

## Chapter 4 Determinants

### EXERCISE 4.1

#### Question 1:

Evaluate the determinant  $\begin{vmatrix} 2 & 4 \\ -5 & -1 \end{vmatrix}$

#### Solution:

$$\text{Let } |A| = \begin{vmatrix} 2 & 4 \\ -5 & -1 \end{vmatrix}$$

Hence,

$$\begin{aligned} |A| &= \begin{vmatrix} 2 & 4 \\ -5 & -1 \end{vmatrix} \\ &= 2(-1) - 4(-5) \\ &= -2 + 20 \\ &= 18 \end{aligned}$$

#### Question 2:

Evaluate the determinants:

$$(i) \quad \begin{vmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{vmatrix}$$

$$(ii) \quad \begin{vmatrix} x^2 - x + 1 & x - 1 \\ x + 1 & x + 1 \end{vmatrix}$$

#### Solution:

(i)

$$\begin{aligned} \begin{vmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{vmatrix} &= (\cos \theta)(\cos \theta) - (-\sin \theta)(\sin \theta) \\ &= \cos^2 \theta + \sin^2 \theta \\ &= 1 \end{aligned}$$

(ii)

$$\begin{aligned} \begin{vmatrix} x^2 - x + 1 & x - 1 \\ x + 1 & x + 1 \end{vmatrix} &= (x^2 - x + 1)(x + 1) - (x - 1)(x + 1) \\ &= x^3 - x^2 + x + x^2 - x + 1 - (x^2 - 1) \\ &= x^3 + 1 - x^2 + 1 \\ &= x^3 - x^2 + 2 \end{aligned}$$

### Question 3:

If  $A = \begin{bmatrix} 1 & 2 \\ 4 & 2 \end{bmatrix}$ , then show that  $|2A| = 4|A|$

### Solution:

The given matrix is  $A = \begin{bmatrix} 1 & 2 \\ 4 & 2 \end{bmatrix}$

Therefore,

$$\begin{aligned} 2A &= 2 \begin{pmatrix} 1 & 2 \\ 4 & 2 \end{pmatrix} \\ &= \begin{pmatrix} 2 & 4 \\ 8 & 4 \end{pmatrix} \end{aligned}$$

Hence,

$$\begin{aligned} LHS &= |2A| \\ &= \begin{vmatrix} 2 & 4 \\ 8 & 4 \end{vmatrix} \\ &= 2 \times 4 - 4 \times 8 \\ &= 8 - 32 \\ &= -24 \end{aligned}$$

Now,

$$\begin{aligned} |A| &= \begin{vmatrix} 1 & 2 \\ 4 & 2 \end{vmatrix} = 1 \times 2 - 2 \times 4 \\ &= 2 - 8 \\ &= -6 \end{aligned}$$

Therefore,

$$\begin{aligned} RHS &= 4|A| \\ &= 4(-6) \\ &= -24 \end{aligned}$$

Thus,  $|2A| = 4|A|$  proved.

**Question 4:**

$$A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 4 \end{pmatrix}$$

If  $A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 4 \end{pmatrix}$ , then show that  $|3A| = 27|A|$

**Solution:**

$$A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 4 \end{pmatrix}$$

The given matrix is

It can be observed that in the first column, two entries are zero. Thus, we expand along the first column ( $C_1$ ) for easier calculation.

$$\begin{aligned} |A| &= 1 \begin{vmatrix} 1 & 2 \\ 0 & 4 \end{vmatrix} - 0 \begin{vmatrix} 0 & 1 \\ 1 & 4 \end{vmatrix} + 0 \begin{vmatrix} 0 & 1 \\ 1 & 2 \end{vmatrix} \\ &= 1(4 - 0) - 0 + 0 \\ &= 4 \end{aligned}$$

Therefore,

$$\begin{aligned} 27|A| &= 27|4| \\ &= 108 \quad \dots(1) \end{aligned}$$

Now,

$$3A = 3 \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 4 \end{pmatrix} = \begin{pmatrix} 3 & 0 & 3 \\ 0 & 3 & 6 \\ 0 & 0 & 12 \end{pmatrix}$$

Therefore,

$$\begin{aligned} |3A| &= 3 \begin{vmatrix} 3 & 6 \\ 0 & 12 \end{vmatrix} - 0 \begin{vmatrix} 0 & 3 \\ 0 & 12 \end{vmatrix} + 0 \begin{vmatrix} 0 & 3 \\ 3 & 6 \end{vmatrix} \\ &= 3(36 - 0) \\ &= 36(36) \\ &= 108 \quad \dots(2) \end{aligned}$$

From equations (1) and (2),

$$|3A| = 27|A|$$

Thus,  $|3A| = 27|A|$  proved.

**Question 5:**

Evaluate the determinants

$$(i) \begin{vmatrix} 3 & -1 & -2 \\ 0 & 0 & -1 \\ 3 & -5 & 0 \end{vmatrix}$$

$$(ii) \begin{vmatrix} 3 & -4 & 5 \\ 1 & 1 & -2 \\ 2 & 3 & 1 \end{vmatrix}$$

$$(iii) \begin{vmatrix} 0 & 1 & 2 \\ -1 & 0 & -3 \\ -2 & 3 & 0 \end{vmatrix}$$

$$(iv) \begin{vmatrix} 2 & -1 & -2 \\ 0 & 2 & -1 \\ 3 & -5 & 0 \end{vmatrix}$$

**Solution:**

$$(i) \text{ Let } A = \begin{vmatrix} 3 & -1 & -2 \\ 0 & 0 & -1 \\ 3 & -5 & 0 \end{vmatrix}$$

It can be observed that in the second row, two entries are zero. Thus, we expand along the second row for easier calculation.

Hence,

$$\begin{aligned} |A| &= -0 \begin{vmatrix} -1 & -2 \\ -5 & 0 \end{vmatrix} + 0 \begin{vmatrix} 3 & -2 \\ 3 & 0 \end{vmatrix} - (-1) \begin{vmatrix} 3 & -1 \\ 3 & -5 \end{vmatrix} \\ &= (-15 + 3) \\ &= -12 \end{aligned}$$

$$(ii) \text{ Let } A = \begin{vmatrix} 3 & -4 & 5 \\ 1 & 1 & -2 \\ 2 & 3 & 1 \end{vmatrix}$$

Hence,

$$\begin{aligned}
 |A| &= 3 \begin{vmatrix} 1 & -2 \\ 3 & 1 \end{vmatrix} + 4 \begin{vmatrix} 1 & -2 \\ 2 & 1 \end{vmatrix} + 5 \begin{vmatrix} 1 & 1 \\ 2 & 3 \end{vmatrix} \\
 &= 3(1+6) + 4(1+4) + 5(3-2) \\
 &= 3(7) + 4(5) + 5(1) \\
 &= 21 + 20 + 5 \\
 &= 46
 \end{aligned}$$

