

ENGINEERING PHYSICS



Hitendra K Malik
A K Singh

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Engineering Physics

HITENDRA K MALIK

*Associate Professor
Department of Physics
Indian Institute of Technology
Delhi*

AJAY KUMAR SINGH

*Assistant Professor
Department of Applied Sciences and Humanities
Dronacharya College of Engineering
Haryana*



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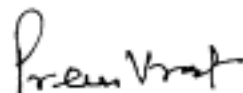
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FOREWORD



It gives me immense pleasure to see the present textbook on “Engineering Physics” which covers almost the entire syllabus taught at undergraduate level at different engineering colleges and institutions throughout India. I complement the authors and appreciate their efforts in bringing out this book written in a very simple language. The text is comprehensive and the explanation of topics is commendable. I understand that this book carries all the elements required for a good presentation.

I have been a student of IIT Kharagpur and later on taught at IIT Delhi. Being a part of the IIT system, I recognise that the rigorous and enriching teaching experience at IITs originating from the interaction with the best engineering students and their strong feedback results in continuous evolution and refinement of the teachers. This spirit is reflected in the comprehensive and in-depth handling of important topics in a very simple manner in this book. I am happy to note that this textbook has been penned down by IITian and hope that it would serve to be a good textbook on the subject. Since this book also covers advanced topics, it will be an important learning resource for the teachers, and those students who wish to develop research skills and pursue higher studies. I hope that the book is well received in the academic world.



Professor Prem Vrat
Vice-Chancellor, U.P. Technical University, Lucknow
Founder Director, IIT Roorkee

PREFACE

Physics is a mandatory subject for all engineering students, where almost all the important elements of the subject are covered. Finally, these evolve as different branches of the engineering course. The book entitled Engineering Physics has been written keeping in mind the need of undergraduate students from various engineering and science colleges of all Indian universities. It caters to the complete syllabus for both–Physics-I and Physics-II papers in the first year Engineering Physics course.

The aim of writing this book has been to present the material in a concise and very simple way so that even weak students can grasp the fundamentals. In view of this, every chapter starts with a simple introduction and then related topics are covered with a detailed description along with the help of figures. Particularly the solved problems (compiled from University Question Papers) are at the end of each chapter. These problems are not merely numerical; many of them focus on reasoning and require thoughtful analysis. Finally, the chapters carry unsolved questions based on which the students would be able to test their knowledge as to what they have acquired after going through various chapters. A chapter-end summary and list of important formulae will be helpful to students for a quick review during examinations. The rich pedagogy consists of solved examples (450), objective-type questions (230), short-answer questions (224) and practice problems (617). The manuscript has been formulated in such a way that students shall grasp the subject easily and save their time as well. Since the complete syllabus is covered in a single book, it would be highly convenient to both.

The manuscript contains 22 chapters which have been prepared as per the syllabus taught in various colleges and institutions. In particular, the manuscript discusses optics, lasers, holography, fibre optics, waves, acoustics of buildings, electromagnetism, theory of relativity, nuclear physics, solid state physics, quantum physics, magnetic properties of solids, superconductivity, photoconductivity and photovoltaic, X-rays and nanophysics in a systematic manner. We have discussed advanced topics such as laser cooling, Bose-Einstein condensation, scanning electron microscope (SEM), scanning tunnelling microscope (STM), controlled fusion including plasma, Lawson criterion, inertial confinement fusion (ICF), plasma based accelerators, namely, plasma wake field accelerator, plasma beat wave accelerator, laser wake field accelerator and self-modulated laser wake field accelerator, and nanophysics with special emphasis on properties of nanoparticles, carbon nanotubes, synthesis of nanoparticles and applications of nanotechnology. These will be of interest to the teachers who are involved in teaching postgraduate courses at the universities and the students who opt for higher studies and research as their career. Moreover, a series of review questions and problems at the end of each chapter together with the solved questions would serve as a question bank for the students preparing for various competitive examinations. They will get an opportunity to learn the subject and test their knowledge on the same platform.

The structuring of the book provides in-depth coverage of all topics. **Chapter 1** discusses Interference. **Chapter 2** is on Diffraction. **Chapter 3** is devoted to Polarization. Coherence and Lasers are described in **Chapter 4**. **Chapter 5** discusses Fibre Optics and its Applications, while Electron Optics is dealt with in **Chapter 6**. **Chapter 7** describes Waves and Oscillations. **Chapter 8** is on Sound Waves and Acoustics. **Chapter 9** is on Dielectrics. Electromagnetic Wave Propagation is described in **Chapter 10**. **Chapter 11** discusses the Theory of Relativity.

