

# MATRICES

# SALIENT FEATURES

1. The book provides straightforward and modern approach to the subject concept and evolution from simple and readily understood principles.
2. The book is written in an innovative style, presenting the subject matter in an explicit, lucid and comprehensive manner.
3. All fundamentals, concepts and theorems of the included topics have been explained with micro analysis.
4. A large number of solved examples along with unsolved ones are given in the book, which will enable the student to built up confidence regarding the understanding of the subject matter.
5. A unique feature of this book is to provide step-by-step clarity in relevant topics.
6. The book covers the part of syllabus for all B.Sc./B.Tech./B.C.A./M.Tech. and B.B.A. students of all Indian Universities.
7. The book is also helpful for the aspirants of IIT, MNER, GATE, I.A.S., P.C.S. and other competitive exams.
8. All the questions are unique and interesting.
9. Index is provided at the end of the book, to get the desirable concept or definition easily.
10. Overall book contains simplicity of presentation, along with detailed description of subject matter, so that students develop problem-solving approach.

# MATRICES

By

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# PREFACE

This book is intended to serve as a textbook for the course in 'Matrices' for B.Sc./B.Tech./M.Tech./B.B.A. and B.C.A. students of different Indian Universities exams. The various concepts and related theorems have been given in a lucid and simple manner, leaving no scope of confusion. The language used in this book is simple and it contains a fairly large number of solved and unsolved problems.

The requirements of the students have been a major factor kept in mind during compilation of this book. In every chapter concepts and theorems are discussed in details. This has been done with a view that even the beginners may not find any difficulty in grasping the subject matter. Great care has been taken in treatment of subject matter. The subject matter is systematic. It includes various important topics in the course studies of this subject. Planning has been done to present solutions to the problems in a lucid way.

We earnestly hope that the present work will serve alike, the students and our esteemed and learned colleagues in the best possible way. We have a conscious effort to make the book students friendly. We hope that the students will find the book interesting. We have made our best efforts to bring the book free from errors. However, we shall be grateful, if the readers communicate us any omission or errors or any valuable suggestions for improvement of the quality of the book for next edition.

—Authors

# ACKNOWLEDGEMENTS

We acknowledge the contribution of Prof. A.K. Singh, H.O.D. and Director Tehri Campus, H.N.B. Garhwal University, Prof. P.K. Mittal, former H.O.D. Maths, Govt. P.G. College, Rishikesh (Uttarakhand), Dr. Anita Tomar, H.O.D. Maths, Govt. Degree College, Vikasnagar (Dehradun), & Dr. Mukesh Bijalwan, Astd. Prof., ICFAI Univ., Dehradun, for their valuable suggestions during compilation of this book.

We express our special thanks to Prof. M.L. Dewal, former Principal G.B. Pant Engineering College, Pauri Garhwal for encouraging us time to time, motivating during preparation of the manuscripts of this book.

At last, we are indebted to our parents for all their blessings, guidelines and sincere support throughout the compilation period of this book.

—Authors

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# FOREWORD

I feel privileged to go through the text of the book, it has been written with a view point of welfare of the concerned students. It reflects upon the labour to which author has been put to, in the preparation of the book. The author has left no stone unturned in giving the most comprehensive shape to the matter included in the book. The mathematical theorems and problems are well explanatory and are anticipated with perfection. At last, I can say that the author's have become successful in achieving their goal.

I wish them lots of congratulations.

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# Chapter 1

## INTRODUCTION TO MATRICES

### 1.1 MATRIX: DEFINITION

---

A matrix is rectangular array of scalars *i.e.*, all those numbers that obey the algebraic laws of addition, subtraction, multiplication and division. The system of numbers, arranged in rectangular array is in rows and columns and bounded by brackets. Normally, this array is enclosed within square brackets. [ ], sometimes parenthesis ( ) or otherwise double vertical bars || are used.

More refined definition illustrates matrix as set of  $(mn)$  numbers (real or complex) which are arranged in a rectangular array having  $m$  rows (horizontal lines) and  $n$  vertical columns, called as  $(m \times n)$  type matrix.

Each of  $(mn)$  numbers which constitutes matrix, is called element of matrix.

For example,  $\begin{bmatrix} 5 & 7 & -1 \\ 3 & 4 & 8 \end{bmatrix}$  is a  $2 \times 3$  matrix or in other words, it is called matrix of order  $2 \times 3$ . It has got 2 rows and 3 columns and 5, 7, -1, 3, 4, 8 are its elements.