(iii) Let  $A = \begin{vmatrix} 0 & 1 & 2 \\ -1 & 0 & -3 \\ -2 & 3 & 0 \end{vmatrix}$

Hence,

$$\begin{aligned}
 |A| &= 0 \begin{vmatrix} 0 & -3 \\ 3 & 0 \end{vmatrix} - 1 \begin{vmatrix} -1 & -3 \\ -2 & 0 \end{vmatrix} + 2 \begin{vmatrix} -1 & 0 \\ -2 & 3 \end{vmatrix} \\
 &= 0 - 1(0-6) + 2(-3-0) \\
 &= -1(-6) + 2(-3) \\
 &= 6 - 6 = 0
 \end{aligned}$$

(iv) Let  $A = \begin{vmatrix} 2 & -1 & -2 \\ 0 & 2 & -1 \\ 3 & -5 & 0 \end{vmatrix}$

Hence,

$$\begin{aligned}
 |A| &= 2 \begin{vmatrix} 2 & -1 \\ -5 & 0 \end{vmatrix} - 0 \begin{vmatrix} -1 & -2 \\ -5 & 0 \end{vmatrix} + 3 \begin{vmatrix} -1 & -2 \\ 2 & -1 \end{vmatrix} \\
 &= 2(0-5) - 0 + 3(1+4) \\
 &= -10 + 15 = 5
 \end{aligned}$$

### Question 6:

If  $A = \begin{pmatrix} 1 & 1 & -2 \\ 2 & 1 & -3 \\ 5 & 4 & -9 \end{pmatrix}$ , find  $|A|$

**Solution:**

Let  $A = \begin{pmatrix} 1 & 1 & -2 \\ 2 & 1 & -3 \\ 5 & 4 & -9 \end{pmatrix}$

Hence,

$$\begin{aligned}
 |A| &= 1 \begin{vmatrix} 1 & -3 \\ 4 & -9 \end{vmatrix} - 1 \begin{vmatrix} 2 & -3 \\ 5 & -9 \end{vmatrix} - 2 \begin{vmatrix} 2 & 1 \\ 5 & 4 \end{vmatrix} \\
 &= 1(-9+12) - 1(-18+15) - 2(8-5) \\
 &= 1(3) - 1(-3) - 2(3) \\
 &= 3 + 3 - 6 \\
 &= 0
 \end{aligned}$$

### Question 7:

Find the values of  $x$ , if

$$(i) \quad \begin{vmatrix} 2 & 4 \\ 5 & 1 \end{vmatrix} = \begin{vmatrix} 2x & 4 \\ 6 & x \end{vmatrix}$$

$$(ii) \quad \begin{vmatrix} 2 & 3 \\ 4 & 5 \end{vmatrix} = \begin{vmatrix} x & 3 \\ 2x & 5 \end{vmatrix}$$

### Solution:

$$(i) \quad \begin{vmatrix} 2 & 4 \\ 5 & 1 \end{vmatrix} = \begin{vmatrix} 2x & 4 \\ 6 & x \end{vmatrix}$$

Therefore,

$$\Rightarrow 2 \times 1 - 5 \times 4 = 2x \times x - 6 \times 4$$

$$\Rightarrow 2 - 20 = 2x^2 - 24$$

$$\Rightarrow 2x^2 = 6$$

$$\Rightarrow x^2 = 3$$

$$\Rightarrow x = \pm\sqrt{3}$$

$$(ii) \quad \begin{vmatrix} 2 & 3 \\ 4 & 5 \end{vmatrix} = \begin{vmatrix} x & 3 \\ 2x & 5 \end{vmatrix}$$

Therefore,

$$\Rightarrow 2 \times 5 - 3 \times 4 = x \times 5 - 3 \times 2x$$

$$\Rightarrow 10 - 12 = 5x - 6x$$

$$\Rightarrow -2 = -x$$

$$\Rightarrow x = 2$$

### Question 8:

If  $\begin{vmatrix} x & 2 \\ 18 & x \end{vmatrix} = \begin{vmatrix} 6 & 2 \\ 18 & 6 \end{vmatrix}$ , the  $x$  is equal to

(A) 6

(B)  $\pm 6$

(C)  $-6$

(D) 0

**Solution:**

$$\begin{vmatrix} x & 2 \\ 18 & x \end{vmatrix} = \begin{vmatrix} 6 & 2 \\ 18 & 6 \end{vmatrix}$$

Therefore,

$$\Rightarrow x^2 - 36 = 36 - 36$$

$$\Rightarrow x^2 - 36 = 0$$

$$\Rightarrow x^2 = 36$$

$$\Rightarrow x = \pm 6$$

Thus, the correct option is B.

## EXERCISE 4.2

### Question 1:

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} x & a & x+a \\ y & b & y+b \\ z & c & z+c \end{vmatrix} = 0$$

### Solution:

$$\begin{aligned} \Delta &= \begin{vmatrix} x & a & x+a \\ y & b & y+b \\ z & c & z+c \end{vmatrix} \\ &= \begin{vmatrix} x & a & x \\ y & b & y \\ z & c & z \end{vmatrix} + \begin{vmatrix} x & a & a \\ y & b & b \\ z & c & c \end{vmatrix} \end{aligned}$$

Here, two columns of each determinant are identical.

Hence,

$$\begin{aligned} \Delta &= 0 + 0 \\ &= 0 \end{aligned}$$

### Question 2:

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} a-b & b-c & c-a \\ b-c & c-a & a-b \\ c-a & a-b & b-c \end{vmatrix} = 0$$

### Solution:

$$\begin{aligned} \Delta &= \begin{vmatrix} a-b & b-c & c-a \\ b-c & c-a & a-b \\ c-a & a-b & b-c \end{vmatrix} \\ &= \begin{vmatrix} a-c & b-a & c-b \\ b-c & c-a & a-b \\ -(a-c) & -(b-a) & -(c-b) \end{vmatrix} & [R_1 \rightarrow R_1 + R_2] \\ &= \begin{vmatrix} a-c & b-a & c-b \\ b-c & c-a & a-b \\ a-c & b-a & c-b \end{vmatrix} \end{aligned}$$



Here, the two rows  $R_1$  and  $R_3$  are identical.