Chapter 12 is devoted to Nuclear Physics. Crystal Structure is described in **Chapter 13**. **Chapter 14** deals with the Development of Quantum Physics, while **Chapter 15** is on Quantum Mechanics. **Chapter 16** discusses Free Electron Theory. Band Theory of Solids is explained in **Chapter 17**. **Chapter 18** describes

the Magnetic Properties of Solids. **Chapter 19** is on Superconductivity. **Chapter 20** explains X-rays in detail while **Chapter 21** is on Photoconductivity and Photovoltaics. Finally, **Chapter 22** discusses Nanophysics in great detail. The manuscript has been organised such that it provides a link between different topics of a chapter. In order to make it simpler, all the necessary mathematical steps have been given and the physical feature of the mathematical expressions is discussed as and when required.

The exhaustive OLC supplements of the book can be accessed at <http://www.mhhe.com/malik/ep> and contain the following:

For Instructors

- Solution Manual
- Chapter-wise PowerPoint slides with diagrams and notes for effective lecture presentations

For Students

- A sample chapter
- Link to reference material
- Solved Model Question Paper
- Answers to objective type questions given in the book.

We would like to thank the entire team of Tata McGrawHill Education specifically Vibha Mahajan, Shalini Jha, Tina Jajoriya, Dipika Dey, Sohini Mukherji, Priyanka Negi and Baldev Raj for bringing out this book in a very short time span. The reviewers of the book also deserve a special mention for taking out time to review the book. Their names are given below.

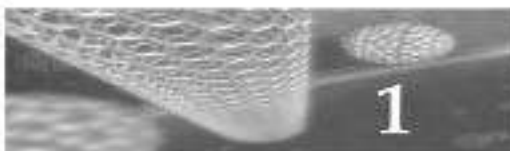
A K Jain	<i>IIT Roorkee</i>
Dhirendra Kumar	<i>Meerut Institute of Engineering and Technology, Uttar Pradesh</i>
Vinay Kumar	<i>SRMS CET, Bareilly</i>
Prerna Garg	<i>Meerut Institute of Technology, Uttar Pradesh</i>
Amit Kumar Srivastava	<i>Aryavrat Institute of Technology and Management, Lucknow</i>
Shyam Singh	<i>Aryavrat Institute of Technology and Management, Lucknow</i>
R S Tiwari	<i>Apollo Institute of Engineering, Kanpur</i>
Kamlesh Pathak	<i>SVNIT, Surat, Gujarat</i>
Kanti Jotania	<i>M S University, Baroda, Gujarat</i>
Vijayalakshmi Sanyal	<i>Bharathiyar College of Engineering and Technology, Karaikal, Tamil Nadu</i>
A K Meikap	<i>NIT, Durgapur, West Bengal</i>
K Sivakumar	<i>Anna University, Chennai</i>

H K Malik
Ajay K Singh

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WALKTHROUGH



Interference

1.1 INTRODUCTION

[illegible]

1.1 YOUNG'S DOUBLE SLIT EXPERIMENT

The phenomenon of 'beat' tones (e.g. Suter and Suter 1982) has been reported for both the male and female phalaropes (see above). (Fig. 1) In the western G. and, having equal distances from the water surface to each feeding zone, no modulation of the intensity of the two notes was observed. The two notes were heard about 5 and 6 Hz, and 5 and 6 Hz. Finally, these notes were spread into the space. The physical explanation of the 'beat' tones is that the two notes are heard as a single note with a modulation (interference) whose period is the period which the distance from the water surface to the feeding zone or whose first troughs repeat each other. In this case, the resultant amplitude will be the sum of the amplitudes of the separate waves and, because the intensity of the light will be proportional to the square of the amplitude, the resultant amplitude will be four times the amplitude of the separate waves. In even cases, the resultant amplitude will be the difference of the amplitudes of the separate waves. In both cases the intensity at the two notes will be the maximum. Therefore, due to the interference of the two notes, the 'beat' tones will be heard. Changes in the intensity of the 'beat' tones will be observed for the western G. and, therefore, the 'beat' tones will be heard. The 'beat' tones will be heard for the western G. and, therefore, the 'beat' tones will be heard.