In order to locate the position of particular element of matrix, we specify the number of row and column in which the element occurs. Any element occurring in  $i^{\text{th}}$  row and  $j^{\text{th}}$  column will be referred to as  $(i, j)^{\text{th}}$  element.

Hence any  $(m \times n)$  matrix can be represented as :

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} \end{bmatrix}$$
$$= (a_{ij})_{m \times n}$$

Here each element possess two suffixes. The first suffix indicates row and second suffix indicates column in which element lies. Entries  $a_{ij}$  belong to algebraic system is called field and  $a_{ij}$  refers to

element which belongs to  $i^{\text{th}}$  row and  $j^{\text{th}}$  column of matrix, normally may be called as the  $(i, j)^{\text{th}}$  element.

In compact form, above matrix can be also written as

$$A = [a_{ij}]_{m \times n} \text{ or } A = [a_{ij}]_{mn} \text{ where } i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, n.$$

Generally, matrix is denoted by capital letters *i.e.*, A, B, etc., while its elements are represented by small letters.

## 1.2 MATRICES : IT'S TYPES

1. **Real Matrix** : Any matrix is said to be real if all of its elements are real numbers, *i.e.*,

*For example,*

$$A = \begin{bmatrix} 1 & 2 \\ \sqrt{2} & 7 \\ -5 & 8 \end{bmatrix} \text{ is a real matrix.}$$

2. **Row Matrix** : Any matrix which contains only one row and any number of columns, is called row matrix or row vector. If row matrix has  $m$  columns, then order of that row matrix is  $1 \times m$ .

*For example,*

$$A = [a_1 \quad a_2 \quad a_3 \quad \dots \quad a_m]_{1 \times m}$$

is a row matrix of order  $(1 \times m)$

3. **Column Matrix** : If a matrix contains only one column and any number of rows, then that matrix is called column matrix or column vector. If column matrix has  $n$  rows, then order of column matrix is  $n \times 1$ .

*For example,*

$$A = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_n \end{bmatrix}_{n \times 1} \text{ is a column matrix of order } (n \times 1)$$

4. **Zero or Null Matrix** : An  $(m \times n)$  matrix is called zero matrix if all of its elements are zeroes.

*For example,*

$$O = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}_{2 \times 3} \text{ is a null matrix of order } (2 \times 3).$$

5. **Square Matrix** : If  $m = n$ , *i.e.*, a matrix in which number of rows is equal to number of columns, is called square matrix.

Thus a matrix  $A = [a_{ij}]_{m \times n}$  is a square matrix of  $m = n$  *i.e.*, it is denoted by  $A = [a_{ij}]_{m \times n}$  or  $A = [a_{ij}]_n$ .

Hence for square matrix, having  $n$  rows and  $n$  columns, we call it as "Square matrix of order  $n$ " or an " $n$  rowed square matrix".

*For example,*  $\begin{bmatrix} 7 & 2 & 5 \\ 1 & 3 & 9 \\ 8 & 4 & 12 \end{bmatrix}$  is square matrix of order 3 and its diagonal elements are 7, 3, 12.

Here elements 7, 3, 12 of square matrix are called its diagonal elements and diagonal along which these elements lie is called principal diagonal.

In Square matrix,  $I = [a_{ij}]$

- (a) For element lying along principal diagonal we have  $i = j$
- (b) For elements lying above the principal diagonal we have  $i < j$
- (c) For elements lying below the principal diagonal we have  $i > j$
- (d) For non diagonal elements we have  $i \neq j$ .

The sum of all diagonal elements of square matrix is called its trace. Hence, trace of  $n$  rowed squared matrix  $A = [a_{ij}]$  is

$$a_{11} + a_{22} + a_{33} + a_{44} + \dots + a_{nn} = \sum_{i=1}^n a_{ij}.$$

6. **Diagonal Matrix** : If all the elements of a square matrix are zero except those in leading diagonal, then that matrix is called as diagonal matrix. Thus, if the square matrix  $A = [a_{ij}]$  is such that  $a_{ij} = 0$ , when  $i \neq j$ , then  $A$  is called diagonal matrix.

For example,  $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 8 \end{bmatrix}$  is a diagonal matrix and it may be written as  $\text{diag}(1, 4, 8)$ .