Hence,  $\Delta = 0$

### Question 3:

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} 2 & 7 & 65 \\ 3 & 8 & 75 \\ 5 & 9 & 86 \end{vmatrix} = 0$$

### Solution:

$$\begin{aligned} \Delta &= \begin{vmatrix} 2 & 7 & 65 \\ 3 & 8 & 75 \\ 5 & 9 & 86 \end{vmatrix} \\ &= \begin{vmatrix} 2 & 7 & 63+2 \\ 3 & 8 & 72+3 \\ 5 & 9 & 81+5 \end{vmatrix} \\ &= \begin{vmatrix} 2 & 7 & 63 \\ 3 & 8 & 72 \\ 5 & 9 & 81 \end{vmatrix} + \begin{vmatrix} 2 & 7 & 2 \\ 3 & 8 & 3 \\ 5 & 9 & 5 \end{vmatrix} \\ &= \begin{vmatrix} 2 & 7 & 9(7) \\ 3 & 8 & 9(8) \\ 5 & 9 & 9(9) \end{vmatrix} + 0 & \quad [\because \text{Two columns are identical}] \\ &= 9 \begin{vmatrix} 2 & 7 & 7 \\ 3 & 8 & 8 \\ 5 & 9 & 9 \end{vmatrix} \\ &= 0 & \quad [\because \text{Two columns are identical}] \end{aligned}$$

### Question 4:

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} 1 & bc & a(b+c) \\ 1 & ca & b(c+a) \\ 1 & ab & c(a+b) \end{vmatrix} = 0$$

**Solution:**

$$\begin{aligned}\Delta &= \begin{vmatrix} 1 & bc & a(b+c) \\ 1 & ca & b(c+a) \\ 1 & ab & c(a+b) \end{vmatrix} \\ &= \begin{vmatrix} 1 & bc & ab+bc+ca \\ 1 & ca & ab+bc+ca \\ 1 & ab & ab+bc+ca \end{vmatrix} \quad [C_3 \rightarrow C_3 + C_2]\end{aligned}$$

Here, the two columns  $C_1$  and  $C_3$  are proportional.

Hence,  $\Delta = 0$

**Question 5:**

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ a+b & p+q & x+y \end{vmatrix} = 2 \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix}$$

**Solution:**

$$\begin{aligned}\Delta &= \begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ a+b & p+q & x+y \end{vmatrix} \\ &= \begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ a & p & x \end{vmatrix} + \begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ b & q & y \end{vmatrix} \\ &= \Delta_1 + \Delta_2 \dots \dots \dots (1)\end{aligned}$$

Now,

$$\begin{aligned}
\Delta_1 &= \begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ a & p & x \end{vmatrix} \\
&= \begin{vmatrix} b+c & q+r & y+z \\ c & r & z \\ a & p & x \end{vmatrix} && [R_2 \rightarrow R_2 - R_3] \\
&= \begin{vmatrix} b & q & y \\ c & r & z \\ a & p & x \end{vmatrix} && [R_1 \rightarrow R_1 - R_2] \\
&= (-1)^2 \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} \\
\Delta_1 &= \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} && [R_1 \leftrightarrow R_3 \text{ and } R_2 \leftrightarrow R_3] \quad \dots(2) \\
\Delta_2 &= \begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ b & q & y \end{vmatrix} \\
\Delta_2 &= \begin{vmatrix} c & r & z \\ c+a & r+p & z+x \\ b & q & y \end{vmatrix} && [R_1 \rightarrow R_1 - R_3] \\
\Delta_2 &= \begin{vmatrix} c & r & z \\ a & p & x \\ b & q & y \end{vmatrix} && [R_2 \rightarrow R_2 - R_1] \\
\Delta_2 &= (-1)^2 \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} \\
&= \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} && [R_1 \leftrightarrow R_2 \text{ and } R_2 \leftrightarrow R_3] \quad \dots(3)
\end{aligned}$$

From (1),(2) and (3), we have

$$\begin{aligned}\Delta &= \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} + \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix} \\ &= 2 \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix}\end{aligned}$$

Hence,  $\begin{vmatrix} b+c & q+r & y+z \\ c+a & r+p & z+x \\ a+b & p+q & x+y \end{vmatrix} = 2 \begin{vmatrix} a & p & x \\ b & q & y \\ c & r & z \end{vmatrix}$  proved.

### Question 6:

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} 0 & a & -b \\ -a & 0 & -c \\ b & c & 0 \end{vmatrix} = 0$$

**Solution:**

$$\begin{aligned}\Delta &= \begin{vmatrix} 0 & a & -b \\ -a & 0 & -c \\ b & c & 0 \end{vmatrix} \\ &= \frac{1}{c} \begin{vmatrix} 0 & ac & -bc \\ -a & 0 & -c \\ b & c & 0 \end{vmatrix} && [R_1 \rightarrow cR_1] \\ &= \frac{1}{c} \begin{vmatrix} ab & ac & 0 \\ -a & 0 & -c \\ b & c & 0 \end{vmatrix} && [R_1 \rightarrow R_1 - bR_2] \\ &= \frac{a}{c} \begin{vmatrix} b & c & 0 \\ -a & 0 & -c \\ b & c & 0 \end{vmatrix}\end{aligned}$$

Here, the two rows  $R_1$  and  $R_3$  are identical.

Hence,  $\Delta = 0$

**Question 7:**

Using the property of determinants and without expanding, prove that:

$$\begin{vmatrix} -a^2 & ab & ac \\ ba & -b^2 & bc \\ ca & cb & -c^2 \end{vmatrix} = 4a^2b^2c^2$$

**Solution:**

$$\Delta = \begin{vmatrix} -a^2 & ab & ac \\ ba & -b^2 & bc \\ ca & cb & -c^2 \end{vmatrix}$$

$$= abc \begin{vmatrix} -a & b & c \\ a & -b & c \\ a & b & -c \end{vmatrix}$$

[Taking out factors  $a, b, c$  from  $R_1, R_2, R_3$ ]

$$= a^2b^2c^2 \begin{vmatrix} -1 & 1 & 1 \\ 1 & -1 & 1 \\ 1 & 1 & -1 \end{vmatrix}$$

[Taking out factors  $a, b, c$  from  $C_1, C_2, C_3$ ]

$$= a^2b^2c^2 \begin{vmatrix} -1 & 1 & 1 \\ 0 & 0 & 2 \\ 0 & 2 & 0 \end{vmatrix}$$

[ $R_2 \rightarrow R_2 + R_1$  and  $R_3 \rightarrow R_3 + R_1$ ]

$$= a^2b^2c^2 (-1) \begin{vmatrix} 0 & 2 \\ 2 & 0 \end{vmatrix}$$

$$= -a^2b^2c^2 (0 - 4)$$

$$= 4a^2b^2c^2$$

**Question 8:**

By using properties of determinants show that:

$$(i) \quad \begin{vmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{vmatrix} = (a-b)(b-c)(c-a)$$

$$(ii) \quad \begin{vmatrix} 1 & 1 & 1 \\ a & b & c \\ a^3 & b^3 & c^3 \end{vmatrix} = (a-b)(b-c)(c-a)(a+b+c)$$

