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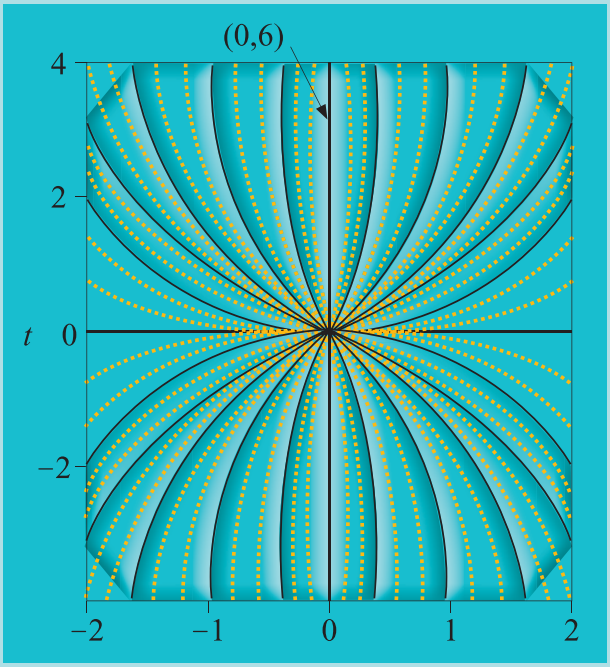
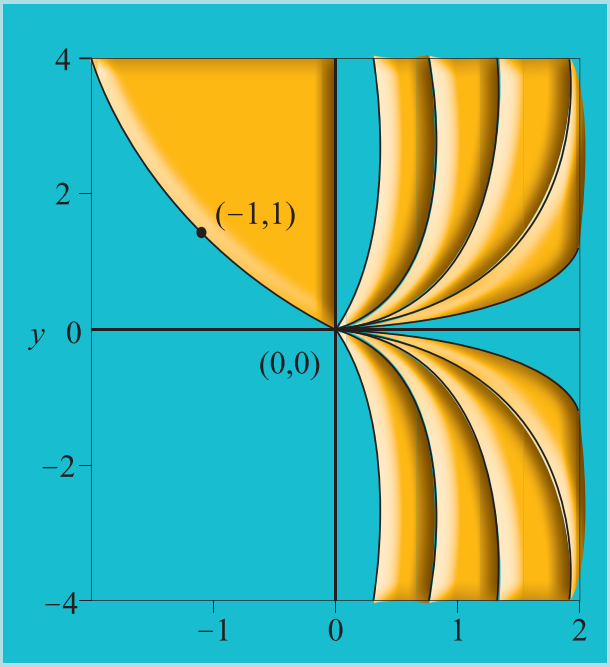
Prof. (Dr.) Chaitanya Kumar
Dr. Bhavneet Kaur
Dr. Geetan Manchanda

A Textbook on

Differential Equations and Applications





Sultan Chand & Sons

LATEST UGCF – 2022 PATTERN

Based on National Education Policy 2020

A TEXTBOOK ON

DIFFERENTIAL EQUATIONS AND APPLICATIONS

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to

Our families for their encouragement and constant support

Preface

The authors take immense pleasure in presenting to the readers the book entitled **"A Textbook on Differential Equations and Applications"**, created and compiled with an objective to provide the readers with a worthwhile experience of learning the basic concepts of differential equations and their applications.

This book has been designed in accordance with the Undergraduate Curriculum Framework-2022, followed by the Central Universities of India, including University of Delhi under the National Education Policy (NEP)-2020. It is exclusively crafted to cater to the interest of students of B.Sc. (Hons.) Mathematics (DSC-6) Semester-II, GE-3(i) Hons. courses, Semester-III (Other than Mathematics), B.A. (Prog.) Semester-III, Discipline A-3 and GE-3(i) Bachelor in Multidisciplinary Courses Semseter-III. It is also useful for B.Tech students of various Universities and for the preparation of competitive examinations. The students of open and distance education courses will also find the book very beneficial.

A sincere and humble attempt has been made to provide the readers a complete and self-sufficient book written in a lucid and simplified manner, giving comprehensive step-by-step explanations for better understanding of the subject.

There are thirteen chapters in this book. In each chapter the concepts are vividly explained, supported by nearly 352 examples and 227 exercises to provide the students an integrated view of the theory and its applications. A separate chapter comprising practicals of differential equations using the softwares Mathematica, Maxima and Octave is also provided to emphasize the importance of qualitative analysis of the systems defined by the differential equations. Finally, recent University of Delhi Question Papers with their solutions have been included for ample practice.

Most of the questions conform to the examination pattern followed in the University Examinations and Professional Examinations.

