

# Selected Solutions for *An Introduction to Tensors and Group Theory for Physicists, 2nd ed.*

October 3, 2018

## Introduction

This is an incomplete, evolving solutions manual to [Jee15]. Note that this is the second edition of this text, and that exercise and problem numbering differs between editions. Solutions posted here have primarily been written by students in courses I taught in the UC Berkeley Physics department between 2012 and 2016. If you are interested in improving existing solutions or adding new ones of your own, please email me at nadirj@princeton.edu.

## 1 A Quick Introduction to Tensors

### 2 Vector Spaces

**Exercise 2.1 :** Verify equation 2.7, which states

$$\Delta_{S^2} Y(\theta, \phi) = -l(l+1)Y(\theta, \phi).$$

**Solution:** Pick a vector  $f \in \mathcal{H}_l(\mathbb{R}^3)$ . This function has two useful properties: in spherical coordinates, we may write our function as  $f(r, \theta, \phi) = r^l Y(\theta, \phi)$  – this is a property of  $P_l(\mathbb{R}^3)$ , which contains  $\mathcal{H}_l(\mathbb{R}^3)$  as a subspace. And, since we have chosen it from  $\mathcal{H}_l(\mathbb{R}^3)$ , it satisfies  $\Delta f = 0$ . We write the Laplacian explicitly and combine terms

$$\begin{aligned}\Delta f &= \left( \frac{\partial^2}{\partial r^2} + \frac{2}{r} \frac{\partial}{\partial r} + \frac{1}{r^2} \Delta_{S^2} \right) r^l Y(\theta, \phi) \\ &= l(l-1)r^{l-2}Y + \frac{2}{r}lr^{l-1}Y + r^{l-2}\Delta_{S^2}Y \\ &= l(l-1)r^{l-2}Y + 2lr^{l-2}Y + r^{l-2}\Delta_{S^2}Y \\ &= l(l+1)r^{l-2}Y + r^{l-2}\Delta_{S^2}Y\end{aligned}$$

But we know this quantity is equal to zero. Therefore,

$$\Delta_{S^2} Y(\theta, \phi) = -l(l+1)Y(\theta, \phi)$$

as claimed. Thus all harmonic  $l$ -degree polynomials correspond to a matching spherical harmonic, which corresponds to the restriction of the said polynomial to the unit sphere.

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**Exercise 2.3 :** Given a vector  $v$  and a finite basis  $\mathcal{B} = \{e_i\}_{i=1,\dots,n}$ , show that the expression of  $v$  as a linear combination of the  $e_i$  is unique.

**Solution:** Suppose that our representation of  $v$  in the basis  $\mathcal{B}$  is explicitly given by  $v = a^i e_i$ , where the  $a^i$  are scalars in the appropriate field. Now, suppose that there exists another representation of  $v$  in the same basis, given by  $v = b^i e_i$ . Then we may write:

$$\begin{aligned}v - v &= 0 \\ &= a^i e_i - b^i e_i \\ &= (a^i - b^i) e_i\end{aligned}$$

# Group Theory Solutions Manual

**Peter Atkins, Julio de Paula, Ronald  
Friedman**



## Group Theory Solutions Manual:

*Student Solutions Manual to Accompany Atkins' Physical Chemistry 11th Edition* Peter Bolgar, Vladimiras Oleinikovas, Aimee North, Haydn Lloyd, James Keeler, Stephanie Smith, 2018 The Student Solutions Manual to accompany Atkins Physical Chemistry 11th Edition provides full worked solutions to the a exercises and the odd numbered discussion questions and problems presented in the parent book The manual is intended for students and provides helpful comments and friendly advice to aid understanding Student Solutions Manual for Physical Chemistry C. A. Trapp, Peter Atkins, Julio dePaula, 2009-12-18 With its modern emphasis on the molecular view of physical chemistry its wealth of contemporary applications vivid full color presentation and dynamic new media tools the thoroughly revised new edition is again the most modern most effective full length textbook available for the physical chemistry classroom Available in Split Volumes For maximum flexibility in your physical chemistry course this text is now offered as a traditional text or in two volumes Volume 1 Thermodynamics and Kinetics ISBN 1 4292 3127 0 Volume 2 Quantum Chemistry Spectroscopy and Statistical Thermodynamics ISBN 1 4292 3126 2 Student's Solutions Manual to Accompany Atkins' Physical Chemistry C. A. Trapp, M. P. Cady, Carmen Giunta, 2010 This solutions manual provides the authors detailed solutions to exercises and problems in physical chemistry It comprises solutions to exercises at the end of each chapter and solutions to numerical theoretical and additional problems A Gentle Introduction to Group Theory Bana Al Subaiei, Muneerah Al Nuwairan, 2023-05-31 The book is intended to serve as an introductory course in group theory geared towards second year university students It aims to provide them with the background needed to pursue more advanced courses in algebra and to provide a rich source of examples and exercises Studying group theory began in the late eighteenth century and is still gaining importance due to its applications in physics chemistry geometry and many fields in mathematics The text is broadly divided into three parts The first part establishes the prerequisite knowledge required to study group theory This includes topics in set theory geometry and number theory Each of the chapters ends with solved and unsolved exercises relating to the topic By doing this the authors hope to fill the gaps between all the branches in mathematics that are linked to group theory The second part is the core of the book which discusses topics on semigroups groups symmetric groups subgroups homomorphisms isomorphism and Abelian groups The last part of the book introduces SAGE a mathematical software that is used to solve group theory problems Here most of the important commands in SAGE are explained and many examples and exercises are provided **Symmetry, Broken Symmetry, and Topology in Modern Physics** Mike Guidry, Yang Sun, 2022-03-31 A pedagogical introduction to the modern applications of groups algebras and topology for undergraduate and graduate students in physics **Physical Chemistry** Peter Atkins, Julio de Paula, Ronald Friedman, 2014 This title takes an innovative molecular approach to the teaching of physical chemistry The authors present the subject in a rigorous but accessible manner allowing students to gain a thorough understanding of physical chemistry **Handbook of**