**Solution:**

$$(i) \quad \text{Let } \Delta = \begin{vmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{vmatrix}$$

$$\begin{aligned}
\Delta &= \begin{vmatrix} 0 & a-c & a^2-c^2 \\ 0 & b-c & b^2-c^2 \\ 1 & c & c^2 \end{vmatrix} && [R_1 \rightarrow R_1 - R_3 \text{ and } R_2 \rightarrow R_2 - R_3] \\
&= (c-a)(b-c) \begin{vmatrix} 0 & -1 & -a-c \\ 0 & 1 & b+c \\ 1 & c & c^2 \end{vmatrix} \\
&= (b-c)(c-a) \begin{vmatrix} 0 & 0 & -a+b \\ 0 & 1 & b+c \\ 1 & c & c^2 \end{vmatrix} && [R_1 \rightarrow R_1 + R_2] \\
&= (a-b)(b-c)(c-a) \begin{vmatrix} 0 & 0 & -1 \\ 0 & 1 & b+c \\ 1 & c & c^2 \end{vmatrix} \\
&= (a-b)(b-c)(c-a) \begin{vmatrix} 0 & -1 \\ 1 & b+c \end{vmatrix} \\
&= (a-b)(b-c)(c-a)
\end{aligned}$$

Hence,  $\begin{vmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{vmatrix} = (a-b)(b-c)(c-a)$  proved.

(ii) Let  $\Delta = \begin{vmatrix} 1 & 1 & 1 \\ a & b & c \\ a^3 & b^3 & c^3 \end{vmatrix}$

$$\begin{aligned}
\Delta &= \begin{vmatrix} 0 & 0 & 1 \\ a-c & b-c & c \\ a^3-c^3 & b^3-c^3 & c^3 \end{vmatrix} && [C_1 \rightarrow C_1 - C_3 \text{ and } C_2 \rightarrow C_2 - C_3] \\
&= \begin{vmatrix} 0 & 0 & 1 \\ a-c & b-c & c \\ (a-c)(a^2+ac+c^2) & (b-c)(b^2+bc+c^2) & c^3 \end{vmatrix} \\
&= (c-a)(b-c) \begin{vmatrix} 0 & 0 & 1 \\ -1 & 1 & c \\ -(a^2+ac+c^2) & (b^2+bc+c^2) & c^3 \end{vmatrix}
\end{aligned}$$

Applying  $C_1 \rightarrow C_1 + C_2$ ,

$$\begin{aligned}
\Delta &= (c-a)(b-c) \begin{vmatrix} 0 & 0 & 1 \\ 0 & 1 & c \\ (b^2-a^2)+(bc-ac) & (b^2+bc+c^2) & c^3 \end{vmatrix} \\
&= (b-c)(c-a)(a-b) \begin{vmatrix} 0 & 0 & 1 \\ 0 & 1 & c \\ -(a+b+c) & (b^2+bc+c^2) & c^3 \end{vmatrix} \\
&= (a-b)(b-c)(c-a)(a+b+c) \begin{vmatrix} 0 & 0 & 1 \\ 0 & 1 & c \\ -1 & (b^2+bc+c^2) & c^3 \end{vmatrix} \\
&= (a-b)(b-c)(c-a)(a+b+c)(-1) \begin{vmatrix} 0 & 1 \\ 1 & c \end{vmatrix} \\
&= (a-b)(b-c)(c-a)(a+b+c)
\end{aligned}$$

$$\text{Hence, } \begin{vmatrix} 1 & 1 & 1 \\ a & b & c \\ a^3 & b^3 & c^3 \end{vmatrix} = (a-b)(b-c)(c-a)(a+b+c) \quad \text{proved.}$$

### Question 9:

By using properties of determinants show that:

$$\begin{vmatrix} x & x^2 & yz \\ y & y^2 & zx \\ z & z^2 & xy \end{vmatrix} = (x-y)(y-z)(z-x)(xy+yz+zx)$$

### Solution:

$$\Delta = \begin{vmatrix} x & x^2 & yz \\ y & y^2 & zx \\ z & z^2 & xy \end{vmatrix}$$

Let

$$\Delta = \begin{vmatrix} x & x^2 & yz \\ y-x & y^2-x^2 & zx-yz \\ z-x & z^2-x^2 & xy-yz \end{vmatrix} \quad [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1]$$

$$= \begin{vmatrix} x & x^2 & yz \\ -(x-y) & -(x-y)(x+y) & z(x-y) \\ (z-x) & (z-x)(z+x) & -y(z-x) \end{vmatrix}$$

$$= (x-y)(z-x) \begin{vmatrix} x & x^2 & yz \\ -1 & -x-y & z \\ 1 & (z+x) & -y \end{vmatrix}$$

$$\Delta = (x-y)(z-x) \begin{vmatrix} x & x^2 & yz \\ -1 & -x-y & z \\ 0 & z-y & z-y \end{vmatrix} \quad [R_3 \rightarrow R_3 + R_2]$$

$$= (x-y)(z-x)(z-y) \begin{vmatrix} x & x^2 & yz \\ -1 & -x-y & z \\ 0 & 1 & 1 \end{vmatrix}$$

$$= [(x-y)(z-x)(z-y)] \left[ (-1) \begin{vmatrix} x & yz \\ -1 & z \end{vmatrix} + 1 \begin{vmatrix} x & x^2 \\ -1 & -x-y \end{vmatrix} \right]$$

$$= (x-y)(z-x)(z-y) [(-xz - yz) + (-x^2 - xy + x^2)]$$

$$= -(x-y)(z-x)(z-y)(xy + yz + zx)$$

$$= (x-y)(y-z)(z-x)(xy + yz + zx)$$

Hence,  $\begin{vmatrix} x & x^2 & yz \\ y & y^2 & zx \\ z & z^2 & xy \end{vmatrix} = (x-y)(y-z)(z-x)(xy + yz + zx)$  proved.

### Question 10:

By using properties of determinants show that:

$$(i) \quad \begin{vmatrix} x+4 & 2x & 2x \\ 2x & x+4 & 2x \\ 2x & 2x & x+4 \end{vmatrix} = (5x+4)(4-x)^2$$

$$(ii) \quad \begin{vmatrix} y+k & y & y \\ y & y+k & y \\ y & y & y+k \end{vmatrix} = k^2(3y+k)$$



