

Phys 500, Quantum Mechanics

Homework 5 • Reference Solution

Solution to Problem 1. Because H must be Hermitian, V_{12} is real. Energies up to second order perturbation are given by

$$E_n = E_n^{(0)} + \lambda \langle n^{(0)} | V | n^{(0)} \rangle + \lambda^2 \sum_{k \neq n} \frac{[\langle k^{(0)} | V | n^{(0)} \rangle]^2}{E_n^{(0)} - E_k^{(0)}} + O(\lambda^3),$$

so

$$E_1 = E_1^{(0)} + \frac{\lambda^2 V_{21}^2}{E_1^{(0)} - E_2^{(0)}} + O(\lambda^3),$$
$$E_2 = E_2^{(0)} + \frac{\lambda^2 V_{12}^2}{E_2^{(0)} - E_1^{(0)}} + O(\lambda^3).$$

To solve for the energies exactly, we look for the eigenvalues of the matrix

$$H = \begin{pmatrix} E_1^{(0)} & \lambda V_{12} \\ \lambda V_{12} & E_2^{(0)} \end{pmatrix},$$

and the exact energies are

$$E = \frac{1}{2} \left[E_1^{(0)} + E_2^{(0)} \pm (E_1^{(0)} - E_2^{(0)}) \sqrt{1 + \frac{4\lambda^2 V_{12}^2}{(E_1^{(0)} - E_2^{(0)})^2}} \right]$$
$$= \frac{1}{2} \left[E_1^{(0)} + E_2^{(0)} \pm (E_1^{(0)} - E_2^{(0)}) \left(1 + \frac{2\lambda^2 V_{12}^2}{(E_1^{(0)} - E_2^{(0)})^2} + O(\lambda^4) \right) \right]$$
$$= E_1^{(0)} + \frac{\lambda^2 V_{12}^2}{E_1^{(0)} - E_2^{(0)}} + O(\lambda^4) \quad \text{or} \quad E_2^{(0)} - \frac{\lambda^2 V_{12}^2}{E_1^{(0)} - E_2^{(0)}} + O(\lambda^4),$$

which are consistent with the perturbation result.

Solution to Problem 2: Time-dependent perturbation theory.

(a) Exact solution of the differential equation. For the time-dependent expansion coefficients $c_1(t)$, $c_2(t)$ in the interaction picture, we have the linear differential equations

$$i\hbar \dot{c}_1(t) = \gamma e^{-i(\omega - \omega_{21})t} c_2(t), \quad (1a)$$

$$i\hbar \dot{c}_2(t) = \gamma e^{i(\omega - \omega_{21})t} c_1(t). \quad (1b)$$

We take the time derivative of Eq. (1b) and insert Eq. (1a) into the resulting expression. We obtain a linear second order differential equation for c_2 ,

$$\frac{\gamma^2}{\hbar^2} c_2 + i(\omega - \omega_{21}) \dot{c}_2 + \ddot{c}_2 = 0.$$

This differential equation is solved by the Ansatz $c_2 = \exp(i\Omega t)$, with

$$\Omega = -\frac{\omega - \omega_{21}}{2} \pm \frac{\sqrt{(\omega - \omega_{21})^2 + 4\gamma^2/\hbar^2}}{2}.$$

The general solution is thus

$$c_2(t) = \exp(-i(\omega - \omega_{21})/2 t) \left[a \sin \left(\frac{\sqrt{(\omega - \omega_{21})^2 + 4\gamma^2/\hbar^2}}{2} t \right) + b \cos \left(\frac{\sqrt{(\omega - \omega_{21})^2 + 4\gamma^2/\hbar^2}}{2} t \right) \right].$$

500 Solved Problems In Quantum Mechanics Banyunore

Padhraic Smyth



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Exploring Quantum Mechanics Victor Galitski, Boris Karnakov, Vladimir Kogan, 2013-03-01 A series of seminal technological revolutions has led to a new generation of electronic devices miniaturized to such tiny scales where the strange laws of quantum physics come into play There is no doubt that unlike scientists and engineers of the past technology leaders of the future will have to rely on quantum mechanics in their everyday work This makes teaching and learning the subject of paramount importance for further progress Mastering quantum physics is a very non trivial task and its deep understanding can only be achieved through working out real life problems and examples It is notoriously difficult to come up with new quantum mechanical problems that would be solvable with a pencil and paper and within a finite amount of time This book remarkably presents some 700 original problems in quantum mechanics together with detailed solutions covering nearly 1000 pages on all aspects of quantum science The material is largely new to the English speaking audience The problems have been collected over about 60 years first by the lead author the late Prof Victor Galitski Sr Over the years new problems were added and the material polished by Prof Boris Karnakov Finally Prof Victor Galitski Jr has extended the material with new problems particularly relevant to modern science

