Dr. Brij Mohan Yadav
Assistant Professor
Department of Mathematics

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Theory of Matrix

Annexure -I

15-4/2017-TC
Government of India
Ministry of Human Resource Development
Department of Higher Education
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Pay Matrix Proposed for IITs/IISc/IIM/NITIE/IISER/NIT/IIIT – in 4-tier structure* (All figures are in Rupees)								
Cadre Title	**Asst. Prof. Grade II**		**Asst. Prof. Grade I**		**Associate Prof.**	**Professor**		
6^{th} PC Pay Band	PB3 15600-39100			PB4 37400-67000				67000-79000
Grade Pay – IIT etc.	**6000**	**7000**	**8000**	**9000****	**9500**	**10000**	**10500**	**HAG**
Index of Rationalisation	2.67	2.67	2.67	2.67	2.67	2.72	2.72	2.72
Entry Pay IIT etc.	21600	25790	38000	49200	52300	53000	58500	67000
Cell No. / Pay Level	**10**	**11**	**12**	**13A1**	**13A2**	**14**	**14A**	**15**
1	57700	68900	101500	131400	139600	144200	159100	182200
2	59400	71000	104500	135300	143800	148500	163900	187700
3	61200	73100	107600	139400	148100	153000	168800	193300
4	63000	75300	110800	143600	152500	157600	173900	199100
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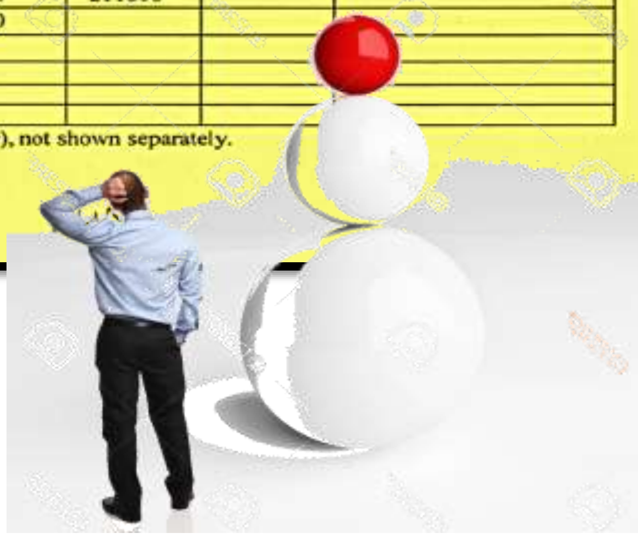
7	68800	82300	121000	156900	166700	172200	190000	217600
8	70900	84800	124600	161600	171700	177400	195700	224100
9	73000	87300	128300	166400	176900	182700	201600	
10	75200	89900	132100	171400	182200	188200	207600	
11	77500	92600	136100	176500	187700	193800	213800	
12	79800	95400	140200	181800	193300	199600	220200	
13	82200	98300	144400	187300	199100	205600		
14	84700	101200	148700	192900	205100	211800		
15	87200	104200	153200	198700	211300			
16	89800	107300	157800	204700				
17	92500	110500	162500					
18	95300	113800	167400					
19	98200	117200						

*As ISM, Dhanbad has become IIT, not shown separately; ** 9000 grade pay also has Asso. Prof (pre 4-tier), not shown separately.



Introduction

Matrix

Definition:

- Matrix is the structural organization of numbers.
- it is a rectangular array of numbers which is arranged in a rows and columns.
-

It is denoted by ( ) or [ ] symbols.

The array of numbers below is an example of matrix.

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \ldots\ldots\ldots\ldots\ldots\ldots & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{24} \ldots\ldots\ldots\ldots\ldots\ldots & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{34} \ldots\ldots\ldots\ldots\ldots\ldots & a_{3n} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \ \ldots\ldots\ldots\ldots\ldots\ldots & \ldots\ldots \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \ \ldots\ldots\ldots\ldots\ldots\ldots & \ldots\ldots \\ a_{m1} & a_{m2} & a_{m3} & a_{m4} \ldots\ldots\ldots\ldots\ldots\ldots & a_{mn} \end{pmatrix}$$