**Solution:**

$$\begin{aligned} \text{(i)} \quad \Delta &= \begin{vmatrix} x+4 & 2x & 2x \\ 2x & x+4 & 2x \\ 2x & 2x & x+4 \end{vmatrix} \\ \Delta &= \begin{vmatrix} 5x+4 & 5x+4 & 5x+4 \\ 2x & x+4 & 2x \\ 2x & 2x & x+4 \end{vmatrix} & [R_1 \rightarrow R_1 + R_2 + R_3] \\ &= (5x+4) \begin{vmatrix} 1 & 1 & 1 \\ 2x & x+4 & 2x \\ 2x & 2x & x+4 \end{vmatrix} \\ &= (5x+4) \begin{vmatrix} 1 & 0 & 0 \\ 2x & -x+4 & 0 \\ 2x & 0 & -x+4 \end{vmatrix} & [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1] \\ &= (5x+4)(4-x)(4-x) \begin{vmatrix} 1 & 0 & 0 \\ 2x & 1 & 0 \\ 2x & 0 & 1 \end{vmatrix} \\ &= (5x+4)(4-x)^2 \begin{vmatrix} 1 & 0 \\ 2x & 1 \end{vmatrix} \\ &= (5x+4)(4-x)^2 \end{aligned}$$

$$\text{Hence, } \begin{vmatrix} x+4 & 2x & 2x \\ 2x & x+4 & 2x \\ 2x & 2x & x+4 \end{vmatrix} = (5x+4)(4-x)^2 \quad \text{proved.}$$

$$\text{(ii)} \quad \Delta = \begin{vmatrix} y+k & y & y \\ y & y+k & y \\ y & y & y+k \end{vmatrix}$$

$$\begin{aligned}
\Delta &= \begin{vmatrix} 3y+k & 3y+k & 3y+k \\ y & y+k & y \\ y & y & y+k \end{vmatrix} && [R_1 \rightarrow R_1 + R_2 + R_3] \\
&= (3y+k) \begin{vmatrix} 1 & 1 & 1 \\ y & y+k & y \\ y & y & y+k \end{vmatrix} \\
&= (3y+k) \begin{vmatrix} 1 & 0 & 0 \\ y & k & 0 \\ y & 0 & k \end{vmatrix} && [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1] \\
&= k^2 (3y+k) \begin{vmatrix} 1 & 0 & 0 \\ y & 1 & 0 \\ y & 0 & 1 \end{vmatrix}
\end{aligned}$$

Expanding along  $C_3$

$$\begin{aligned}
\Delta &= k^2 (3y+k) \begin{vmatrix} 1 & 0 \\ y & 1 \end{vmatrix} \\
&= k^2 (3y+k)
\end{aligned}$$

$$\text{Hence, } \begin{vmatrix} y+k & y & y \\ y & y+k & y \\ y & y & y+k \end{vmatrix} = k^2 (3y+k) \quad \text{proved.}$$

### Question 11:

By using properties of determinants show that:

$$\text{(i) } \begin{vmatrix} a-b-c & 2a & 2a \\ 2b & b-c-a & 2b \\ 2c & 2c & c-a-b \end{vmatrix} = (a+b+c)^3$$

$$\text{(ii) } \begin{vmatrix} x+y+2z & x & y \\ z & y+z+2x & y \\ z & x & z+x+2y \end{vmatrix} = 2(x+y+z)^3$$

**Solution:**

$$\text{(i) } \Delta = \begin{vmatrix} a-b-c & 2a & 2a \\ 2b & b-c-a & 2b \\ 2c & 2c & c-a-b \end{vmatrix}$$

$$\begin{aligned}
\Delta &= \begin{vmatrix} a+b+c & a+b+c & a+b+c \\ 2b & b-c-a & 2b \\ 2c & 2c & c-a-b \end{vmatrix} & [R_1 \rightarrow R_1 + R_2 + R_3] \\
&= (a+b+c) \begin{vmatrix} 1 & 1 & 1 \\ 2b & b-c-a & 2b \\ 2c & 2c & c-a-b \end{vmatrix} \\
&= (a+b+c) \begin{vmatrix} 1 & 0 & 0 \\ 2b & -(a+b+c) & 0 \\ 2c & 0 & -(a+b+c) \end{vmatrix} & [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1] \\
&= (a+b+c)^3 \begin{vmatrix} 1 & 0 & 0 \\ 2b & -1 & 0 \\ 2c & 0 & -1 \end{vmatrix} \\
&= (a+b+c)^3 (-1)(-1) \\
&= (a+b+c)^3
\end{aligned}$$

Hence, proved.

$$\begin{aligned}
\Delta &= \begin{vmatrix} x+y+2z & x & y \\ z & y+z+2x & y \\ z & x & z+x+2y \end{vmatrix} \\
\text{(ii)} \quad \Delta &= \begin{vmatrix} 2(x+y+z) & x & y \\ 2(x+y+z) & y+z+2x & y \\ 2(x+y+z) & x & z+x+2y \end{vmatrix} & [C_1 \rightarrow C_1 + C_2 + C_3] \\
&= 2(x+y+z) \begin{vmatrix} 1 & x & y \\ 1 & y+z+2x & y \\ 1 & x & z+x+2y \end{vmatrix} \\
&= 2(x+y+z) \begin{vmatrix} 1 & x & y \\ 0 & x+y+z & 0 \\ 0 & 0 & x+y+z \end{vmatrix} & [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\
&= 2(x+y+z)^3 \begin{vmatrix} 1 & x & y \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} \\
&= 2(x+y+z)^3 (1)(1-0) \\
&= 2(x+y+z)^3
\end{aligned}$$

Hence, proved.

**Question 12:**

By using properties of determinants show that:

$$\begin{vmatrix} 1 & x & x^2 \\ x^2 & 1 & x \\ x & x^2 & 1 \end{vmatrix} = (1-x^3)^2$$

**Solution:**

$$\begin{aligned} \Delta &= \begin{vmatrix} 1 & x & x^2 \\ x^2 & 1 & x \\ x & x^2 & 1 \end{vmatrix} \\ &= \begin{vmatrix} 1+x+x^2 & 1+x+x^2 & 1+x+x^2 \\ x^2 & 1 & x \\ x & x^2 & 1 \end{vmatrix} \quad [R_1 \rightarrow R_1 + R_2 + R_3] \\ &= (1+x+x^2) \begin{vmatrix} 1 & 1 & 1 \\ x^2 & 1 & x \\ x & x^2 & 1 \end{vmatrix} \\ \Delta &= (1+x+x^2) \begin{vmatrix} 1 & 0 & 0 \\ x^2 & 1-x^2 & x-x^2 \\ x & x^2-x & 1-x \end{vmatrix} \quad [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1] \\ \Delta &= (1+x+x^2)(1-x)(1-x) \begin{vmatrix} 1 & 0 & 0 \\ x^2 & 1+x & x \\ x & -x & 1 \end{vmatrix} \\ &= (1-x^3)(1-x) \begin{vmatrix} 1 & 0 & 0 \\ x^2 & 1+x & x \\ x & -x & 1 \end{vmatrix} \end{aligned}$$

Expanding along  $R_1$

$$\begin{aligned} \Delta &= (1-x^3)(1-x)(1) \begin{vmatrix} 1+x & x \\ -x & 1 \end{vmatrix} \\ &= (1-x^3)(1-x)(1+x+x^2) \\ &= (1-x^3)(1-x^3) \\ &= (1-x^3)^2 \end{aligned}$$

Hence, proved.