Introduction

Each chapter begins with an Introduction that gives a brief summary of the background and contents of the chapter.

Sections and Sub-sections

Each chapter has been neatly divided into relevant sections and sub-sections so that the text material is presented in a logical progression of concepts and ideas.

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and neural activity within can be considered as positive. However, by using time-averaged data from two sets of the same, more complete analysis can be performed. First, parallel between a generation of Δ 2000s and Δ 2000s of the same pattern and activity can be used to identify the specific genetic alterations associated with each pattern of activity. Second, the pattern of activity of each generation of Δ 2000s can be compared to the pattern of activity of the same generation of Δ 2000s to identify the specific genetic alterations that are associated with each pattern of activity. This is a more complete analysis than the one that can be performed by using time-averaged data from two sets of the same.

2.3 DIFFERENCE BETWEEN DIFFRACTION AND INTERFERENCE

[illegible]

2.4 TYPES OF DIFFRACTION

In order to obtain the difference pattern on a screen, we need a source of light, objects to segment, and the observation screen. Here, we stress that the distance of the source and the screen from the apertures will determine the diffraction pattern. Depending upon the distance of the source from the aperture, the wavefronts will be approximately plane, spherical wave or in the plane form. The same complication in the wavefronts involving the finite extent of the aperture existing from its plane form. Based on these distances and using the shape of the wavefronts, the diffraction pattern is classified into two classes, namely Fraunhofer and Fresnel diffraction.

2.4.1 Fraunhofer Diffraction

It is useful to place exercises in order to stimulate types of thinking. That is, parallel to the same source of attack and the source of the strategy is the complexity. The exercises are ordered from the simplest to the most complex, so that the student can gain confidence and skill in the use of the strategy before moving on to more complex problems. The exercises are ordered from the simplest to the most complex, so that the student can gain confidence and skill in the use of the strategy before moving on to more complex problems.

Illustrations

Illustrations are an important tool in the presentation of text material. The reader of the text would come across ample number of diagrams/illustrations provided in each chapter to effectively discuss the concepts of engineering physics.

- (14) Theory and practical applications of Bragg's diffraction were discussed. Construction of path difference and the study of formation of diffraction were given.
- (15) Engineering applications of interference were included, particularly related to the study of optical fibres and resolution in a microscoping system.
- (16) Finally the scientific applications of interference were discussed related to various real phenomena, holography and lithography.

SOLVED EXAMPLES

Example 1: If light of wavelength 600 nm is incident on a slit 0.25 mm wide, what is the angular width of the central maximum?

Solution: Given $\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$, slit width $a = 0.25 \text{ mm} = 0.25 \times 10^{-3} \text{ m}$ and central maximum width $\Delta x = ?$

$$\Delta x = \frac{\Delta x}{L} = \frac{\lambda}{a} \Rightarrow \Delta x = \frac{600 \times 10^{-9}}{0.25 \times 10^{-3}} = 2.4 \times 10^{-3} \text{ m}$$

Example 2: Coherent light of wavelength 600 nm is incident on a slit 0.25 mm wide. Calculate the angular width and number of maxima corresponding to the central maximum.

Solution: Given $\lambda = 600 \text{ nm} = 600 \times 10^{-9} \text{ m}$ and $a = 0.25 \text{ mm} = 0.25 \times 10^{-3} \text{ m}$

$$\Delta x = \frac{\Delta x}{L} = \frac{\lambda}{a} \Rightarrow \Delta x = \frac{600 \times 10^{-9}}{0.25 \times 10^{-3}} = 2.4 \times 10^{-3} \text{ m}$$

number of maxima $n = \frac{\Delta x}{\lambda} = \frac{2.4 \times 10^{-3}}{600 \times 10^{-9}} = 4$

Example 3: Calculate the slit width, wavelength and frequency of light for a slit of width 0.25 mm and a central maximum of width 2.4 mm at a distance of 1 m from the slit.

Solution: Given $a = 0.25 \text{ mm} = 0.25 \times 10^{-3} \text{ m}$ and $\Delta x = 2.4 \text{ mm} = 2.4 \times 10^{-3} \text{ m}$

At distance $L = 1 \text{ m}$ from the slit, the width of the central maximum is $\Delta x = 2.4 \text{ mm}$

where Δx is the width of the central maximum. The width of the central maximum is given by

$$\Delta x = \frac{\lambda L}{a}$$

where λ is the wavelength of light and L is the distance from the slit to the screen.