In This matrix

- There are m-rows and n-coloums.
- The order (dimension) of Matrix is m x n
- The numbers a_{11} a_{12} a_{13} …….. a_{ij}… are called elements (or entries) of the matrix.
- Element a_{ij} refers to the element located in the i-th row and j-th coloumn
- Thus the above matrix is expressed as

$$A=[a_{ij}]_{m\times n}$$

Where i= 1,2,3,………m
j=1,2,3……….n

m-by-n Matrix

a_{ij} ***n- coloumns*** *j- changes*

m-rows

i- changes

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \ldots\ldots\ldots\ldots & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{24} \ldots\ldots\ldots\ldots & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{34} \ldots\ldots\ldots\ldots & a_{3n} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \;\; \ldots\ldots\ldots\ldots & \ldots\ldots \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \;\; \ldots\ldots\ldots\ldots & \ldots\ldots \\ a_{m1} & a_{m2} & a_{m3} & a_{m4} \ldots\ldots\ldots\ldots & a_{mn} \end{pmatrix}$$

An English mathematician named Cullis was the first to use modern bracket notation for matrices in 1913
and
he simultaneously demonstrated the first significant use of the notation **A** = $[a_{i,j}]$ to represent a matrix where $a_{i,j}$ refers to the *i*th row and the *j*th column

The term "matrix" (Latin for "womb", derived from *mater*—mother) was coined by James Joseph Sylvester in 1850, who understood a matrix as an object giving rise to a number of determinants today called minors, that is to say, determinants of smaller matrices that derive from the original one by removing columns and rows.

In an 1851 paper, Sylvester explains:I have in previous papers defined-

a "Matrix" as a rectangular array of terms, out of which different systems of determinants may be engendered as from the womb of a common parent.

$$\begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 8 & 9 & 10 \end{pmatrix}$$

- The number of rows and columns that a matrix has is called its **dimension** or its **order**.
- By convention, rows are listed first; and columns, second.

Thus, we would say that the dimension (or order) of the above matrix is 3 X 3, meaning that it has 3 rows and 3 columns.

- # Numbers that appear in the rows and columns of a matrix are called **elements** of the matrix.
- In the above matrix, the element in the first column of the first row is 1; the element in the second column of the first row is 2; and so on.

Matrix notation

We use symbols to identify matrix elements and matrices.

Matrix elements: Consider the matrix below, in which matrix elements are represented entirely by symbols.

$$\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$$

By convention, first subscript refers to the **row number**; and the second subscript, to the **column number**.
Thus, the first element in the first row is represented by a_{11}. The second element in the first row is represented by a_{12}. And so on, until we reach the fourth element in the second row, which is represented by a_{22}.

Matrices There are several ways to represent a matrix symbolically. The simplest is to use a boldface letter, such as **A**, **B**, or **C**. Thus, **A** might represent a 3X3 matrix, as illustrated below.

$$\mathbf{A} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 8 & 9 & 10 \end{pmatrix}$$

Another approach for representing matrix **A** is:

$$\mathbf{A} = [\ a_{ij}\ ],$$

Where i = 1, 2, 3 and j = 1, 2, 3

This notation indicates that **A** is a matrix with 3 rows and 3 columns. The actual elements of the array are not displayed; they are represented by the symbol a_{ij}.

Matrix Equality:

To understand matrix algebra, we need to understand matrix equality. Two matrices are equal if all three of the following conditions are met.

Each matrix has the same number of rows.

Each matrix has the same number of columns.

Corresponding elements within each matrix are equal.

2. Type of Matrices:-

(a) Square matrix

(b) Non- square matrix

(c) Row matrix

(d) Column matrix

(e) Triangular matrix:- Triangular matrix are four types

(i) Upper triangular matrix

(ii) Lower triangular matrix

(iii) Strictly upper triangular matrix

(iv) Strictly lower triangular matrix

(f) Symmetric matrix

(g) Skew- symmetric matrix

Remark: Every square matrix can be expressed as sum of symmetric and skew-symmetric matrix.

(h) Diagonal matrix

(i) Identity matrix

(j) Scalar matrix

Remark: -

Every scalar matrix is also a diagonal matrix but if the diagonal elements are 1 of the scalar

matrix then it is also an identity matrix. In other words, we can say that every identity

matrix is a diagonal and scalar matrix.