**Question 13:**

By using properties of determinants show that:

$$\begin{vmatrix} 1+a^2-b^2 & 2ab & -2b \\ 2ab & 1-a^2+b^2 & 2a \\ 2b & -2a & 1-a^2-b^2 \end{vmatrix} = (1+a^2+b^2)^3$$

**Solution:**

$$\begin{aligned} \Delta &= \begin{vmatrix} 1+a^2-b^2 & 2ab & -2b \\ 2ab & 1-a^2+b^2 & 2a \\ 2b & -2a & 1-a^2-b^2 \end{vmatrix} \\ &= \begin{vmatrix} 1+a^2+b^2 & 0 & -b(1+a^2+b^2) \\ 0 & 1+a^2+b^2 & a(1+a^2+b^2) \\ 2b & -2a & 1-a^2-b^2 \end{vmatrix} & [R_1 \rightarrow R_1 + bR_3 \text{ and } R_2 \rightarrow R_2 - aR_3] \\ &= (1+a^2+b^2)^2 \begin{vmatrix} 1 & 0 & -b \\ 0 & 1 & a \\ 2b & -2a & 1-a^2-b^2 \end{vmatrix} \\ &= (1+a^2+b^2)^2 \left[ (1) \begin{vmatrix} 1 & a \\ -2a & 1-a^2-b^2 \end{vmatrix} - b \begin{vmatrix} 0 & 1 \\ 2b & -2a \end{vmatrix} \right] \\ &= (1+a^2+b^2)^2 [1-a^2-b^2+2a^2-b(-2b)] \\ &= (1+a^2+b^2)^2 (1+a^2+b^2) \\ &= (1+a^2+b^2)^3 \end{aligned}$$

Hence, proved.

**Question 14:**

By using properties of determinants show that:

$$\begin{vmatrix} a^2+1 & ab & ac \\ ab & b^2+1 & bc \\ ca & cb & c^2+1 \end{vmatrix} = 1+a^2+b^2+c^2$$

**Solution:**

$$\Delta = \begin{vmatrix} a^2+1 & ab & ac \\ ab & b^2+1 & bc \\ ca & cb & c^2+1 \end{vmatrix}$$

Taking out common factors  $a, b, c$  from  $R_1, R_2, R_3$  respectively,

$$\begin{aligned}
\Delta &= abc \begin{vmatrix} a + \frac{1}{a} & b & c \\ a & b + \frac{1}{b} & c \\ a & b & c + \frac{1}{c} \end{vmatrix} \\
&= abc \begin{vmatrix} a + \frac{1}{a} & b & c \\ -\frac{1}{a} & \frac{1}{b} & 0 \\ -\frac{1}{a} & 0 & \frac{1}{c} \end{vmatrix} \quad [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\
&= abc \times \frac{1}{abc} \begin{vmatrix} a^2 + 1 & b^2 & c^2 \\ -1 & 1 & 0 \\ -1 & 0 & 1 \end{vmatrix} \quad [C_1 \rightarrow aC_1, C_2 \rightarrow bC_2 \text{ and } C_3 \rightarrow cC_3] \\
&= \begin{vmatrix} a^2 + 1 & b^2 & c^2 \\ -1 & 1 & 0 \\ -1 & 0 & 1 \end{vmatrix} \\
&= -1 \begin{vmatrix} b^2 & c^2 \\ 1 & 0 \end{vmatrix} + 1 \begin{vmatrix} a^2 + 1 & b^2 \\ -1 & 1 \end{vmatrix} \\
&= -1(-c^2) + (a^2 + 1 + b^2) \\
&= 1 + a^2 + b^2 + c^2
\end{aligned}$$

Hence, proved.

### Question 15:

Let  $A$  be a square matrix of order  $3 \times 3$ , then  $|kA|$  is equal to:

- (A)  $k|A|$                       (B)  $k^2|A|$                       (C)  $k^3|A|$                       (D)  $3^k|A|$

**Solution:**

$$A = \begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix}$$

Let

Then,

$$kA = \begin{pmatrix} ka_1 & kb_1 & kc_1 \\ ka_2 & kb_2 & kc_2 \\ ka_3 & kb_3 & kc_3 \end{pmatrix}$$

$$|kA| = \begin{vmatrix} ka_1 & kb_1 & kc_1 \\ ka_2 & kb_2 & kc_2 \\ ka_3 & kb_3 & kc_3 \end{vmatrix}$$

Taking out common factors  $k$  from each row

$$|kA| = k^3 \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}$$

$$= k^3 |A|$$

The correct option is C.

#### Question 16:

Which of the following is correct?

- (A) Determinant is a square matrix.
- (B) Determinant is a number associated to a matrix.
- (C) Determinant is a number associated to a square matrix.
- (D) None of the above.

#### Solution:

We know that to every square matrix,  $A = [a_{ij}]$  of order  $n$ , we can associate a number called the determinant of square matrix  $A$ , where  $a_{ij} = (i, j)^{th}$  element of  $A$ .

Thus, the determinant is a number associated to a square matrix.

Hence, the correct option is C.

## **EXERCISE 4.3**

### **Question 1:**

Find area of the triangle with vertices at the point given in each of the following:

- (i)  $(1,0), (6,0), (4,3)$
- (ii)  $(2,7), (1,1), (10,8)$
- (iii)  $(-2,-3), (3,2), (-1,-8)$

### **Solution:**

- (i) The area of the triangle with vertices  $(1,0), (6,0), (4,3)$  is given by the relation,

$$\begin{aligned}\Delta &= \frac{1}{2} \begin{vmatrix} 1 & 0 & 1 \\ 6 & 0 & 1 \\ 4 & 3 & 1 \end{vmatrix} \\ &= \frac{1}{2} [1(0-3) - 0(6-4) + 1(18-0)] \\ &= \frac{1}{2} [-3 + 18] \\ &= \frac{1}{2} [15] \\ &= \frac{15}{2}\end{aligned}$$

Hence, area of the triangle is  $\frac{15}{2}$  square units.

- (ii) The area of the triangle with vertices  $(2,7), (1,1), (10,8)$  is given by the relation,

$$\begin{aligned}\Delta &= \frac{1}{2} \begin{vmatrix} 2 & 7 & 1 \\ 1 & 1 & 1 \\ 10 & 8 & 1 \end{vmatrix} \\ &= \frac{1}{2} [2(1-8) - 7(1-10) + 1(8-10)] \\ &= \frac{1}{2} [2(-7) - 7(-9) + 1(-2)] \\ &= \frac{1}{2} [-14 + 63 - 2] \\ &= \frac{1}{2} [47] \\ &= \frac{47}{2}\end{aligned}$$



Hence, area of the triangle is  $\frac{47}{2}$  square units.