**Mathematics for Engineers and Scientists** Andrei D. Polyanin, Alexander V. Manzhirov, 2006-11-27 Covering the main fields of mathematics this handbook focuses on the methods used for obtaining solutions of various classes of mathematical equations that underlie the mathematical modeling of numerous phenomena and processes in science and technology The authors describe formulas methods equations and solutions that are frequently used in scientific and engineering applications and present classical as well as newer solution methods for various mathematical equations The book supplies numerous examples graphs figures and diagrams and contains many results in tabular form including finite sums and series and exact solutions of differential integral and functional equations      *Group Theory in a Nutshell for Physicists* Anthony Zee, 2016-03-29 A concise modern textbook on group theory written especially for physicists Although group theory is a mathematical subject it is indispensable to many areas of modern theoretical physics from atomic physics to condensed matter physics particle physics to string theory In particular it is essential for an understanding of the fundamental forces Yet until now what has been missing is a modern accessible and self contained textbook on the subject written especially for physicists *Group Theory in a Nutshell for Physicists* fills this gap providing a user friendly and classroom tested text that focuses on those aspects of group theory physicists most need to know From the basic intuitive notion of a group A Zee takes readers all the way up to how theories based on gauge groups could unify three of the four fundamental forces He also includes a concise review of the linear algebra needed for group theory making the book ideal for self study Provides physicists with a modern and accessible introduction to group theory Covers applications to various areas of physics including field theory particle physics relativity and much more Topics include finite group and character tables real pseudoreal and complex representations Weyl Dirac and Majorana equations the expanding universe and group theory grand unification and much more The essential textbook for students and an invaluable resource for researchers Features a brief self contained treatment of linear algebra An online illustration package is available to professors Solutions manual available only to professors      **Catalog of Copyright Entries. Third Series** Library of Congress. Copyright Office, 1970      **Quanta, Matter, and Change** Peter Atkins, Julio de Paula, Ronald Friedman, 2009 aspects of the learning process are fully supported including the understanding of terminology notation mathematical concepts and the application of physical chemistry to other branches of science Building on the heritage of the world renowned Atkins Physical Chemistry *Quanta Matter and Change* gives a refreshing new insight into the familiar by illuminating physical chemistry from a new direction Book Jacket *Physical Chemistry* Robert G. Mortimer, 2008-05-29 In this third edition core applications have been added along with more recent developments in the theories of chemical reaction kinetics and molecular quantum mechanics as well as in the experimental study of extremely rapid chemical reactions Fully revised concise edition covering recent developments in the field Supports student learning with step by step explanation of fundamental principles an appropriate level of math rigor and pedagogical tools to aid comprehension Encourages readers to apply theory in practical situations      Atkins' Physical

Chemistry 11e Peter Atkins, Julio De Paula, James Keeler, 2019-09-06 Atkins Physical Chemistry Molecular Thermodynamics and Kinetics is designed for use on the second semester of a quantum first physical chemistry course Based on the hugely popular Atkins Physical Chemistry this volume approaches molecular thermodynamics with the assumption that students will have studied quantum mechanics in their first semester The exceptional quality of previous editions has been built upon to make this new edition of Atkins Physical Chemistry even more closely suited to the needs of both lecturers and students Reorganised into discrete topics the text is more flexible to teach from and more readable for students Now in its eleventh edition the text has been enhanced with additional learning features and maths support to demonstrate the absolute centrality of mathematics to physical chemistry Increasing the digestibility of the text in this new approach the reader is brought to a question then the math is used to show how it can be answered and progress made The expanded and redistributed maths support also includes new Chemist's toolkits which provide students with succinct reminders of mathematical concepts and techniques right where they need them Checklists of key concepts at the end of each topic add to the extensive learning support provided throughout the book to reinforce the main take home messages in each section The coupling of the broad coverage of the subject with a structure and use of pedagogy that is even more innovative will ensure Atkins Physical Chemistry remains the textbook of choice for studying physical chemistry

