Variational methods for boundary value problems

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Dedicated to Dr. Alex McNabb on the occasion of his 70th birthday in January
2000.

Abstract.   The variational formulation of boundary value problems is valuable in providing
remarkably easy computational algorithms as well as an alternative framework with which to
prove existence results. Boundary conditions impose constraints which can be annoying from a
computational point of view. The question is then posed: what is the most general boundary
value problem which can be posed in variational form with the boundary conditions appearing
naturally? Special cases of two-point problems in one-dimension and some higher dimensional
problems are addressed. There is a deep connection with self-adjointness for the linear case.
Further cases under which a Lagrangian may or may not exist are explained.

Keywords: natural boundary conditions, self-adjointness, Hamiltonian, Lagrangian.

1.   Introduction

1.1.   Background

Variational methods provide a conceptual and computational framework for bound-
ary value problems (BVPs). In the paper we derive conditions which guarantee that
a given BVP can be reformulated in variational form. This can be a way of proving
existence for BVPs (Graham-Eagle and Wake [6]) and it also provides a scheme
for determination of a computational algorithm as in Fradkin and Wake [5]. In the
case of nonlinear eigenvalue problems, these can be a way of producing outcomes
like parameter path-following as has been produced by other means by computer
packages like Auto (Doedel [2]).

The question of what precise conditions need to be imposed on boundary value
problems so that they can be written in variational form has been discussed spas-
modically in the literature, see for example Anderson and Thompson [1], Fels [3],

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Variational Methods, for Boundary Value Problems, for Systems of Elliptic Equations M. A. Lavrent'ev,1963 **Variational Methods for Boundary Value Problems for Systems of Elliptic Equations** M. A. Lavrent'ev,2016-01-14 Famous monograph by a distinguished mathematician presents an innovative approach to classical boundary value problems The treatment employs the basic scheme first suggested by Hilbert and developed by Tonnelli 1963 edition   Variational Methods for Boundary Value Problems for Systems of Elliptic Equations Mikhail Alekseevich Lavrent-Ev,1963   **Multiple Solutions Of Boundary Value Problems: A Variational Approach** John R Graef,Lingju Kong,2015-08-26 Variational methods and their generalizations have been verified to be useful tools in proving the existence of solutions to a variety of boundary value problems for ordinary impulsive and partial differential equations as well as for difference equations In this monograph we look at how variational methods can be used in all these settings In our first chapter we gather the basic notions and fundamental theorems that will be applied in the remainder of this monograph While many of these items are easily available in the literature we gather them here both for the convenience of the reader and for the purpose of making this volume somewhat self contained Subsequent chapters deal with the Sturm Liouville problems multi point boundary value problems problems with impulses partial differential equations and difference equations An extensive bibliography is also included   Variational Methods for Boundary Value Problems Bernie Pui Man Tsang,1999   **Methods of Functional Analysis for Application in Solid Mechanics** J. Mason,2013-10-22 Publications oriented to the interests of engineering scientists and graduate students on topics of functional analysis and its applications are rare this book has been written to fill the gap in the literature It provides a readable account of basic mathematic topics with illustrative examples and chapters devoted to finite elements variational principles of elasticity and plasticity variational inequalities and elastic stability The text is entirely self contained and covers a wide range of topics and ideas from elementary concepts to modern theories and applications and includes numerous references It is written for engineers graduate students and researchers who need a general knowledge of modern mathematical methods in solid mechanics   **Variational Methods in Boundary Value Problems** Hans F. Weinberger,1961   **The Nonlinear Theory of Elastic Shells** A. Libai,2012-12-02 The Nonlinear Theory of Elastic Shells One Spatial Dimension presents the foundation for the nonlinear theory of thermoelastic shells undergoing large strains and large rotations This book discusses several relatively simple equations for practical application Organized into six chapters this book starts with an overview of the description of nonlinear elastic shell This text then discusses the foundation of three dimensional continuum mechanics that are relevant to the shell theory approach Other chapters cover several topics including birods beamshells and axishells that begins with a derivation of the equations of motion by a descent from the equations of balance of linear and rotational momentum of a three dimensional material continuum This book discusses as well the approach to deriving complete field equations for one or two dimensional continua

