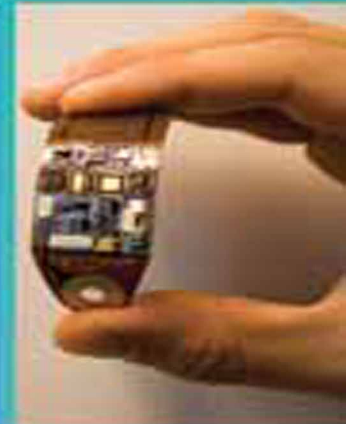
A TEXTBOOK OF

ENGINEERING PHYSICS



For the Students of B.E./B.Tech. I & II Semester of M.G. University, Kerala

Prof. A. ATMAJAN
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PREFACE

We are happy to bring out this work **A Textbook of Engineering Physics** for Engineering students of Mahatma Gandhi University, Kerala.

Physics is a mandatory subject for all engineering branches. The book "A Textbook of Engineering Physics" has been written on the basis of the revised syllabus of Mahatma Gandhi University. It includes the complete syllabus for first year engineering physics in a simple and concise manner. Sincere attempts have been made to provide an excellent understanding of basic concepts and advanced applications. Every chapter begins with a small introduction followed with detailed explanations, suitable figures and concludes with solved problems, model questions and problems for practice. These questions are not merely values but are collected from the year question papers of previous. It will give an opportunity to students to learn and test their subject knowledge. Maximum efforts has been made to make this edition up-to-date.

We are very much thankful to our Management, Principal and members of staff for their unstinting support and directions. We are also obliged to our publisher, S.Chand & Company Ltd., New Delhi, especially Mr. Navin Joshi, Vice President (Publishing), Mr. Bhagirath Kaushik, General Manager (S&M), Mr. Mohandas Menon, Branch Manager, Cochin, Mr. Rajananda Kamath, Asstt. Sales Manager, Cochin, Mr. Sunil V.A, Territory Manager, Cochin, Mr. Sumesh, Sales Executive, Cochin, Mr. Vinod, Senior Sales Executive, Cochin, and to all the Editorial Staff for the support extended to us for publishing this book.

Critical evaluation and suggestion for improvement will always be most welcome and will be acknowledged most gratefully.

Kottayam **AUTHORS**

M.G. UNIVERSITY B.TECH.
FIRST AND SECOND SEMESTER
Revised Syllabus

ENGINEERING PHYSICS

MODULE I – LASERS AND HOLOGRAPHY

Lasers - Principle of laser - Absorption - Spontaneous emission - Stimulated emission - Characteristics of laser - Population inversion - Metastable states - Pumping - Pumping Methods - Pumping Schemes - 3 level and 4 level pumping - Optical resonator - Components of laser - Typical laser systems like Ruby laser - He-Ne laser - Semiconductor laser - Applications of laser

Holography - Basic principle -Recording and reconstruction- comparison with ordinary photography-Applications of Hologram (11 Hrs.)

MODULE II – NANOTECHNOLOGY AND SUPERCONDUCTIVITY

Introduction to nanoscale science and technology - nanostructures-nanoring, nanorod, nanoparticle, nanoshells - Properties of nanoparticles - optical, electrical, magnetic, mechanical properties and quantum confinement - Classification of nanomaterials - C_{60}, metallic nanocomposites and polymer nanocomposites - Applications of nanotechnology

B. Superconductivity - Introduction - Properties of super conductors - Zero electrical resistance - Critical temperature - Critical current - Critical magnetic field - Meissner effect - Isotope effect - Persistence of current - Flux quantization - Type I and Type II superconductors - BCS Theory (Qualitative study) - Josephson effect - D.C Josephson effect - A.C Josephson effect - Applications of superconductors. (11 Hrs.)

MODULE III – CRYSTALLOGRAPHY AND MODERN ENGINEERING MATERIALS

A. Crystallography – Space lattice - Basis - Unit cell - Unit cell parameters - Crystal systems - Bravais lattices - Three cubic lattices - sc, bcc, and fcc - Number of atoms per unit cell - Co-ordination number - Atomic radius - Packing factor - Relation between density and crystal lattice constants - Lattice planes and Miller indices-Separation between lattice planes in sc - Bragg's law - Bragg's x-ray spectrometer - Crystal structure analysis.

