oint \mu_0 \vec{H} \cdot dl = \mu_0 I$ ([illegible])

$\oint \vec{H} \cdot dl = I$ —(1)

current charge density $I = \int_s \vec{J} \cdot d\vec{s}$ —(2)

$\oint \vec{H} \cdot dl = \int_s \vec{J} \cdot d\vec{s}$

by using stokes theorem

$\oint_L \vec{H} \cdot dl = \int_S \text{curl } \vec{H} \cdot ds$

$\int \text{curl } \vec{H} \cdot d\vec{s} = \int_s \vec{J} \cdot d\vec{s}$

$\text{curl } \vec{H} = \vec{J}$ —(3)

By equation of continuity

$\text{div } \vec{J} + \frac{d\rho}{dt} = 0$ —

$\text{div } \vec{J} = \frac{-d\rho}{dt}$ —— (4)

$\text{div } (\text{curl } \vec{H}) = \text{div } \vec{J}$ —(5)

$0 = \text{div } \vec{J}$

i.e. $\text{div } \vec{J} = 0$

while introducing a new term [illegible] is then modified equation is

$\text{curl } \vec{H} = \vec{J} + \vec{J_D}$ —(6)

[illegible] is introduced by maxwell and known as displacement current charge density

$\text{div } \vec{H}$ = $\text{div } (\text{curl } \vec{H}) = \text{div } (\vec{J} + \vec{J_D})$

$\text{div } (\text{curl } \vec{H}) = \text{div } \vec{J} + \text{div } \vec{J_D}$

$\text{div } \vec{J} = \text{div } \vec{J_D}$ — (6)

from maxwell's [illegible] equation

$\frac{-d\rho}{dt} = -\text{div } \vec{J_D}$

by 1st eqn of maxwell

$\rho = \text{div } D$

$\frac{d}{dt} \text{ div } \vec{D} = \text{div } \vec{J_D}$ —(8)

$\frac{dD}{dt} = J_D$ —(9)

sub [illegible] eqn (7) [illegible] (6)

$\text{curl } \vec{H} = \vec{J} + \frac{dD}{dt}$ $\quad \nabla \cdot D = 0$

$\nabla \times H = \vec{J} + \frac{dD}{dt}$ [illegible]

Conduction current:- movement of charges in a conductor when a field is applied. By ohm's law $V = IR$ and $V = EL$, [illegible]

The resistance of conductor is defined $R = \frac{l}{\sigma A}$

$E = \frac{I}{\sigma A}$

$E = [illegible]\, I$

or $J = \sigma E$

Displacement Current

A time varying E field is considered as an [illegible] current of [illegible] with change of Q and [illegible] $E = \frac{Q}{[illegible]}$

$D = \epsilon E$

On comparing [illegible]

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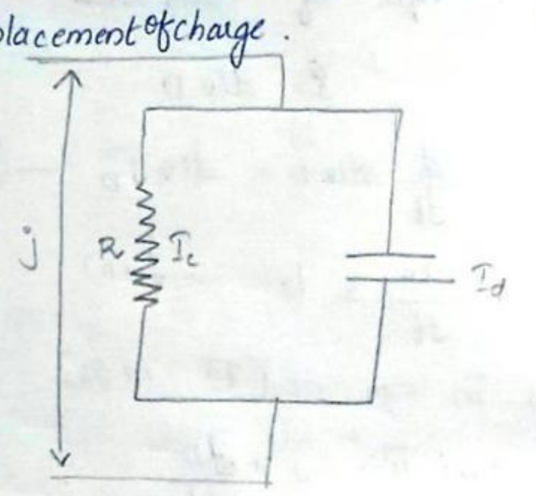
displacement current $I_d = A \frac{dD}{dt}$ $\{D \to \varepsilon_0 E\}$

displacement current density, $J_d = \frac{dD}{dt}$

connection of displacement current with conduction current

displacement current is the current ie, set up in a dielectric medium due to variation of induced displacement of charge.