7. **Scalar Matrix** : A diagonal matrix of order  $n$  in which all diagonal elements are equal, is called scalar matrix.

Thus in scalar matrix  $A = [a_{ij}]_{n \times n}$  we have

$$a_{ij} = \begin{cases} 0 & \text{when } i \neq j \\ \lambda & \text{when } i = j, \text{ where } \lambda = \text{constant} \end{cases}$$

For example,  $\begin{bmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5 \end{bmatrix}$ ,  $\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$  are scalar matrices.

8. **Unit Matrix or Identity Matrix** : Scalar matrix each of whose diagonal element is unity is called unit matrix or identity matrix.  $I$  is denoted by  $I_n$ .

Here,  $A = [a_{ij}]_{n \times n}$  is unit matrix if  $a_{ij} = \begin{cases} 0 & ; i \neq j \\ 1 & ; i = j \end{cases}$

So,  $I_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ ;  $I_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$  are unit matrices of order 2 and 3 respectively.

9. **Triangular Matrix** : A square matrix in which all the elements either below or above the principal diagonal are zero is called as triangular matrix. Thus a triangular matrix can be upper triangular or lower triangular.
10. **Upper Triangular Matrix** : A square matrix in which all elements below the leading diagonal is equal to zero is called upper triangular matrix. Thus, square matrix  $A = [a_{ij}]$  is upper triangular matrix if  $a_{ij} = 0$  for  $i > j$ .

For example,

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ 0 & a_{22} & a_{23} & \cdots & a_{2n} \\ 0 & 0 & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & & \cdots & a_{nn} \end{bmatrix}$$

is an upper triangular matrix.

11. **Lower Triangular Matrix:** A square matrix in which all the elements above the leading diagonal is equal to zero is called a lower triangular. Thus, the square matrix  $A = [a_{ij}]_n$  is a lower triangular matrix of  $a_{ij} = 0$  for  $i < j$ .

For example,

$$A = \begin{bmatrix} a_{11} & 0 & 0 & \cdots & 0 \\ a_{21} & a_{22} & 0 & \cdots & 0 \\ a_{31} & a_{32} & a_{33} & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & & \cdots & a_{nn} \end{bmatrix}$$

is a lower triangular matrix.

12. **Equal Matrices:** Any two matrices A and B are said to be equal (written as  $A \equiv B$ ) if and only if they are of same order and their corresponding elements are equal.

Thus, if:  $A = [a_{ij}]_{m \times n}$  and  $B = [b_{ij}]_{p \times q}$ , then  $A = B$  if and only if

1.  $m = p$  and  $n = q$ .
2.  $a_{ij} = b_{ij} \forall i$  and  $j$ .

For example,

$$\begin{bmatrix} 7 & 4 & 2 \\ 1 & 3 & 5 \\ 6 & 7 & 12 \end{bmatrix} \text{ and } \begin{bmatrix} 7 & 4 & 2 \\ 1 & 3 & 5 \\ 6 & 7 & 12 \end{bmatrix} \text{ are equal.}$$

While  $\begin{bmatrix} 2 & 4 & 2 \\ 6 & 9 & 4 \\ 3 & 6 & 8 \end{bmatrix}$  and  $\begin{bmatrix} 2 & 4 & 8 \\ 6 & 9 & 5 \\ 3 & 6 & 8 \end{bmatrix}$  are not equal, as corresponding elements are not equal.

13. **Sub-matrices of a Matrix:**

A matrix which is obtained by deleting or eliminating off. Some rows and columns from given  $(m \times n)$  matrix A is called the sub-matrix of A.

Thus, matrix  $B = \begin{bmatrix} 1 & 2 \\ 4 & 8 \end{bmatrix}$  is sub-matrix of matrix,  $A = \begin{bmatrix} 3 & 6 & 8 & 14 \\ 9 & 5 & 4 & 2 \\ 7 & 1 & 1 & 2 \\ 9 & 3 & 4 & 8 \end{bmatrix}$ .

A square sub-matrix of square matrix A is called principal sub-matrix of A, if its diagonal elements are also diagonal elements of matrix A. All principal sub-matrices, are obtained only by emitting corresponding rows and columns.

