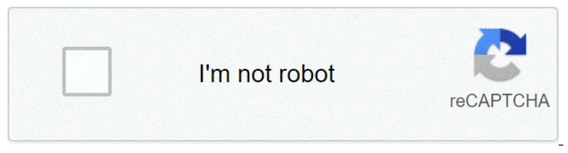

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It aims to present an introduction to linear algebra which will be found helpful to allreaders regardless of their fields of specification. More material has been included than can be covered in mostfirst courses. This has been done to make the book more flexible, to provide a useful book of reference, and tostimulate further interest in the subject.Each chapter begins with clear statements of pertinent definitions, principles, and theorems together withillustrative and other descriptive material. This is followed by graded sets of solved and supplementaryproblems. The solved problems serve to illustrate and amplify the theory, and to provide the repetition of basicprinciples so vital to effective learning. Numerous proofs, especially those of all essential theorems, areincluded among the solved problems. The supplementary problems serve as a complete review of the materialof each chapter.The first three chapters treat vectors in Euclidean space, matrix algebra, and systems of linear equations.These chapters provide the motivation and basic computational tools for the abstract investigations of vectorspaces and linear mappings which follow. After chapters on inner product spaces and orthogonality and ondeterminants, there is a detailed discussion of eigenvalues and eigenvectors giving conditions for representinga linear operator by a diagonal matrix. This naturally leads to the study of various canonical forms,specifically, the triangular, Jordan, and rational canonical forms. Later chapters cover linear functions andthe dual space V*, and bilinear, quadratic, and Hermitian forms. The last chapter treats linear operators oninner product spaces.The main changes in the fourth edition have been in the appendices. First of all, we have expandedAppendix A on the tensor and exterior products of vector spaces where we have now included proofs on theexistence and uniqueness of such products. We also added appendices covering algebraic structures, includingmodules, and polynomials over a field. Appendix D, Odds and Ends, includes the MoorePenrosegeneralized inverse which appears in various applications, such as statistics. There are also many additionalsolved and supplementary problems.Finally, we wish to thank the staff of the McGraw-Hill Schaums Outline Series, especially Charles Wall,for their unfailing cooperation.SEYMOUR LIPSCHUTZMARC LARS LIPSONiiiThis page intentionally left blank ContentsCHAPTER 1 Vectors in Rn and Cn, Spatial Vectors 11.1 Introduction 1.2 Vectors in Rn 1.3 Vector Addition and Scalar Multi-plication 1.4 Dot (Inner) Product 1.5 Located Vectors, Hyperplanes, Lines,Curves in Rn 1.6 Vectors in R3 (Spatial Vectors), ijk Notation 1.7Complex Numbers 1.8 Vectors in CnCHAPTER 2 Algebra of Matrices 272.1 Introduction 2.2 Matrices 2.3 Matrix Addition and Scalar Multiplica-tion 2.4 Summation Symbol 2.5 Matrix Multiplication 2.6 Transpose of aMatrix 2.7 Square Matrices 2.8 Powers of Matrices, Polynomials inMatrices 2.9 Invertible (Nonsingular) Matrices 2.10 Special Types ofSquare Matrices 2.11 Complex Matrices 2.12 Block MatricesCHAPTER 3 Systems of Linear Equations 573.1 Introduction 3.2 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