from the integral equations of motion and thermodynamics of a three dimensional continuum The final chapter deals with the analysis of unishells This book is a valuable resource for physicists mathematicians and scientists *Variational Methods for Boundary Value Problems for Systems of Elliptic Equations* Mikhail Mikhaĭlovich Lavrent'ev,1963 **Variational Methods, for Boundary Value Problems, for Systems of Elliptic Equations** Mikhail Alekseevich Lavrent□v,1963 **Variational and Free Boundary Problems** Avner Friedman,Joel Spruck,2012-12-06 This IMA Volume in Mathematics and its Applications VARIATIONAL AND FREE BOUNDARY PROBLEMS is based on the proceedings of a workshop which was an integral part of the 1990 91 IMA program on Phase Transitions and Free Boundaries The aim of the workshop was to highlight new methods directions and problems in variational and free boundary theory with a concentration on novel applications of variational methods to applied problems We thank R Fosdick M E Gurtin W M Ni and L A Peletier for organizing the year long program and especially J Sprock for co organizing the meeting and co editing these proceedings We also take this opportunity to thank the National Science Foundation whose financial support made the workshop possible Avner Friedman Willard Miller Jr PREFACE In a free boundary one seeks to find a solution u to a partial differential equation in a domain a part r of its boundary of which is unknown Thus both u and r must be determined In addition to the standard boundary conditions on the un known domain an additional condition must be prescribed on the free boundary A classical example is the Stefan problem of melting of ice here the temperature sat isfies the heat equation in the water region and yet this region itself or rather the ice water interface is unknown and must be determined together with the tempera ture within the water Some free boundary problems lend themselves to variational formulation *Encyclopaedia of Mathematics* Michiel Hazewinkel,2013-12-01 *Research Topics in Analysis, Volume I* Shouchuan Hu,Nikolaos S. Papageorgiou,2022-11-29 This book which is the first of two volumes presents in a unique way some of the most relevant research tools of modern analysis This work empowers young researchers with all the necessary techniques to explore the various subfields of this broad subject and introduces relevant frameworks where these tools can be immediately deployed Volume I starts with the foundations of modern analysis The first three chapters are devoted to topology measure theory and functional analysis Chapter 4 offers a comprehensive analysis of the main function spaces while Chapter 5 covers more concrete subjects like multivariate analysis which are closely related to applications and more difficult to find in compact form Chapter 6 deals with smooth and non smooth calculus of functions Chapter 7 introduces certain important classes of nonlinear operators and Chapter 8 complements the previous three chapters with topics of variational analysis Each chapter of this volume finishes with a list of problems handy for understanding and self study and historical notes that give the reader a more vivid picture of how the theory developed Volume II consists of various applications using the tools and techniques developed in this volume By offering a clear and wide picture of the tools and applications of modern analysis this work can be of great benefit not only to mature graduate students seeking topics for research but also to experienced researchers with

an interest in this vast and rich field of mathematics   **Encyclopaedia of Mathematics** M. Hazewinkel,2013-12-01
      Variational Methods for a Class of Boundary Value Problems Exterior to a Thin Domain Nilima Nigam,1999   *Two-point Boundary Value Problems: Shooting Methods* Sanford M. Roberts,Jerome S. Shipman,1972   **Variational Methods for Non-linear Boundary-value Problems** Philippe G. Ciarlet,1966   *Weak and Variational Methods for Moving Boundary Problems* Charles M. Elliott,J. R. Ockendon,1982   <u>V Hotine-Marussi Symposium on Mathematical Geodesy</u> Fernando Sansò,2013-03-09 Just as in the era of great achievements by scientists such as Newton and Gauss the mathematical theory of geodesy is continuing the tradition of producing exciting theoretical results but today the advances are due to the great technological push in the era of satellites for earth observations and large computers for calculations Every four years a symposium on methodological matters documents this ongoing development in many related underlying areas such as estimation theory stochastic modelling inverse problems and satellite positioning global reference systems This book presents developments in geodesy and related sciences including applied mathematics among which are many new results of high intellectual value to help readers stay on top of the latest happenings in the field   <u>Subject Guide to Books in Print</u> ,2001

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