Liquid crystals - Liquid crystals, display systems-merits and demerits - Metallic glasses - Types of metallic glasses (Metal-metalloid glasses, Metal-metal glasses) - Properties of metallic glasses (Structural, electrical, magnetic and chemical properties)

Shape memory alloys - Shape memory effect, pseudo elasticity (11 Hrs.)

MODULE IV – ULTRASONICS

A. Ultrasonics - Production of ultrasonics - Magnetostriction method - Piezoelectric method - Properties of ultrasonics - Non destructive testing - Applications

B. Spectroscopy - Rayleigh scattering (Qualitative) - Raman effect - Quantum theory of Raman effect - Experimental study of Raman effect and Raman spectrum - Applications of Raman effect

C. Acoustics - Reverberation - Reverbaration time - Absorption of sound - Sabine's formula (no derivation) - Factors affecting acoustics properties (11 Hrs.)

MODULE V – FIBRE OPTICS

Principle and propagation of light in optical fibre - Step index (Single Mode and Multi Mode fibre) and graded index fibre - N.A. and acceptance angle - Characteristics of optical fibres (Pulse dispersion, attenuation, V-number, Bandwidth-distance product)

Applications of optical fibres - Fibre optic communication system (Block diagram) - Optical fibre sensors (any five) - Optical fibre bundle. (11 Hrs.)

CONTENTS

CHAPTER

1 LASERS AND HOLOGRAPHY

1.1 Introduction

The word laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser is one of the outstanding inventions of the second half of the last century. Laser has become a valuable tool in a variety of fields starting with medicine to communications. Laser is a light source but it is very much different from many of traditional light sources. Laser is not used for illumination purposes alike the other light sources. Lasers produce a highly directional and intense beam with a narrow frequency range than that available from the common types of light sources. They are more widely used as a high power electromagnetic beam rather than a light beam. The laser beams are used as a special type of drill bit to drill holes in hard materials, as a saw to cut thick metal sheets, as a phonograph needle for compact discs, as knife during surgical operations, as target designators for military weapons and so on. Thus, laser is a high technology device affecting our lives in many ways.

1.2 A Brief History of the Laser

Lasers are in fact generators of light. They are based on the amplification of light by means of stimulated radiation of atoms or molecules. In 1917 Einstein predicted the possibility of such stimulated radiation.

In 1952, Ch. Townes, J. Gordon & H. Zeiger in U.S.A. and Basov & A. Prokhorov in USSR, independently suggested the principle of generating and amplifying microwave oscillations based on the concept of stimulated radiation. It leads to the invention of a two level system called MASER (Microwave Amplification by Stimulated Emission of Radiation) in 1954. Later in 1955 Basov and Prokhonov suggested use of three -level system.

In 1958, Townes & Schawlow and Basov & Prokhorov independently expressed their ideas about extending the maser concept to optical frequencies. They developed the concept of an optical amplifier surrounded by an optical mirror resonant cavity to allow the growth of the beam. They received Nobel Prizes for their work in this field.

In 1960, Theodore Maiman of Hughes Research Laboratories produced the first laser using a ruby crystal as the amplifier and a flash lamp as the energy source. The helical flash lamp surrounded a rod-shaped ruby crystal, and the optical cavity was formed by coating the flattened ends of the ruby rode with a highly reflecting material. An intense red beam was observed to emerge from the end of the rod when the flash lamp was fired.

The first gas laser was developed in 1961 by A. Javan, W. Bennett, and D. Harriott of Bell Laboratories, using a mixture of Helium and Neon gases. At the same laboratory, L.G. Johnson and K. Nassau demonstrated the first Neodymium laser, which has since become one of the most reliable lasers available. This was followed in 1962 by the first semiconductor laser, demonstrated by R. Hall at the General Electric Research Laboratories.

Table1.1: Major landmarks in the development of lasers

Year	Discoverer	Type of Laser/Principle
1917	Albert Einstein	Stimulated Emission Process
1952	N.G. Basov, A.M. Prokhorov and Townes	Master Principle
1954	Townes, Gordon, Zeiger	Maser
1958	Townes, Schawlow, Basov, Prokhorov	Laser Principle
1960	Theodore Maiman	Ruby Laser
1961	A. Javan, W. Bennett and D. Harriott	Helium - Neon Laser
1961	L.F. Johnson and K. Nassau	Neodymium Laser
1962	R. Hall	Semiconductor Laser
1963	C. K. N. Patel	Carbon dioxide Laser
1964	W. Bridges	Argon ion Laser
1966	W. Silfvast, G. R. Fowles and B. D. Hopkins	He-Cd Laser
1966	P. P. Sorokin and J. R. Lankard	Tunable Dye Laser
1975	J. J. Ewing and C. Brau	Excimer Laser
1976	J.M.J. Madey and coworkers	Free-election Laser
1979	Walling and coworkers	Alexandrite Laser
1985	D. Mathews and coworkers	X-ray Laser