*Buildings* Peter Abramenko, Kenneth S. Brown, 2008-12-16 This text started out as a revised version of Buildings by the second named author 53 but it has grown into a much more voluminous book The earlier book was intended to give a short friendly elementary introduction to theory accessible to readers with a minimal background Moreover it approached buildings from only one point of view sometimes called the old fashioned approach A building is a simplicial complex with certain properties The current book includes all the material of the earlier one but we have added a lot In particular we have included the modern or W metric approach to buildings which looks quite different from the old fashioned approach but is equivalent to it This has become increasingly important in the theory and applications of buildings We have also added a thorough treatment of the Moufang property which occupies two chapters And we have added many new exercises and illustrations Some of the exercises have hints or solutions in the back of the book A more extensive set of solutions is available in a separate solutions manual which may be obtained from Springer's Mathematics Editorial Department We have tried to add the new material in such a way that readers who are content with the old fashioned approach can still get an elementary treatment of it by reading selected chapters or sections In particular many readers will want to omit the optional sections marked with a star The introduction below provides more detailed guidance to the reader

*Inorganic Chemistry* Mark Weller, Mark T. Weller, Tina Overton, Jonathan Rourke, Fraser Armstrong, 2014 Leading the reader from the fundamental principles of inorganic chemistry right through to cutting edge research at the forefront of the subject Inorganic Chemistry Sixth Edition is the ideal course companion for the duration of a student's degree The authors have drawn upon their extensive teaching

and research experience in updating this established text the sixth edition retains the much praised clarity of style and layout from previous editions while offering an enhanced Frontiers section Exciting new applications of inorganic chemistry have been added to this section in particular relating to materials chemistry and medicine This edition also sees a greater use of learning features to provide students with all the support they need for their studies Providing comprehensive coverage of inorganic chemistry while placing it in context this text will enable the reader to fully master this important subject Online Resource Centre For registered adopters of the text Figures marginal structures and tables of data ready to download Test bank For students Answers to self tests and exercises from the book Videos of chemical reactions Tables for group theory Web links Interactive structures and other resources on [www.chemtube3d.com](http://www.chemtube3d.com)

**A Laboratory Manual of General Chemistry for Use in Colleges** William Crowell Bray, Wendell Mitchell Latimer, 1921 **Group Theory and Chemistry** David M. Bishop, 1993-01-14 Concise self contained introduction to group theory and its applications to chemical problems Symmetry matrices molecular vibrations transition metal chemistry more Relevant math included Advanced undergraduate graduate level 1973 edition **A Course in Formal Languages, Automata and Groups** Ian M. Chiswell, 2008-11-14 This book is based on notes for a master s course given at Queen Mary University of London in the 1998 9 session Such courses in London are quite short and the course consisted essentially of the material in the rst three chapters together with a two hour lecture on connections with group theory Chapter 5 is a considerably expanded version of this For the course the main sources were the books by Hopcroft and Ullman 20 by Cohen 4 and by Epstein et al 7 Some use was also made of a later book by Hopcroft and Ullman 21 The ulterior motive in the rst three chapters is to give a rigorous proof that various notions of recursively enumerable language are equivalent Three such notions are considered These are generated by a type 0 grammar recognised by a Turing machine deterministic or not and defined by means of a Godel numbering having defined recursively enumerable for sets of natural numbers It is hoped that this has been achieved without too many arguments using complicated notation This is a problem with the entire subject and it is important to understand the idea of the proof which is often quite simple Two particular places that are heavy going are the proof at the end of Chapter 1 that a language recognised by a Turing machine is type 0 and the proof in Chapter 2 that a Turing machine computable function is partial recursive

**Communication Theory and Signal Processing for Transform Coding** Khamies El-Shennawy, 2014-06-08 This book is tailored to fulfil the requirements in the area of the signal processing in communication systems The book contains numerous examples solved problems and exercises to explain the methodology of Fourier Series Fourier Analysis Fourier Transform and properties Fast Fourier Transform FFT Discrete Fourier Transform DFT and properties Discrete Cosine Transform DCT Discrete Wavelet Transform DWT and Contourlet Transform CT The book is characterized by three directions the communication theory and signal processing point of view the mathematical point of view and utility computer programs The contents of this book include chapters in communication system and signals Fourier Series and Power Spectra

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