$I_c = \frac{V}{R}$ $Q = CV$

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

$\therefore I_d = \frac{dq}{dt} = \frac{dcv}{dt}$

$I_d = c\frac{dv}{dt}$

$j = I/A$ current charge density $= j$

$\therefore J_c = I_c/A = \sigma E$

$E = \frac{V}{d}$ $C = \frac{\varepsilon_0 A}{d}$ $D = \varepsilon_0 E$

$J_d = \frac{I_d}{A} = \frac{c}{A}\frac{dv}{dt} = \frac{\varepsilon_0 A}{dA}\frac{dv}{dt} = \frac{\varepsilon_0 V}{d} = \frac{\varepsilon_0 Ed}{dt}$

$J_d = \frac{dD}{dt}$

$J_D = \varepsilon_0 E$ $J_c = \frac{I_c}{A} = \sigma E$

Total $= J_c + J_d$
(current charge density)

Velocity of EM-Wave In Free Space.

according to maxwell's assumption the velocity of EM waves in free space ie,

$$V = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \quad \text{——— (1)}$$

proof :- Maxwell's equation assumes the simpler form.

$div.\ \vec{D} = 0$ ——— (2)

There is no free charge

$div\ \vec{B} = 0$ ——— (3)

$curl\ \vec{E} = -\frac{dB}{dt}$ ——— (4)

$curl\ \vec{H} = \frac{-dB}{dt}$ ——— (5)

$J = 0$ there is no conduction current

multiply eqn (4) by curl

$curl(curl\ \vec{E}) = curl - \frac{dB}{dt}$ — (6) $(B = \mu H)$

$curl(curl\ \vec{E}) = curl - \frac{d\mu\vec{H}}{dt}$

$= -\frac{d\,curl\,\mu\vec{H}}{dt}$

$= -\mu\frac{d\,curl\,\vec{H}}{dt}$

$= -\mu\frac{d\vec{B}}{dt} \times \frac{dD}{dt}$

$= -\mu\frac{d}{dt} \times \frac{d\varepsilon_0 E}{dt}$

$= -\mu\varepsilon_0 \frac{d}{dt}\left(\frac{dE}{dt}\right)$

double differentiation

$= -\mu \frac{d^2}{dt^2}(E\varepsilon)$

$$= -\mu\epsilon \frac{d^2 E}{dt^2} \quad \text{---} (6)$$

$$\text{curl}(\text{curl } E) = -\mu\epsilon \frac{d^2 E}{dt^2}$$ grad → gradient

$$\text{curl}(\text{curl } E) = \text{gradient}(\text{div } E) - \nabla^2 E$$

$$\text{div } \vec{D} = 0 \quad \therefore \text{div } \vec{E} = 0$$

$$\text{curl curl } E = -\nabla^2 E \quad \text{———} (7)$$

$$-\mu\epsilon \frac{d^2 E}{dt^2} = -\nabla^2 E \quad \text{———} (8)$$

$$\mu\epsilon \frac{d^2 E}{dt^2} = \nabla^2 E$$

Eqn no (8) is well known as differential eqn

This shows that $\vec{E}$ is propogated as a wave with,

therefore the above eqn is simplified in the form of

$$v = \frac{1}{\sqrt{\mu\epsilon}}$$

$$\text{III}^{ly} \quad \nabla^2 H = \mu_0 \epsilon_0 \frac{d^2 H}{dt^2}$$

$$v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$ This is the velocity of EM waves velocity is

same $\left(v = \left(8.85 \times 10^{-12} \times \frac{4\pi}{10^{7}} \right)^{-1/2} = 2.997 \times 10^{8} \text{ m/s} \right)$

Poyentors theorem

The rate of energy transfer (per unit vol) from a region of space equals the rate of work done on a charge distribution + energy flux leaving that region

$$-\frac{du}{dt} = \nabla \cdot S + J \cdot E$$

Maxwells Equations (4 equations)

Gradient, divergence, curl, Gauss divergent theorem, Stoke's (theorem. theorem and its proof)

Test :- Maxwells Equations (4 equations)