TYPES OF MATRICES

1. Row matrix or vector

Any number of columns but only one row

$$\begin{bmatrix} 1 & 1 & 6 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 3 & 5 & 2 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \cdots & a_{1n} \end{bmatrix}$$

TYPES OF MATRICES

2.Column matrix or vector:

The number of rows may be any integer but the number of columns is always 1

$$\begin{bmatrix} 1 \\ 4 \\ 2 \end{bmatrix} \qquad \begin{bmatrix} 1 \\ -3 \end{bmatrix} \qquad \begin{bmatrix} a_{11} \\ a_{21} \\ \vdots \\ a_{m1} \end{bmatrix}$$

TYPES OF MATRICES

3. Rectangular matrix

Contains more than one element and number of rows is not equal to the number of columns

$$\begin{bmatrix} 1 & 1 \\ 3 & 7 \\ 7 & -7 \\ 7 & 6 \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 2 & 0 & 3 & 3 & 0 \end{bmatrix}$$

$$m \neq n$$

TYPES OF MATRICES

4. Square matrix

The number of rows is equal to the number of columns

(a square matrix **A** has an order of m)

m x m

$$\begin{bmatrix} 1 & 1 \\ 3 & 0 \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 \\ 9 & 9 & 0 \\ 6 & 6 & 1 \end{bmatrix}$$

The principal or main diagonal of a square matrix is composed of all elements a_{ij} for which $i=j$

TYPES OF MATRICES

5. Diagonal matrix

A square matrix where all the elements are zero except those on the main diagonal

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 5 & 0 \\ 0 & 0 & 0 & 9 \end{bmatrix}$$

i.e. $a_{ij} = 0$ for all $i = j$ /

$a_{ij} \neq 0$ for some or all $i = j$

TYPES OF MATRICES

6. Unit or Identity matrix - I

A diagonal matrix with ones on the main diagonal

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} a_{ij} & 0 \\ 0 & a_{ij} \end{bmatrix}$$

i.e. $a_{ij} = 0$ for all $i \neq j$

$a_{ij} = 1$ for some or all $i = j$

TYPES OF MATRICES

7. Null (zero) matrix - 0

All elements in the matrix are zero

$$\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$a_{ij} = 0$$ For all i,j

TYPES OF MATRICES

8. Triangular matrix

A square matrix whose elements above or below the main diagonal are all zero

$$\begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 0 \\ 5 & 2 & 3 \end{bmatrix} \quad \begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 0 \\ 5 & 2 & 3 \end{bmatrix} \quad \begin{bmatrix} 1 & 8 & 9 \\ 0 & 1 & 6 \\ 0 & 0 & 3 \end{bmatrix}$$

TYPES OF MATRICES

8a. Upper triangular matrix

A square matrix whose elements below the main diagonal are all zero

$$\begin{bmatrix} a_{ij} & a_{ij} & a_{ij} \\ 0 & a_{ij} & a_{ij} \\ 0 & 0 & a_{ij} \end{bmatrix} \quad \begin{bmatrix} 1 & 8 & 7 \\ 0 & 1 & 8 \\ 0 & 0 & 3 \end{bmatrix} \quad \begin{bmatrix} 1 & 7 & 4 & 4 \\ 0 & 1 & 7 & 4 \\ 0 & 0 & 7 & 8 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

i.e. $a_{ij} = 0$ for all $i > j$

TYPES OF MATRICES

8b. Lower triangular matrix

A square matrix whose elements above the main diagonal are all zero

$$\begin{bmatrix} a_{ij} & 0 & 0 \\ a_{ij} & a_{ij} & 0 \\ a_{ij} & a_{ij} & a_{ij} \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 0 \\ 5 & 2 & 3 \end{bmatrix}$$

i.e. $a_{ij} = 0$ for all $i < j$

TYPES OF MATRICES

9. Scalar matrix

A diagonal matrix whose main diagonal elements are equal to the same scalar

A scalar is defined as a single number or constant

$$\begin{bmatrix} a_{ij} & 0 & 0 \\ 0 & a_{ij} & 0 \\ 0 & 0 & a_{ij} \end{bmatrix} \quad \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 6 & 0 & 0 & 0 \\ 0 & 6 & 0 & 0 \\ 0 & 0 & 6 & 0 \\ 0 & 0 & 0 & 6 \end{bmatrix}$$

i.e. $a_{ij} = 0$ for all $i = j$ /
$a_{ij} = a$ for all $i = j$

3. MATRIX OPERATIONS

(a) Matrix addition

(b) Matrix subtraction

(c) Matrix multiplication

(d) Elementary operation

(i) Elementary row operation

(ii) Elementary column operation

4. Matrix properties

(i) Vector dependence:

(ii) Matrix rank: No. of non- zero rows in echelon form is called rank of the matrix.

(iii) Matrix determinant: Matrix determinant is a value (i.e. scalar quantity).

