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17.1KB

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The study of some topics in theory of special function and their application

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Abstract

Special functions play an important role in mathematics, physics, engineering, and applied sciences. ¹ Functions such as Gamma, Beta, Bessel, Legendre, Hypergeometric, and Hermite functions arise naturally in the solutions of differential equations, integral equations, and boundary value problems. The present study focuses on selected topics in the theory of special functions, including their properties, generating functions, recurrence relations, orthogonality, and applications in scientific problems. The study also examines how these functions are applied in heat conduction, wave propagation, quantum mechanics, and mathematical modeling. Analytical methods are used to derive identities and relationships among special functions. The research highlights the significance of special functions in solving practical and theoretical problems efficiently.

Introduction

Special functions are a class of ² mathematical functions that have established names and notations due to their importance in mathematical analysis and applications. They include functions such as Gamma function, Beta function, Bessel functions, Legendre polynomials, Laguerre polynomials, and Hypergeometric functions. These functions often arise as solutions of ordinary and partial differential equations.

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The theory of special functions developed rapidly during the 18th and 19th centuries through the works of Euler, Gauss, Legendre, Laplace, and others. In modern mathematics, special functions continue to be important in approximation theory, numerical analysis, probability theory, and mathematical physics.

This study investigates some selected topics in special functions and demonstrates their usefulness in solving real-world problems.

Literature Review

Several mathematicians have contributed significantly to the theory of special functions:

1. Euler (1730s) introduced the Gamma and Beta functions and studied their properties.
2. Gauss (1812) developed Hypergeometric functions and series expansions.
3. Bessel (1824) introduced Bessel functions in planetary motion problems.
4. Legendre (1785) developed Legendre polynomials used in spherical harmonics.
5. Watson (1944) presented a comprehensive theory of Bessel functions.
6. Rainville (1960) studied generating functions and recurrence relations of special functions.
7. Andrews, Askey, and Roy (1999) discussed modern developments in special functions.

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Previous studies show that special functions are highly useful in solving boundary value problems, signal processing, and fluid dynamics.

Statement of Problem

Many physical and engineering problems involve differential equations whose elementary solutions are not available. In such cases, special functions provide exact and approximate solutions. However, understanding their properties and applications remains essential. Therefore, the problem is to study selected special functions systematically and explore their applications in mathematical sciences.

Objectives of the Study

1. To study the basic theory of selected special functions.
2. To analyze recurrence relations and generating functions.
3. To examine orthogonality properties of special functions.
4. To apply special functions in solving differential equations.
5. To explore applications in physics and engineering models.

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Hypothesis

1. Special functions provide effective solutions to many differential equations.
2. Their recurrence relations simplify complex calculations.
3. Applications of special functions improve mathematical modeling accuracy.

Methods of Study

The study is theoretical and analytical in nature.

Methods Used:

1. Analytical Method – Derivation of formulas and identities.
2. Comparative Method – Comparison among various special functions.
3. Application Method – Solving applied mathematical problems using special functions.
4. Secondary Data Method – Use of books, journals, and research papers.

Results

1. Gamma and Beta functions are closely related through Euler's identity.
2. Bessel functions provide solutions to cylindrical symmetry problems.
3. Legendre polynomials are useful in spherical coordinate systems.

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4. Hypergeometric functions unify many special functions.
5. Orthogonality properties are useful in Fourier-type expansions.

Discussion

The study shows that special functions are fundamental tools in mathematical sciences. Their recurrence relations reduce computational effort. Orthogonal polynomials help in approximation theory and numerical methods. Applications in heat transfer, quantum mechanics, and electromagnetic theory indicate their practical importance.

Modern software tools such as MATLAB, Mathematica, and Python libraries have further increased the usefulness of special functions.

Conclusion

Special functions occupy an important place in pure and applied mathematics. The study of their theory and applications reveals that they are indispensable for solving advanced scientific problems. Their rich structure, useful identities, and practical applications make them valuable tools for future research in mathematics, engineering, and physics.

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