Exercises in Quantum Mechanics H.A. Mavromatis, 2013-06-29 This monograph is written within the framework of the quantum mechanical paradigm It is modest in scope in that it is restricted to some observations and solved illustrative problems not readily available in any of the many standard and several excellent texts or books with solved problems that have been written on this subject Additionally a few more or less standard problems are included for continuity and purposes of comparison The hope is that the points made and problems solved will give the student some additional insights and a better grasp of this fascinating but mathematically somewhat involved branch of physics The hundred and fourteen problems discussed have intentionally been chosen to involve a minimum of technical complexity while still illustrating the consequences of the quantum mechanical formalism Concerning notation useful expressions are displayed in rectangular boxes while calculational details which one may wish to skip are included in square brackets

QUANTUM MECHANICS ARULDHAS, G., 2010-09-30 Quantum mechanics is an important area of physics and students of ten find it tough from the understanding point of view By providing 500 problems with their solutions Professor Aruldhas with his expertise in and long experience of teaching the subject makes the students comprehend the fundamental concepts of Quantum Mechanics with ease This problem book provides a thorough understanding of the subject and its applications to various physical and chemical problems The text includes typical problems that illustrate the concepts It is self explanatory comprehensive and user friendly Key Features Gives in the beginning of each chapter an outline of the theory required for solving problems Includes problems from the simple plug ins to increasing order of difficulty to strengthen the student s understanding of the subject Provides many mathematical steps to make the book user friendly Gives solutions of problems with different types of potentials including the Dirac delta

function potential Both undergraduate and postgraduate students of physics and chemistry as well as those preparing for the Joint CSIR UGC test for JRF and other competitive examinations should find this book extremely practical and valuable

Solved Problems in Quantum Mechanics Leonardo Angelini, 2019 This book presents a large collection of problems in Quantum Mechanics that are solvable within a limited time and using simple mathematics The problems test both the students understanding of each topic and their ability to apply this understanding concretely Solutions to the problems are provided in detail eliminating only the simplest steps No problem has been included that requires knowledge of mathematical methods not covered in standard courses such as Fuchsian differential equations The book is in particular designed to assist all students who are preparing for written examinations in Quantum Mechanics but will also be very useful for teachers who have to pose problems to their students in lessons and examinations

Problems in Quantum Mechanics Florin Constantinescu, E. Magyari, 1976 *Problems And Solutions On Quantum Mechanics (Second Edition)* Swee Cheng Lim, Choy Heng Lai, Leong-chuan Kwek, 2022-06-02 This volume is a comprehensive compilation of carefully selected questions at the PhD qualifying exam level including many actual questions from Columbia University University of Chicago MIT State University of New York at Buffalo Princeton University University of Wisconsin and the University of California at Berkeley over a twenty year period Topics covered in this book include the basic principles of quantum phenomena particles in potentials motion in electromagnetic fields perturbation theory and scattering theory among many others This latest edition has been updated with more problems and solutions and the original problems have also been modernized excluding outdated questions and emphasizing those that rely on calculations The problems range from fundamental to advanced in a wide range of topics on quantum mechanics easily enhancing the student s knowledge through workable exercises Simple to solve problems play a useful role as a first check of the student s level of knowledge whereas difficult problems will challenge the student s capacity on finding the solutions

Problems & Solutions in Nonrelativistic Quantum Mechanics Anton Z. Capri, 2002 This invaluable book consists of problems in nonrelativistic quantum mechanics together with their solutions Most of the problems have been tested in class The degree of difficulty varies from very simple to research level The problems illustrate certain aspects of quantum mechanics and enable the students to learn new concepts as well as providing practice in problem solving The book may be used as an adjunct to any of the numerous books on quantum mechanics and should provide students with a means of testing themselves on problems of varying degrees of difficulty It will be useful to students in an introductory course if they attempt the simpler problems The more difficult problems should prove challenging to graduate students and may enable them to enjoy problems at the forefront of quantum mechanics

Problems in Quantum Mechanics Gordon Leslie Squires, 1995-03-16 Many students find quantum mechanics conceptually difficult when they first encounter the subject In this book the postulates and key applications of quantum mechanics are well illustrated by means of a carefully chosen set of problems complete with detailed step by step solutions Beginning with a chapter on orders

of magnitude a variety of topics are then covered including the mathematical foundations of quantum mechanics Schrödinger's equation angular momentum the hydrogen atom the harmonic oscillator spin time independent and time dependent perturbation theory the variational method multielectron atoms transitions and scattering Throughout the physical interpretation or application of certain results is highlighted thereby providing useful insights into a wide range of systems and phenomena This approach will make the book invaluable to anyone taking an undergraduate course in quantum mechanics