(iv) Matrix inverse:

5. CONCLUSION: USE AND ITS APPLICATIONS

(a) Matrix is used in **advanced statistics**, largely because it provides two benefits.

(i) Compact notation for describing sets of data and sets of equations.

(ii) Efficient methods for manipulating sets of data and solving sets of equations.

(b) Operation Research (In LPP : Transportation problems, Assignment problems, game theory etc. **In NLPP** Hessian Matrix used function is convex/concave **)**

(c) Networking Theory

(d) System Theory , Control Theory

(e) Summation, Mean scores, Deviation scores, Variance-Covariance etc.

Distance Matrix of Cities of California (U.S.)

	Eureka	Los Angeles	Palm Springs	S Lake Tahoe	Sacramento	San Diego	San Francisco	Santa Barbara	Yosemite NP
Eureka		659 / 1061	788 / 1268	393 / 632	304 / 489	776 / 1249	278 / 447	599 / 964	476 / 766
Los Angeles	659 / 1061		103 / 166	441 / 710	383 / 616	127 / 204	403 / 649	96 / 154	307 / 494
Palm Springs	788 / 1268	103 / 166		474 / 763	484 / 779	135 / 217	504 / 811	199 / 320	408 / 657
S Lake Tahoe	353 / 568	467 / 752	510 / 821		135 / 217	554 / 892	222 / 357	536 / 863	213 / 343
Sacramento	304 / 489	383 / 616	484 / 779	99 / 159		510 / 821	87 / 140	391 / 629	172 / 277
San Diego	776 / 1249	127 / 204	135 / 217	529 / 851	510 / 821		548 / 882	228 / 367	434 / 698
San Francisco	278 / 447	403 / 649	504 / 811	182 / 293	87 / 140	548 / 882		321 / 517	184 / 296
Santa Barbara	599 / 964	96 / 154	199 / 320	508 / 817	391 / 629	228 / 367	321 / 517		329 / 529
Yosemite NP	476 / 766	307 / 494	408 / 657	159 / 256	172 / 277	434 / 698	184 / 296	329 / 529	

Miles / Kilometers

Rajouri Garden	15	10	17	12	18	13	21	21	12	19	21	19	14	16	4	11	9	27	13	4	13	20	22	22	4	11	0	12	13	24	16	17	13	5
R.K Puram Sector-12	5	17	9	10	8	12	7	15	7	8	10	12	15	10	13	14	10	21	18	7	11	10	13	16	13	0	11	24	9	14	5	7	3	14
Punjabi Bagh	18	7	17	12	19	12	18	11	14	21	23	18	13	15	7	10	8	26	8	6	12	22	12	21	0	13	4	10	22	24	18	20	15	7
Patparganj	12	18	9	9	9	10	10	14	22	11	13	27	12	6	24	14	12	6	17	20	9	11	10	0	21	16	21	26	17	12	11	21	18	25
Old Delhi Railway Stn.	13	8	10	4	11	1	11	5	68	14	16	23	3	5	16	5	5	16	8	13	2	14	0	10	12	13	13	16	18	16	12	20	15	17
Nehru Place	6	22	6	12	3	14	4	18	16	2	2	21	16	10	22	18	16	16	22	16	13	0	14	11	22	9	20	29	6	6	4	13	10	23
New delhi Railway Stn.	11	9	8	2	10	1	10	6	16	12	15	21	4	4	16	6	4	15	9	12	0	13	2	9	12	11	13	17	16	15	11	18	13	17
Naraina	13	11	13	10	14	13	13	12	8	15	17	15	14	14	8	11	8	25	13	0	12	16	13	20	6	7	4	14	16	20	12	13	9	9
Model Town	19	4	17	10	18	8	18	4	21	21	23	27	8	12	16	4	9	23	0	13	9	22	8	17	8	18	12	11	24	24	19	24	20	16
Mayur Vihar Phase-III	18	24	15	15	14	15	15	20	28	16	18	33	17	11	30	20	18	0	23	26	15	16	16	6	26	21	27	31	22	14	16	26	23	31
Karol Bagh	12	7	10	4	12	5	12	6	14	15	17	20	7	7	12	6	0	19	9	8	4	15	5	13	8	10	9	14	17	18	12	17	12	13
Kamla Nagar	16	5	13	7	15	5	15	1	19	18	20	24	5	9	14	0	6	20	4	11	6	18	4	15	10	14	11	13	20	20	15	21	17	15
Janakpuri Dist. Centre	17	13	19	16	20	17	19	16	12	21	22	17	18	19	0	15	13	30	16	8	17	22	16	25	7	13	5	21	21	26	18	18	14	2
I.T.O	10	12	5	4	7	4	7	9	18	9	12	22	6	0	19	9	7	12	12	14	4	10	5	6	15	10	15	20	14	12	8	17	13	20
I.S.B.T (Kashmere Gate)	15	9	11	6	12	3	13	4	19	15	17	24	0	6	18	5	7	17	8	14	4	16	3	12	13	15	14	17	19	18	14	22	17	19
I.G.I Airport	17	25	20	19	19	23	19	24	8	20	20	0	25	21	17	24	20	33	27	14	21	21	23	27	21	12	18	29	16	26	17	8	12	19
Greater Kailash-II	6	23	8	14	5	16	6	20	15	3	0	20	17	12	22	20	17	18	23	17	15	2	16	31	23	10	21	13	6	7	6	12	9	24
Greater Kailash-I	4	21	5	11	3	13	3	18	15	0	3	20	15	10	21	18	15	18	21	15	21	2	14	12	20	8	19	28	6	8	4	12	9	22
Domestic Airport	11	18	14	14	14	17	13	18	0	14	15	8	19	19	12	18	14	27	21	8	15	15	17	21	14	6	12	22	13	20	11	6	6	13
Delhi University	16	5	14	11	15	5	15	0	19	18	20	24	5	9	16	1	6	20	4	12	6	19	4	14	11	15	12	13	21	21	16	22	17	16
Defence Colony	3	18	2	8	1	11	0	15	13	3	6	19	12	7	19	15	12	15	18	13	10	4	11	9	17	7	17	25	7	8	2	12	8	20
Chandni Chowk	12	8	9	4	11	0	11	5	17	13	16	23	3	4	17	5	5	15	8	13	1	14	1	10	13	12	13	16	17	16	12	19	15	18
Central Mrkt. (Lajpat Ngr.)	4	19	3	10	0	11	1	15	14	3	5	20	12	7	20	15	12	14	18	14	10	3	11	9	19	8	18	26	8	7	3	12	9	12