We gratefully acknowledge the inspiration, encouragement and valuable suggestions received from the teachers who are teaching undergraduate and postgraduate courses in several Universities.

In particular, we convey our thanks to Prof. Rajiv Chopra (Principal, DCAC, University of Delhi), Prof. Suman Sharma (Principal, Lady Shri Ram College for Women, University of Delhi), Prof. Haritma Chopra (Officiating Principal, Maitreyi College, University of Delhi), Prof. Ajay Kumar (NASI, Senior Scientist), Prof. R.K. Mohanty (Officiating President, South Asian University), Prof. Ayub Khan (ex-Head of Department of Mathematics, Jamia Millia Islamia), Prof. Ruchi Das (Head of Department of Mathematics, University of Delhi), Prof. J.K. Singh (Head of Department of Mathematics, Netaji Subhash University of Technology, New Delhi), Prof. C.K.Jaggi (Head of Department of Operations Research, University of Delhi), Prof. Arshad Khan (Jamia Millia Islamia), Prof. Rajiv Agarwal (Principal, Deshbandhu College, University of Delhi), Prof. S.K. Verma (Head of Department at SOL, University of Delhi), Prof. Kul Anand Sharma, Prof. B.K. Tyagi, Dr. Satyendra Kumar, Dr. Arun Bala Vaish.

Gratitude is also due to our families for their unwavering support throughout this journey. Our heartfelt acknowledgement is due to the entire staff of the publisher, Sultan Chand & Sons and their signs for the efficiency, assistance and wholehearted cooperation. Genuine efforts have been made to proofread the book to avoid any errors. However, any mistakes left out inadvertently brought to our notice will be thankfully acknowledged.

New Delhi

Prof. (Dr.) Chaitanya Kumar
Dr. Bhavneet Kaur
Dr. Geetan Manchanda

Syllabus

UNIVERSITY OF DELH
Undergraduate Curriculum Framework (UGCF) – 2022
Based on
National Education Policy-2020

B.Sc. (Hons.) Mathematics (Sem II)
Discipline Specific Core (DSC-6): Ordinary Differential Equations

Unit 1: First-Order Differential Equations

Concept of implicit, general and singular solutions for the first order ordinary differential equation; Bernoulli's equation, Exact equations, Integrating factors, Initial value problems, Reducible second order differential equations; Applications of first order differential equations to Newton's law of cooling, exponential growth and decay problems.

Unit 2: Second and Higher-Order Differential Equations

General solution of homogenous equation of second order, Principle of superposition for a homogenous equation, Wronskian and its properties, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Method of variation of parameters, Method of undetermined coefficients, Two-point boundary value problems, Cauchy-Euler's equation, System of linear differential equations, Application of second order differential equation: Simple pendulum problem.

Unit 3: Formulation and Analysis of Mathematical Models

Introduction to compartmental models, Lake pollution model; Density-dependent growth model, Interacting population models, Epidemic model of influenza and its analysis, Predator-prey model and its analysis, Equilibrium points, Interpretation of phase plane.

List of Practicals

Modeling of the following problems using Sage Math / Mathematica /MATLAB / Maple / Maxima / Scilab/ Octave, etc.

1. Solutions of first, second and third order differential equations.
2. Plotting of family of solutions of differential equations of first, second and third order.
3. Solution of differential equations using method of variation of parameters.
4. Growth and decay model (exponential case only).
5. Lake pollution model (with constant/seasonal flow and pollutant concentration).
6. Density-dependent growth model.
7. Predatory-prey model (basic Volterra model, with density dependence, effect of DDT, two prey one predator).
8. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).

Hons. Courses (Other than Mathematics) (Sem III)
General Elective (GE)-3(i) : Differential Equations
&
B.Sc. (Physical Sciences/ Mathematical Sciences) with Mathematics as one of the Core Discipline (Sem III)
and
B.A. (Prog.) Discipline Specific Core (DSC) A-3: Differential Equations (Sem III)

Unit 1: Ordinary Differential Equations

First order ordinary differential equations: Basic concepts and ideas, First order exact differential equations, Integrating factors and rules to find integrating factors, Linear equations and Bernoulli equations, Initial value problems, Applications of first order differential equations: Orthogonal trajectories and Rate problems; Basic theory of higher order linear differential equations, Wronskian and its properties.

Unit 2: Explicit Methods of Solving Higher-Order Linear Differential Equations

Linear homogeneous equations with constant coefficients, Linear non-homogeneous equations, Method of undetermined coefficients, Method of variation of parameters, Two-point boundary value problems, Cauchy-Euler Equations, System of linear differential equations.