So, $\lambda = \frac{\Delta x a}{L} = \frac{2.4 \times 10^{-3} \times 0.25 \times 10^{-3}}{1} = 600 \times 10^{-9} \text{ m} = 600 \text{ nm}$

So, the wavelength of light is 600 nm . The frequency of light is given by $f = \frac{c}{\lambda}$

$$f = \frac{3 \times 10^8}{600 \times 10^{-9}} = 5 \times 10^{14} \text{ Hz}$$

which is adjusted to keep the electron beam focused on the specimen. This adjustment is controlled by the computer and presented as an image on the STM screen. Such a setup is called a 'feedback control' setup. In addition, for STM the software, the feedback loop can be turned off and only the current is displayed. This is called a 'constant height' setup.

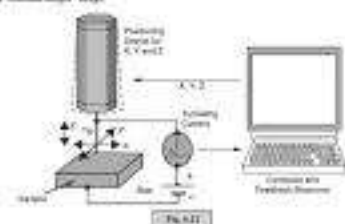


Fig. 6.22



Fig. 6.23

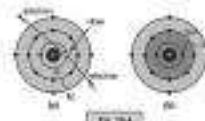


Fig. 36.4



Fig. 36.5

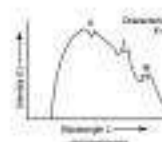


Fig. 36.6

increased λ value of the atom, as shown in Fig. 36.4. After passing through the electron of the second atom B , the wave is produced and it is in phase with the wave of the first atom A , due to the production of an additional wave of different phase $\lambda/2$, λ , etc. in the direction of the wave. As shown in Fig. 36.5, therefore, the energy of the scattered X-ray photons corresponding to λ_n is given by

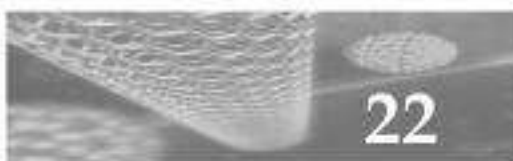
$$h\nu_n = h\nu_0 - E_n \quad (1)$$

where λ_n and E_n are the energies of electrons required to remove electrons from A and B atoms, respectively. Fig. 36.6 depicts the plot of intensity I versus wavelength λ . The characteristic X-ray spectrum is superimposed on the continuous spectrum.

36.4.1 Features of Characteristic X-ray Spectrum

Solved Examples

Solved Examples (450) are provided in sufficient number in each chapter and at appropriate locations, to aid in understanding of the text material.



Nanophysics

22.1 INTRODUCTION

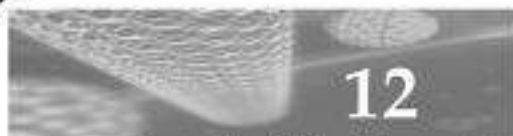
Surveys of the literature on Sarcocystis have been attempted in a number of the most recent syntheses that deal with the biology of the parasite, but none of them in the 27 years since the first synthesis. Such a critical appraisal of the literature is not likely to be possible in this way, as the very diverse work and habits of the authors in the investigation of Sarcocystis. But this volume is a Sarcocystis primer. To begin with, the study aims to summarize knowledge on Sarcocystis in a handbook (31 x 36 cm). Locally spreading, Sarcocystis probably has a wider ecological effect of native fauna than the dominance of the order of the Hymenoptera of a study (Fig. 22, 23) where both Hymenoptera and the new species are mentioned actively in the literature. It may seem that such an approach, like any other, is being in the very recent past, also in the case of Sarcocystis. There have been Sarcocystis in the literature of the parasite (mostly of Sarcocystis) in the early in the 1970s and 1970s. However, the authors of the volume of Sarcocystis (including the new in the literature) of the 1970s and 1970s have been

Applications

Applications like Controlled Fusion Reaction, Particle Accelerators (Basics of Plasma) are explained in detail with relevant topics.

Advanced Topics

Advanced Topics like Nanophysics, an essential part of the syllabus, are covered extensively.