### 1.3 EQUALITY OF MATRICES

Two matrices  $A = [a_{ij}]_{m \times n}$  and  $B = [b_{ij}]_{p \times q}$  are said to be equal if and only if they have same order and their corresponding elements are equal i.e.,  $a_{ij} = b_{ij} \forall i, j$

Thus, if  $A = [a_{ij}]_{m \times n}$  and  $B = [b_{ij}]_{p \times q}$  then  $A = B$  if and only if

1.  $m = p$  and  $n = q$ .
2.  $a_{ij} = b_{ij} \forall i$  and  $j$ .

For example,

1. The equality  $\begin{bmatrix} p & q & r \end{bmatrix} = \begin{bmatrix} a & b & c \end{bmatrix}$  is equivalent to three equations  $p = a, q = b, r = c$

2. The equality  $\begin{bmatrix} p & q & r \\ p' & q' & r' \end{bmatrix} = \begin{bmatrix} a & b & c \\ a' & b' & c' \end{bmatrix}$  is equivalent to six equations.

$$p = a, q = b, r = c, p' = a', q' = b', r' = c'.$$

### 1.4 ADDITION OF MATRICES

Let  $A = [a_{ij}]$  and  $B = [b_{ij}]$  be any two comparable matrices each of type  $m \times n$ . Then their sum  $A + B$  is defined as the matrices  $A + B = [a_{ij} + b_{ij}]$  i.e., the sum of two matrices of the same order is formed by adding the corresponding elements. So matrix  $A + B$  shall be having same order as of  $A$  or  $B$ .

Hence thereof, we can always add any two matrices of same order and they are said to be conformable for addition. If the two matrices are not of the same order, then they are said to be non conformable for addition.

For example,

1.  $A = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \end{bmatrix}$  and  $B = \begin{bmatrix} y_{11} & y_{12} & y_{13} \\ y_{21} & y_{22} & y_{23} \end{bmatrix}$ , then two matrices  $A$  and  $B$  are conformable for addition and we obtain

$$A + B = \begin{bmatrix} x_{11} + y_{11} & x_{12} + y_{12} & x_{13} + y_{13} \\ x_{21} + y_{21} & x_{22} + y_{22} & x_{23} + y_{23} \end{bmatrix}.$$

2. If  $A = \begin{bmatrix} 2 & 8 & 13 \\ 9 & 16 & 4 \end{bmatrix}$  and  $B = \begin{bmatrix} 1 & 8 \\ 2 & 13 \end{bmatrix}$ , then two matrices are not conformable for addition.

### 1.5 PROPERTIES OF MATRIX ADDITION

Matrix Addition obeys following properties :

1. **Matrix addition is commutative:** If  $A$  and  $B$  are same order matrices then

$$A + B = B + A.$$

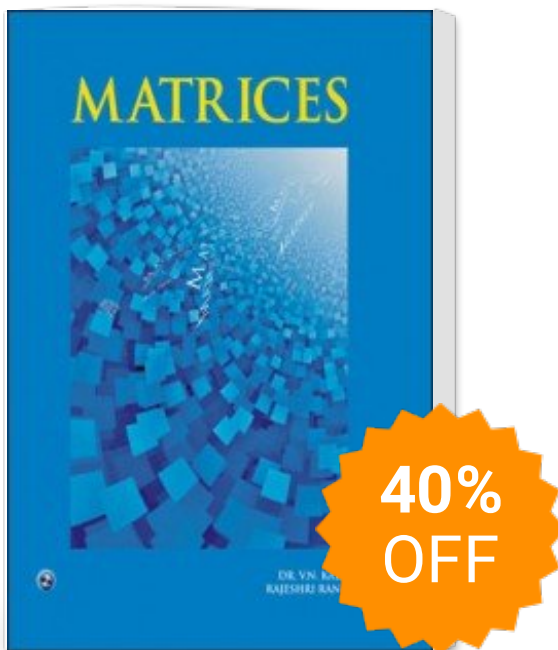
2. **Matrix addition is associative:** If  $A, B$  and  $C$  are three matrices of same order then

$$(A + B) + C = A + (B + C)$$

3. **Existence of Additive Identity:** If  $A = [a_{ij}]_{m \times n}$  be  $(m \times n)$  matrix and if  $O$  be the null matrix of same order as of matrix  $A$ , then

$$A + O = O + A = A$$

# Matrices By Dr. V. N. Kala, Rajeshri Rana



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Rajeshri Rana

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