1.3 Properties (Charecteristics) of Laser Beam

(*a*) Coherence

Coherence refers to the constancy and periodicity of the phase of a wave at subsequent time and phase. A conventional light source such as the incandescent lamp or a natural source such as the sun produces light waves with no common phase relationship. On the other hand, the waves emitted by a laser source will be in phase and are of the same frequency. Therefore the light generated by a laser will be highly coherent. Coherence is classified as spatial coherence and temporal coherence.

(*i*) Spatial coherence: Spatial coherence describes the correlation between signals at different points in space. Thus the Spatial coherence is described as a function of distance. If the two waves have identical propagation characteristics at two different points in space, then the waves are said to be spatially coherent. The coherence length l_c is the distance travelled by a wave without loosing its coherence.

$lc = \lambda\left(\frac{\lambda}{\Delta\lambda}\right) = \frac{\lambda^2}{\Delta\lambda}$, where λ is the wavelength of laser beam and $\Delta\lambda$ is the wavelength spread (line width) of a laser beam.

(*ii*) Temporal coherence: Temporal coherence describes the correlation between signals observed at different moments in time. The two waves are said to be temporally coherent, if they have same propagation characteristics at different instants of time.

$$\text{Coherence time } \tau_c = \left(\frac{1}{\Delta\upsilon}\right)$$

Coherence time is related to coherent length by the equation

$$l_c = c \times \tau_c$$

(*b*) Directionality

The conventional sources emit light in all directions. Lasers emit light only in one direction as the photons travelling along the optical axis of the system are selected with the help of optical resonator. Because of the high directionality of lasers, energy carried by the laser beam can be controlled easily and focused into a small area.

(*c*) Intensity

As the energy is concentrated in a very narrow region, the intensity of laser sources is very high compared to ordinary sources of light. This is the reason why it can be used for operations such as welding, cutting etc.

(*d*) Divergence (Angular Spread)

Light from the conventional sources are highly divergent. But the divergence of the laser beam is very less. The little divergence that exist in it arises out of the wave properties of light. When light issues out of the front mirror, it undergoes diffraction because the semi transparent mirror acts as a circular aperture.

(*e*) Monochromaticity

The light from normal monochromatic source spreads over a wavelength range of the order of 100 to 1000Å. But the laser light is highly monochromatic. The spread is of the order of a few angstroms. (<10Å) only.

1.4 Principle of Laser

The understanding of the working principle of laser requires an appreciation of quantum process that takes place in a material when it undergoes exposure to radiation. A material medium is composed of identical atoms or molecules each of which is characterized by a set of discrete allowed energy states. An atom can move from one energy state to another when it receives or releases an amount of energy equal to the energy difference between the two states.

For the sake of ease in understanding let us restrict our attention to two energy levels E_1 and E_2 of an atom. E_1 is the lower energy level and E_2 is the excited state. As the constituent atoms of the medium are identical, the energy states E_1 and E_2 will be common to all atoms in the medium. Let a monochromatic radiation of frequency ν be incident on the medium. The radiation may be viewed as a stream of photons; each of them carries an amount of energy hn. If $h\nu = E_2 - E_1$, the interaction of radiation with atoms leads to the following three distinct processes in the medium.

(*a*) Absorption

An atom residing in the lower energy state E_1 may absorb the incident photon and is excited to the higher state E_2. This transition is known as stimulated absorption. Corresponding to each transition made by the atom one photon disappears from the incident beam.

The number of absorption transitions occurring in the medium at any instant will be proportional to the number of atoms in the lower state E_1 and the photon density of the incident beam. Normally the number of atoms is greater in the lower energy state and the material absorbs incident energy. Therefore the process of absorption leads to attenuation of radiation as light travels through the medium.

The rate of absorption can be written as $R_{12} = B_{12}\rho_\gamma N_1$ where B_{12} is the Einstein's coefficient, $N_1 \rightarrow$ Number of atoms in the ground state and ρ_γ is the photon density of incident radiation.