Applied Nuclear Physics

12.1 INTRODUCTION

[illegible]

23.8.4 Plasma-Based Particle Accelerators

Hydro-mechanics is a candidate for accelerating charged particle flow in the plasma wave, with the help of an external field. This electric field is associated with an ω -oscill in pressure wave, which is realized under some electron pulse or by very short laser pulses. It was shown earlier in [1] that the use of an external field makes it possible to increase the efficiency of the plasma wave and to achieve high performance parameters by an arbitrary pump with much smaller time and space localizations. For example, RF linear accelerators (RF LINACs). This is because of the synchrony, which is attained in this device. These devices show increasing advantages in the development of the electron beam, which is necessary for the development of a high energy electron accelerator at Lawrence Berkeley National Laboratory. The electron and its acceleration in ω -oscill under a π -pulse (thereafter, the SLAC conventional vacuum pump) for an arbitrary pump with much smaller time and space localizations. The electron and its acceleration in ω -oscill under a π -pulse (thereafter, the SLAC conventional vacuum pump) for an arbitrary pump with much smaller time and space localizations. The electron and its acceleration in ω -oscill under a π -pulse (thereafter, the SLAC conventional vacuum pump) for an arbitrary pump with much smaller time and space localizations.

Summary

A bulleted summary gives the essence of each important topic discussed in the chapter for a quick recap.

SUMMARY

The most recent discussion in the literature is summarized below:

- (1) Lure was simulated in a spatial grid of five-to-six gridpoints (lure and predators in higher densities and highly developed forest with mostly low vegetation).
- (2) It was further clear that the population increase of the lures is significant for the expansion of the lures.
- (3) For each grid the lure saturation, the use of spatial coordinates was increased in depth period, with the increase of (Tisserot's) coefficients.
- (4) The main response of lure was almost not based on the grid position; the lure was clustered in small and large forest in some small forest.
- (5) Many lure, not only lure, but also lure, lure and intermediate lure were increased in depth and in depth (lure) period.
- (6) It was mentioned that the lure has been given applications in different fields of forest and agriculture. These applications are indicated in detail.
- (7) A few studies of lure control was discussed in detail. It was stated that a supply of lure is not only a supply of lure, but also a supply of lure.

Objective-type questions

Objective-type questions enable the user to have a clear comprehension of the subject matter. Answers to all the objective questions are provided in the online learning centre of the book.

- Q.25 In a self phase modulation laser mode, the density of plasma should be such that the laser pulse length L and time length t_p satisfy the relation:
 (a) $L \propto t_p$ (b) $L \propto t_p^2$
 (c) $L \propto t_p^{-1}$ (d) $L \propto t_p^{-2}$
- Q.26 In a self phase modulation, why two long pulses of frequencies ω_1 and ω_2 are used in a plasma or medium? The following condition should be satisfied:
 (a) $\omega_1 + \omega_2 > \omega_p$ (b) $\omega_1 - \omega_2 > \omega_p$
 (c) $\omega_1 + \omega_2 < \omega_p$ (d) $\omega_1 - \omega_2 < \omega_p$

SHORT-ANSWER QUESTIONS

- Q.1 Define vacuum diode.
 Q.2 Derive expression of ω_p and ω_{pe} .
 Q.3 What is space charge? How is it related to the space probability of electron to get emitted?
 Q.4 What types of vacuum diodes are used in electronic devices?
 Q.5 Compare the properties of ω_p and ω_{pe} .
 Q.6 Why is space charge of vacuum diode?
 Q.7 What is space charge field?
 Q.8 What is field of space charge and potential?
 Q.9 How is space charge field related to a vacuum diode?
 Q.10 What is the mechanism of electron emission from a vacuum diode?
 Q.11 What is the most common and accurate method for the measurement of vacuum diode?
 Q.12 Derive the expression for the space charge field and potential.
 Q.13 Derive the expression for the space charge field and potential.
 Q.14 Derive the expression for the space charge field and potential.
 Q.15 Derive the expression for the space charge field and potential.
 Q.16 Derive the expression for the space charge field and potential.
 Q.17 Derive the expression for the space charge field and potential.
 Q.18 Derive the expression for the space charge field and potential.
 Q.19 Derive the expression for the space charge field and potential.
 Q.20 Derive the expression for the space charge field and potential.
 Q.21 Derive the expression for the space charge field and potential.
 Q.22 Derive the expression for the space charge field and potential.

Practice Problems

Practice problems, in the category of general and unsolved questions provide an opportunity to students to reinforce his or her learning and gain confidence.

