

## SOLUTION OF SOLID MECHANIC EQUILIBRIUM PROBLEMS BY POWER SERIES

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### ABSTRACT

The paper presents the application of power series to the numerical solution of equilibrium problems in elasticity. Complete bases of power series that satisfy the differential equations are developed, first for unidimensional problems like the equilibrium of a beam on elastic foundation, second for the harmonic differential equation in two dimensions, with application to the Saint-Venant's torsion problem and, finally, for the biharmonic equation, which can be applied to plane elasticity problems as well as to the plate-bending problem. In the case of unidimensional problems the solution is exact, because the number of boundary conditions is equal to the number of parameters involved in the series expansion, whereas in the two-dimensional problems the solution satisfies exactly the differential equation but only approximately the boundary conditions. The approximation of the solution will depend on the number of points selected at the boundary. The method presented here can also be used for developing high-order finite elements of any number of nodes and boundary shapes using complete polynomial expansions that satisfy the differential equation. Selected practical applications are shown.

**Keywords:** *Beam on elastic foundation, biharmonic equation, boundary conditions, equilibrium problems, finite elements, harmonic equation, plane elasticity, plate-bending problem, power series, Saint-Venant's torsion problem*

### 1. INTRODUCTION

Equilibrium problems are defined by Crandall [1] as

$$L_{2\mu}(\varphi) = 0 \quad \text{in } \Omega \quad (1)$$

with  $B_{2\mu-1}^{\zeta}(\varphi) = 0, \zeta = 1, \dots, \mu$  at the boundary, (2)

where  $L_{2\mu}(\varphi)$  is a partial differential operator of order  $2\mu$ , containing only even partial derivatives, and  $B_{2\mu-1}^{\zeta}(\varphi)$  are  $\mu$  differential operators of order up to  $2\mu - 1$ .

A solution of some equilibrium problems is presented in this paper consisting of power series  $\varphi$  that satisfy identically the homogeneous differential eqn (1) and approximately the boundary conditions in eqn (2). The collocation technique is used at the boundary in such a way that the boundary conditions are satisfied at selected points.

The approximation to the exact solution will depend on the degree  $n$  of the elements of the power series used.

### 2. POWER SERIES SOLUTION OF A DIFFERENTIAL EQUATION

Let  $\varphi$  be a complete power series of degree  $n$ . Let also  $\varphi_i, i = 0, \dots, n$  be some incomplete power series of degree  $\leq n$ , such that

$$\varphi = \sum_{i=0}^n \lambda_i \varphi_i \quad . \quad (3)$$

If all series  $\varphi_i$  satisfy a given differential equation, then  $\varphi$  will also satisfy the said equation. Therefore, if the series  $\varphi_i$  are mutually independent and their sum forms a complete polynomial expression of degree  $n$ , then the elements  $\varphi_i$  can be considered as a base for the

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## **Table of Contents Mechanic Of Solid Manual Solution**

1. Understanding the eBook Mechanic Of Solid Manual Solution
  - The Rise of Digital Reading Mechanic Of Solid Manual Solution
  - Advantages of eBooks Over Traditional Books
2. Identifying Mechanic Of Solid Manual Solution
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Mechanic Of Solid Manual Solution
  - User-Friendly Interface
4. Exploring eBook Recommendations from Mechanic Of Solid Manual Solution
  - Personalized Recommendations
  - Mechanic Of Solid Manual Solution User Reviews and Ratings
  - Mechanic Of Solid Manual Solution and Bestseller Lists
5. Accessing Mechanic Of Solid Manual Solution Free and Paid eBooks
  - Mechanic Of Solid Manual Solution Public Domain eBooks

- Mechanic Of Solid Manual Solution eBook Subscription Services
- Mechanic Of Solid Manual Solution Budget-Friendly Options

6. Navigating Mechanic Of Solid Manual Solution eBook Formats

- ePub, PDF, MOBI, and More
- Mechanic Of Solid Manual Solution Compatibility with Devices
- Mechanic Of Solid Manual Solution Enhanced eBook Features

7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Mechanic Of Solid Manual Solution
- Highlighting and Note-Taking Mechanic Of Solid Manual Solution
- Interactive Elements Mechanic Of Solid Manual Solution

8. Staying Engaged with Mechanic Of Solid Manual Solution

- Joining Online Reading Communities
- Participating in Virtual Book Clubs
- Following Authors and Publishers Mechanic Of Solid Manual Solution

9. Balancing eBooks and Physical Books Mechanic Of Solid Manual Solution

- Benefits of a Digital Library
- Creating a Diverse Reading Collection Mechanic Of Solid Manual Solution

10. Overcoming Reading Challenges

- Dealing with Digital Eye Strain
- Minimizing Distractions
- Managing Screen Time

11. Cultivating a Reading Routine Mechanic Of Solid Manual Solution

- Setting Reading Goals Mechanic Of Solid Manual Solution
- Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Mechanic Of Solid Manual Solution

- Fact-Checking eBook Content of Mechanic Of Solid Manual Solution
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

## 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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