Mumbai Local Train Fare Matrix

Fare Chart (Rs)												
	To											
From	VER	DNG	AZN	AND	WEH	CHK	APR	MAN	SAN	ASA	JNG	GHA
VER	10	10	20	30	40	50	60	70	80	90	100	110
DNG	10	10	10	20	30	40	50	60	70	80	90	100
AZN	20	10	10	10	20	30	40	50	60	70	80	90
AND	30	20	10	10	10	20	30	40	50	60	70	80
WEH	40	30	20	10	10	10	20	30	40	50	60	70
CHK	50	40	30	20	10	10	10	20	30	40	50	60
APR	60	50	40	30	20	10	10	10	20	30	40	50
MAN	70	60	50	40	30	20	10	10	10	20	30	40
SAN	80	70	60	50	40	30	20	10	10	10	20	30
ASA	90	80	70	60	50	40	30	20	10	10	10	20
JNG	100	90	80	70	60	50	40	30	20	20	10	10
GHA	110	100	90	80	70	60	50	40	30	30	20	10

Use of matrices in Railways (Fare Display)

Fare Structure for Rajdhani and Duronto category of Trains										
Charges % of berths	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
2S	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
SL	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
3A	1X	1.1X	1.2X	1.3X	1.4X	1.4X	1.4X	1.4X	1.4X	1.4X
2A	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
1A	1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
X= Base Fare										

Fare Structure for Shatabdi category of Trains										
Charges % of berths	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
CC	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
EC	1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
X= Base Fare										

Anne

15-4/2017-TC

Government of India

Ministry of Human Resource Development

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Pay Matrix Proposed for IITs/IISc/IIM/NITIE/IISER/NIT/IIIT – in 4-tier structure* (All figures are in Rupees)

Cadre Title	Asst. Prof. Grade II		Asst. Prof. Grade I		Associate Prof.	Professor		
6th PC Pay Band	PB3 15600-39100			PB4 37400-67000				67000-79000
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4	63000	75300	110800	143600	152500	157600	173900	199100
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10	75200	89900	132100	171400	182200	188200	207600	
11	77500	92600	136100	176500	187700	193800	213800	
12	79800	95400	140200	181800	193300	199600	220200	
13	82200	98300	[illegible]	[illegible]	199100	205600		
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	211800		
15								
16								
17								

*As ISM, D