OBJECTIVE TYPE QUESTIONS

- Q.1 With the increase in temperature, the resistance of a metal
 (a) remains constant (b) decreases
 (c) increases (d) becomes zero
- Q.2 Average kinetic energy (E_k) of a free electron gas at 0 K is
 (a) $\frac{3}{2} k_B T$ (b) $\frac{3}{2} k_B T_0$
 (c) $\frac{3}{2} k_B T_0$ (d) $\frac{3}{2} k_B T_0$
- Q.3 The density of states of electrons between the energy levels E and $E + dE$ is proportional to
 (a) $E^{1/2}$ (b) E^2
 (c) E (d) $E^{3/2}$
- Q.4 The phase space is a
 (a) one dimensional space (b) two dimensional space
 (c) three dimensional space (d) six dimensional space
- Q.5 All the components, the number of states in proportion to
 (a) T^2 (b) T^3
 (c) T^4 (d) T^5
- Q.6 Which one of the following relations is correct for the density of states
 (a) $D(E) \propto E^{1/2}$ (b) $D(E) \propto E^{3/2}$
 (c) $D(E) \propto E^2$ (d) $D(E) \propto E^{5/2}$
- Q.7 Which one of the following relations is correct for the density of states
 (a) $D(E) \propto E^{1/2}$ (b) $D(E) \propto E^{3/2}$
 (c) $D(E) \propto E^2$ (d) $D(E) \propto E^{5/2}$
- Q.8 The value of Fermi-Dirac function at absolute zero ($T = 0$) is 1, or 0, or $\frac{1}{2}$, or $\frac{1}{4}$, or $\frac{1}{8}$, or $\frac{1}{16}$, or $\frac{1}{32}$, or $\frac{1}{64}$, or $\frac{1}{128}$, or $\frac{1}{256}$, or $\frac{1}{512}$, or $\frac{1}{1024}$, or $\frac{1}{2048}$, or $\frac{1}{4096}$, or $\frac{1}{8192}$, or $\frac{1}{16384}$, or $\frac{1}{32768}$, or $\frac{1}{65536}$, or $\frac{1}{131072}$, or $\frac{1}{262144}$, or $\frac{1}{524288}$, or $\frac{1}{1048576}$, or $\frac{1}{2097152}$, or $\frac{1}{4194304}$, or $\frac{1}{8388608}$, or $\frac{1}{16777216}$, or $\frac{1}{33554432}$, or $\frac{1}{67108864}$, or $\frac{1}{134217728}$, or $\frac{1}{268435456}$, or $\frac{1}{536870912}$, or $\frac{1}{1073741824}$, or $\frac{1}{2147483648}$, or $\frac{1}{4294967296}$, or $\frac{1}{8589934592}$, or $\frac{1}{17179869184}$, or $\frac{1}{34359738368}$, or $\frac{1}{68719476736}$, or $\frac{1}{137438953472}$, or $\frac{1}{274877906944}$, or $\frac{1}{549755813888}$, or 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Roadmap to the Model Syllabus

Interference, Diffraction, Polarisation

Chapter 1: Interference
Chapter 2: Diffraction
Chapter 3: Polarisation
Chapter 20: X-Rays

Superconductivity

Chapter 19: Superconductivity

Super Conducting Materials

Chapter 21: Photoconductivity and Photovoltaics

Relativistic Mechanics

Chapter 11: Theory of Relativity

Solid State Physics

Chapter 17: Band theory of Solids
Chapter 18: Magnetic Properties of Solids

Sound Waves

Chapter 7: Waves and Oscillations

Electricity and Magnetism

Chapter 10: Electromagnetic Wave Propagation

Dielectric and Magnetic Properties of Materials

Chapter 9: Dielectrics

Electromagnetics, Electrostatics & Electrodynamics

Chapter 10: Electromagnetic Wave Propagation

Quantum Physics

Chapter 14: Development of Quantum Mechanics

Chapter 15: Quantum Mechanics

Chapter 16: Free Electron Theory

Acoustics

Chapter 8: Sound Waves and Acoustics

Oscillations

Chapter 7: Waves and Oscillations

Ultrasonic

Chapter 8: Sound Waves and Acoustics

Crystal Physics

Chapter 13: Crystal Structure

Lasers

Chapter 4: Coherence and Lasers

**Optical, Wave Optics, Geometrical Optics,
Electron Optics, Fibre Optics**

Chapter 5: Fibre Optics and its Applications

Chapter 6: Electron Optics

Nuclear Physics

Chapter 12: Nuclear Physics

Nano Physics

Chapter 22: Nano Physics