(iii) The area of the triangle with vertices  $(-2, -3), (3, 2), (-1, -8)$  is given by the relation,

$$\begin{aligned}\Delta &= \frac{1}{2} \begin{vmatrix} -2 & -3 & 1 \\ 3 & 2 & 1 \\ -1 & -8 & 1 \end{vmatrix} \\ &= \frac{1}{2} [-2(2+8) + 3(3+1) + 1(-24+2)] \\ &= \frac{1}{2} [-2(10) + 3(4) + 1(-22)] \\ &= \frac{1}{2} [-20 + 12 - 22] \\ &= -\frac{1}{2} [30] \\ &= -15\end{aligned}$$

Hence, area of the triangle is 15 square units.

### Question 2:

Show that the points  $A(a, b+c), B(b, c+a), C(c, a+b)$  are collinear.

### Solution:

The area of the triangle with vertices  $A(a, b+c), B(b, c+a), C(c, a+b)$  is given by the absolute value of the relation:

$$\begin{aligned}
\Delta &= \frac{1}{2} \begin{vmatrix} a & b+c & 1 \\ b & c+a & 1 \\ c & a+b & 1 \end{vmatrix} \\
&= \frac{1}{2} \begin{vmatrix} a & b+c & 1 \\ b-a & a-b & 0 \\ c-a & a-c & 0 \end{vmatrix} && [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\
&= \frac{1}{2} (a-b)(c-a) \begin{vmatrix} a & b+c & 1 \\ -1 & 1 & 0 \\ 1 & -1 & 0 \end{vmatrix} \\
&= \frac{1}{2} (a-b)(c-a) \begin{vmatrix} a & b+c & 1 \\ -1 & 1 & 0 \\ 0 & 0 & 0 \end{vmatrix} && [R_3 \rightarrow R_3 + R_2] \\
&= 0
\end{aligned}$$

Thus, the area of the triangle formed by points is zero.

Hence, the points are collinear.

### Question 3:

Find values of  $k$  if area of triangle is 4 square units and vertices are:

- (i)  $(k, 0), (4, 0), (0, 2)$
- (ii)  $(-2, 0), (0, 4), (0, k)$

### Solution:

We know that the area of a triangle whose vertices are  $(x_1, y_1), (x_2, y_2)$  and  $(x_3, y_3)$  is the absolute value of the determinant  $(\Delta)$ , where

$$\Delta = \frac{1}{2} \begin{vmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ x_3 & y_3 & 1 \end{vmatrix}$$

It is given that the area of triangle is 4 square units.

Hence,  $\Delta = \pm 4$

- (i) The area of the triangle with vertices  $(k, 0), (4, 0), (0, 2)$  is given by the relation,

$$\begin{aligned}
\Delta &= \frac{1}{2} \begin{vmatrix} k & 0 & 1 \\ 4 & 0 & 1 \\ 0 & 2 & 1 \end{vmatrix} \\
&= \frac{1}{2} [k(0-2) - 0(4-0) + 1(8-0)] \\
&= \frac{1}{2} [-2k + 8] \\
&= -k + 4
\end{aligned}$$

Therefore,  $-k + 4 = \pm 4$

When  $-k + 4 = -4$

Then  $k = 8$

When  $-k + 4 = 4$

Then  $k = 0$

Hence,  $k = 0, 8$

(ii) The area of the triangle with vertices  $(-2, 0), (0, 4), (0, k)$  is given by the relation,

$$\begin{aligned}
\Delta &= \frac{1}{2} \begin{vmatrix} -2 & 0 & 1 \\ 0 & 4 & 1 \\ 0 & k & 1 \end{vmatrix} \\
&= \frac{1}{2} [-2(4-k)] \\
&= k - 4
\end{aligned}$$

Therefore,  $-k + 4 = \pm 4$

When  $k - 4 = 4$

Then  $k = 8$

When  $k - 4 = -4$

Then  $k = 0$

Hence,  $k = 0, 8$

#### Question 4:

- (i) Find equation of line joining  $(1, 2)$  and  $(3, 6)$  using determinants.
- (ii) Find equation of line joining  $(3, 1)$  and  $(9, 3)$  using determinants.

**Solution:**

- (i) Let  $P(x, y)$  be any point on the line joining points  $A(1, 2)$  and  $B(3, 6)$ .

Then, the points  $A, B$  and  $P$  are collinear.

Hence, the area of triangle  $ABP$  will be zero.

Therefore,

$$\begin{aligned}\Rightarrow \frac{1}{2} \begin{vmatrix} 1 & 2 & 1 \\ 3 & 6 & 1 \\ x & y & 1 \end{vmatrix} &= 0 \\ \Rightarrow \frac{1}{2} [1(6-y) - 2(3-x) + 1(3y-6x)] &= 0 \\ \Rightarrow 6-y-6+2x+3y-6x &= 0 \\ \Rightarrow 2y-4x &= 0 \\ \Rightarrow y &= 2x\end{aligned}$$

Thus, the equation of the line joining the given points is  $y = 2x$ .

- (ii) Let  $P(x, y)$  be any point on the line joining points  $A(3, 1)$  and  $B(9, 3)$ .

Then, the points  $A, B$  and  $P$  are collinear.

Hence, the area of triangle  $ABP$  will be zero.

Therefore,

$$\begin{aligned}\Rightarrow \frac{1}{2} \begin{vmatrix} 3 & 1 & 1 \\ 9 & 3 & 1 \\ x & y & 1 \end{vmatrix} &= 0 \\ \Rightarrow \frac{1}{2} [3(3-y) - 1(9-x) + 1(9y-3x)] &= 0 \\ \Rightarrow 9-3y-9+x+9y-3x &= 0 \\ \Rightarrow 6y-2x &= 0 \\ \Rightarrow x-3y &= 0\end{aligned}$$

Thus, the equation of the line joining the given points is  $x-3y=0$ .

**Question 5:**

If area of the triangle is 35 square units with vertices  $(2, -6), (5, 4), (k, 4)$ . Then  $k$  is

- (A) 12                      (B) -2                      (C) -12, -2                      (D) 12, -2

**Solution:**

The area of the triangle with vertices  $(2, -6), (5, 4), (k, 4)$  is given by the relation,

$$\begin{aligned}
 \Delta &= \frac{1}{2} \begin{vmatrix} 2 & -6 & 1 \\ 5 & 4 & 1 \\ k & 4 & 1 \end{vmatrix} \\
 &= \frac{1}{2} [2(4-4) + 6(5-k) + 1(20-4k)] \\
 &= \frac{1}{2} [30 - 6k + 20 - 4k] \\
 &= \frac{1}{2} [50 - 10k] \\
 &= 25 - 5k
 \end{aligned}$$

It is given that the area of the triangle is 35 square units  
Hence,  $\Delta = \pm 35$ .

Therefore,

$$\begin{aligned}
 \Rightarrow 25 - 5k &= \pm 35 \\
 \Rightarrow 5(5 - k) &= \pm 35 \\
 \Rightarrow 5 - k &= \pm 7
 \end{aligned}$$

When,  $5 - k = -7$

Then,  $k = 12$

When,  $5 - k = 7$

Then,  $k = -2$

Hence,  $k = 12, -2$

Thus, the correct option is D.