Unit 3: First and Second Order Partial Differential Equations

Classification and Construction of first order partial differential equations, Method of characteristics and general solutions of first order partial differential equations, Canonical forms and method of separation of variables for first order partial differential equations; Classification and reduction to canonical forms of second order partial differential equations and their general solutions.

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Greek Alphabets

Alpha	A	,	α	Nu	N	,	ν
Beta	B	,	β	Xi	Ξ	,	ξ
Gamma	Γ	,	γ	Omicron	O	,	ο
Delta	Δ	,	δ	Pi	Π	,	π
Epsilon	E	,	ε	Rho	P	,	ρ
Zeta	Z	,	ζ	Sigma	Σ	,	σ
Eta	H	,	η	Tau	T	,	τ
Theta	Θ	,	θ	Upsilon	ϒ	,	υ
Iota	I	,	*ί*	Phi	Φ	,	ϕ
Kappa	K	,	κ	Chi	X	,	ξ
Lambda	Λ	,	λ	Psi	Ψ	,	ψ
Mu	M	,	μ	Omega	Ω	,	ω

Symbols

⇒	implies
⇔	is equivalent to
{ }	set
∈	is an element of
:	such that
⊂	is contained in (is a subset of)
⊃	contains (is a superset of)
$X \sim A$	complement of A with respect to X
∪	union
∩	intersection
Φ	the empty set
∃	there exists
∀	for all
ℕ	the set of all natural numbers
Z	the set of all integers
$\mathbb{Z}^+$	the set of all positive integers
Q	the set of all rational numbers
Q^+	the set of all positive rational numbers
ℝ	the set of all real numbers
$\mathbb{R}^+$	the set of all positive real numbers
∂	del
D	$\frac{d}{dx}$
ln	log
I.F.	Integrating Factor
P.I.	Particular Integral
w.r.t	with respect to

About the Book

This book has been designed in accordance with the Undergraduate Curriculum Framework-2022 followed by the Central Universities of India including University of Delhi under the National Education Policy (NEP)-2020. Keeping in mind the need to uphold students' interest in the subject, vivid explanation of concepts as well as explanatory illustrations followed by exercises have been included. The book is exclusively designed to help and guide the students of Mathematics DSC-6 B.Sc. (Hons.) Mathematics Semester-II; GE-3(I) all Honours Courses (Other than Mathematics); Discipline A-3 (3-Core & 2-Core). It is also useful for B.Tech. students of various Universities and for preparation of competitive examinations. The students of open and distance education courses will also find the book very beneficial.

Salient Features

- *An all-encompassing and self-sufficient textbook* for UGCF-2022 based on NEP-2020.
- Written in a *lucid and simple language.*
- Written with a view to present a *qualitative understanding* of the subject.
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- Many *solved examples and unsolved problems* have been drawn from recent examination papers of Universities.
- Practicals using Softwares (Mathematica, Maxima & Octave) are included for better understanding of the subject.
- Recent *Delhi University Question Papers with Solutions* have been included for ample practice.

About the Authors

Prof. (Dr.) Chaitanya Kumar has been teaching Mathematics in Delhi College of Arts and Commerce, University of Delhi for the last 40 years. He received his Doctorate degree in Mathematics from University of Delhi. He has published several research papers in the area of Boundary Value Problems by Integral Equation Techniques in reputed International Journals. He has been a Research Supervisor at Post Graduate and higher levels. He has authored important books on Mathematics; Essentials of Mathematics for Business Studies, Mathematics for M.C.A. Entrance Examination, Basic Research Methods and Statistics for Social Sciences, Theory of Analytic Geometry and Applied Algebra, Elements of Analysis, Ordinary and Partial Differential Equations, Probability and Statistics, Fundamentals of Calculus and Analytical Geometry for graduate and higher levels.

Dr. Bhavneet Kaur is an Associate Professor, Department of Mathematics, Lady Shri Ram College for Women. She has an experience of 19 years of teaching undergraduate students of University of Delhi. She received her Doctorate degree in Mathematics from University of Delhi in 2016 and is actively involved in research in the field of Celestial Mechanics and Space Dynamics. Her work is published in National and International Journals of repute. She is also a research guide and is fully committed to the welfare of the student fraternity. She has authored an important book on Mathematics, Fundamentals of Calculus.

Geetan Manchanda topped the University of Delhi in her M.Sc. Mathematics with six Gold Medals. She earned her Ph.D. in Applied Mathematics from Jamia Millia Islamia University. Presently, she is serving as an Associate Professor of Mathematics at Maitreyi College, University of Delhi and is actively involved in teaching and research since 16 years. She has published several papers in international journals of repute. She is entirely dedicated to the student community and is continuously devising ways for igniting their minds, bringing out their creativity and instilling love for Mathematics.

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