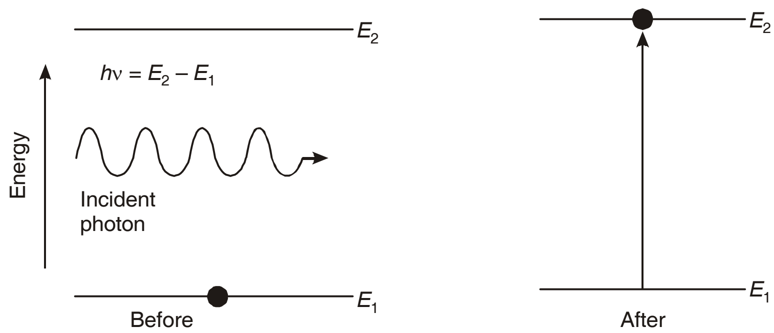

Fig. 1.1. Schematic diagrams showing the absorption process

(*b*) Spontaneous Emission

Excited state with higher energy is inherently unstable because of a natural tendency of atoms to seek out the lowest energy configuration. Therefore excited atoms do not stay in the excited state for a relatively longer time but tend to return to the lower state by giving up the excess energy hn = E_2- E_1, in the form of photons. This type of process in which photon emission occurs without any external impart of energy is called spontaneous emission.

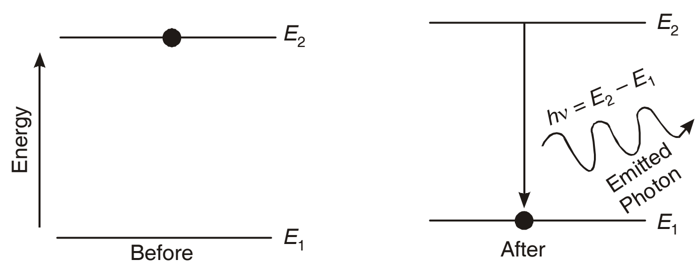

Fig.1.2. Schematic diagrams showing the spontaneous emission

The number of spontaneous transitions taking place in a material during the time 't' is independent of the photons present in the incident radiation and depends only on the density of atoms N_2 in the excited state E_2. The process of spontaneous emission is not amenable for control from out side. The instant of transition, the direction of emission of photons, the phase of photons, the polarization state of the photons etc. are random quantities. In spontaneous emission, there is no correlation between the innumerable photons emitted from an assembly of atoms in the medium. Therefore the light generated by the medium will be incoherent.

The rate of spontaneous emission can be written as $R_{21(Spont)} = A_{21}N_2$ where A_{21} is the Einstein's coefficient and N_2 is the number of atoms in the excited state.

(*c*) Stimulated Emission

An atom in the excited state need not wait for spontaneous emission to occur. There exists an alternate mechanism by which an excited atom can make a downward transition and emit light.

If the atom resides in the upper level E_2, a photon of energy $h\nu = E_2 - E_1$ can trigger and induce a downward transition to the lower level E_1. The transition generates a second photon which would be identical to the triggering photon in respect of frequency, phase, propagation, direction and polarization. Hence instead of one photon, now two photons get de-excited. If the number of atoms in the upper level E_2 is large, one primary photon can trigger an avalanche of secondary photons, all of them are in the same state as that of the stimulating primary photon. This

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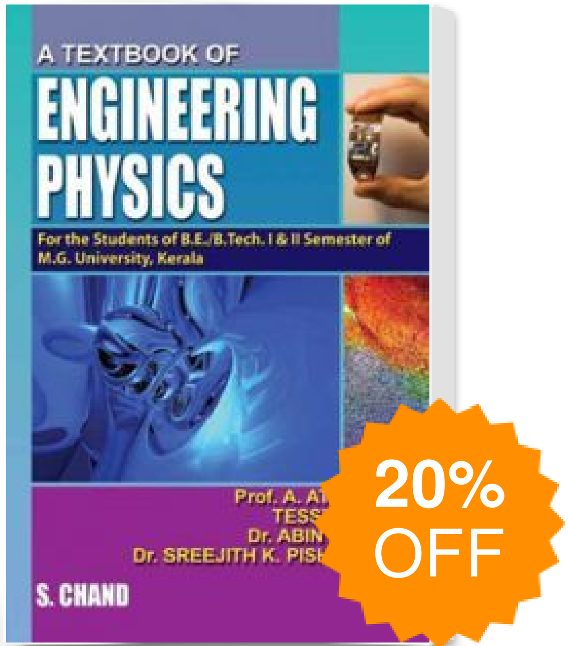

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