Problems in quantum-mechanics, 1978 [Problems and Solutions in Quantum Chemistry and Physics](#) Charles S. Johnson, Lee G. Pedersen, 2013-01-18 Unusually varied problems with detailed solutions cover quantum mechanics wave mechanics angular momentum molecular spectroscopy scattering theory more 280 problems plus 139 supplementary exercises

Problem Solving in Quantum Mechanics Marc Cahay, Supriyo Bandyopadhyay, 2017-04-06 This topical and timely textbook is a collection of problems for students researchers and practitioners interested in state of the art material and device applications in quantum mechanics Most problems are relevant either to a new device or a device concept or to current research topics which could spawn new technology It deals with the practical aspects of the field presenting a broad range of essential topics currently at the leading edge of technological innovation Includes discussion on Properties of Schrödinger Equation Operators Bound States in Nanostructures Current and Energy Flux Densities in Nanostructures Density of States Transfer and Scattering Matrix Formalisms for Modelling Diffusive Quantum Transport Perturbation Theory Variational Approach and their Applications to Device Problems Electrons in a Magnetic or Electromagnetic Field and Associated Phenomena Time dependent Perturbation Theory and its Applications Optical Properties of Nanostructures Problems in Quantum Mechanics For Material Scientists Applied Physicists and Device Engineers is an ideal companion to engineering condensed matter physics or materials science curricula It appeals to future and present engineers physicists and materials scientists as well as professionals in these fields needing more in depth understanding of nanotechnology and nanoscience

Beautiful Models: 70 Years Of Exactly Solved Quantum Many-body Problems Bill Sutherland, 2004-06-21 This invaluable book provides a broad introduction to the fascinating and beautiful subject of many body quantum systems that can be solved exactly The subject began with Bethe's famous solution of the one dimensional Heisenberg magnet more than 70 years ago soon after the invention of quantum mechanics Since then the diversity and scope of such systems have been steadily growing Beautiful Models is self contained and unified in presentation It may be used as an advanced textbook by graduate students and even ambitious undergraduates in physics It is also suitable for the non experts in physics who wish to have an overview of some of the classic and fundamental models in the subject The explanations in the book are detailed enough to capture the interest of the curious reader and complete enough to provide the necessary background material needed to go further into the subject and explore the research literature

Problems in Quantum Mechanics Emilio d'Emilio, Luigi E. Picasso, 2011-09-04 242 solved problems of several degrees of difficulty in

nonrelativistic Quantum Mechanics ranging from the themes of the crisis of classical physics through the achievements in the framework of modern atomic physics down to the still alive more intriguing aspects connected e.g. with the EPR paradox, the Aharonov-Bohm effect, quantum teleportation

Problems and Solutions in Quantum Mechanics Klaus Schulten,
Back-Of-The-Envelope Quantum Mechanics: With Extensions to Many-Body Systems and Integrable Pdes (Second Edition) MAXIM. OLSHANYI (OLSHANII), 2024-01-28
Dimensional and order of magnitude estimates are practiced by almost everybody but taught almost nowhere. When physics students engage in their first theoretical research project they soon learn that exactly solvable problems belong only to textbooks that numerical models are long and resource consuming and that something else is needed to quickly gain insight into the system they are going to study. Qualitative methods are this something else but typically students have never heard of them before. The aim of this book is to teach the craft of qualitative analysis using a set of problems, some with solutions and some without, in advanced undergraduate and beginning graduate Quantum Mechanics. Examples include a dimensional analysis solution for the spectrum of a quartic oscillator, simple WKB formulas for the matrix elements of a coordinate in a gravitational well, and a three-line long estimate for the ionization energy of atoms, uniformly valid across the whole periodic table. The piece de resistance in the collection is a series of dimensional analysis questions in Integrable Nonlinear Partial Differential Equations with no dimensions existing a priori. Solved problems include the relationship between the size and the speed of solitons of the Korteweg-de Vries equation and an expression for the oscillation period of a Nonlinear Schrödinger breather as a function of its width. A new theme that appears in the second edition are the rare and exotic methods in elementary quantum mechanics. The new chapter covers quantum mechanical supersymmetry, power index method, scale invariance, self-similarity, and circle inversion.

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