## EXERCISE 4.4

### Question 1:

Write Minors and Cofactors of the elements of following determinants:

(i)  $\begin{vmatrix} 2 & -4 \\ 0 & 3 \end{vmatrix}$

(ii)  $\begin{vmatrix} a & c \\ b & d \end{vmatrix}$

### Solution:

(i) The given determinant is  $\begin{vmatrix} 2 & -4 \\ 0 & 3 \end{vmatrix}$

Minor of element  $a_{ij}$  is  $M_{ij}$ .

$$M_{11} = \text{minor of element } a_{11} = 3$$

$$M_{12} = \text{minor of element } a_{12} = 0$$

$$M_{21} = \text{minor of element } a_{21} = -4$$

$$M_{22} = \text{minor of element } a_{22} = 2$$

Cofactor of  $a_{ij}$  is  $A_{ij} = (-1)^{i+j} M_{ij}$

$$A_{11} = (-1)^{1+1} M_{11} = (-1)^2 (3) = 3$$

$$A_{12} = (-1)^{1+2} M_{12} = (-1)^3 (0) = 0$$

$$A_{21} = (-1)^{2+1} M_{21} = (-1)^3 (-4) = 4$$

$$A_{22} = (-1)^{2+2} M_{22} = (-1)^4 (2) = 2$$

(ii) The given determinant is  $\begin{vmatrix} a & c \\ b & d \end{vmatrix}$

Minor of element  $a_{ij}$  is  $M_{ij}$ .

$$M_{11} = \text{minor of element } a_{11} = d$$

$$M_{12} = \text{minor of element } a_{12} = b$$

$$M_{21} = \text{minor of element } a_{21} = c$$

$$M_{22} = \text{minor of element } a_{22} = a$$

Cofactor of  $a_{ij}$  is  $A_{ij} = (-1)^{i+j} M_{ij}$

$$A_{11} = (-1)^{1+1} M_{11} = (-1)^2 (d) = d$$

$$A_{12} = (-1)^{1+2} M_{12} = (-1)^3 (b) = -b$$

$$A_{21} = (-1)^{2+1} M_{21} = (-1)^3 (c) = -c$$

$$A_{22} = (-1)^{2+2} M_{22} = (-1)^4 (a) = a$$

## Question 2:

Write Minors and Cofactors of the elements of following determinants:

$$(i) \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

$$(ii) \begin{vmatrix} 1 & 0 & 4 \\ 3 & 5 & -1 \\ 0 & 1 & 2 \end{vmatrix}$$

## Solution:

$$(i) \text{ The given determinant is } \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

Minor of element  $a_{ij}$  is  $M_{ij}$ .

$$M_{11} = \text{minor of element } a_{11} = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = 1$$

$$M_{12} = \text{minor of element } a_{12} = \begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix} = 0$$

$$M_{13} = \text{minor of element } a_{13} = \begin{vmatrix} 0 & 1 \\ 0 & 0 \end{vmatrix} = 0$$

$$M_{21} = \text{minor of element } a_{21} = \begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix} = 0$$

$$M_{22} = \text{minor of element } a_{22} = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = 1$$

$$M_{23} = \text{minor of element } a_{23} = \begin{vmatrix} 1 & 0 \\ 0 & 0 \end{vmatrix} = 0$$

$$M_{31} = \text{minor of element } a_{31} = \begin{vmatrix} 0 & 0 \\ 1 & 0 \end{vmatrix} = 0$$

$$M_{32} = \text{minor of element } a_{32} = \begin{vmatrix} 1 & 0 \\ 0 & 0 \end{vmatrix} = 0$$

$$M_{33} = \text{minor of element } a_{33} = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = 1$$

Cofactor of  $a_{ij}$  is  $A_{ij} = (-1)^{i+j} M_{ij}$

$$A_{11} = (-1)^{1+1} M_{11} = (-1)^2 (1) = 1$$

$$A_{12} = (-1)^{1+2} M_{12} = (-1)^3 (0) = 0$$

$$A_{13} = (-1)^{1+3} M_{13} = (-1)^4 (0) = 0$$

$$A_{21} = (-1)^{2+1} M_{21} = (-1)^3 (0) = 0$$

$$A_{22} = (-1)^{2+2} M_{22} = (-1)^4 (1) = 1$$

$$A_{23} = (-1)^{2+3} M_{23} = (-1)^5 (0) = 0$$

$$A_{31} = (-1)^{3+1} M_{31} = (-1)^4 (0) = 0$$

$$A_{32} = (-1)^{3+2} M_{32} = (-1)^5 (0) = 0$$

$$A_{33} = (-1)^{3+3} M_{33} = (-1)^6 (1) = 1$$

(ii) The given determinant is  $\begin{vmatrix} 1 & 0 & 4 \\ 3 & 5 & -1 \\ 0 & 1 & 2 \end{vmatrix}$

Minor of element  $a_{ij}$  is  $M_{ij}$ .

$$M_{11} = \text{minor of element } a_{11} = \begin{vmatrix} 5 & -1 \\ 1 & 2 \end{vmatrix} = 11$$

$$M_{12} = \text{minor of element } a_{12} = \begin{vmatrix} 3 & -1 \\ 0 & 2 \end{vmatrix} = 6$$

$$M_{13} = \text{minor of element } a_{13} = \begin{vmatrix} 3 & 5 \\ 0 & 1 \end{vmatrix} = 3$$

$$M_{21} = \text{minor of element } a_{21} = \begin{vmatrix} 0 & 4 \\ 1 & 2 \end{vmatrix} = -4$$

$$M_{22} = \text{minor of element } a_{22} = \begin{vmatrix} 1 & 4 \\ 0 & 2 \end{vmatrix} = 2$$



$$M_{23} = \text{minor of element } a_{23} = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = 1$$

$$M_{31} = \text{minor of element } a_{31} = \begin{vmatrix} 0 & 4 \\ 5 & -1 \end{vmatrix} = -20$$

$$M_{32} = \text{minor of element } a_{32} = \begin{vmatrix} 1 & 4 \\ 3 & -1 \end{vmatrix} = -13$$

$$M_{33} = \text{minor of element } a_{33} = \begin{vmatrix} 1 & 0 \\ 3 & 5 \end{vmatrix} = 5$$

Cofactor of  $a_{ij}$  is  $A_{ij} = (-1)^{i+j} M_{ij}$

$$A_{11} = (-1)^{1+1} M_{11} = (-1)^2 (11) = 11$$

$$A_{12} = (-1)^{1+2} M_{12} = (-1)^3 (6) = -6$$

$$A_{13} = (-1)^{1+3} M_{13} = (-1)^4 (3) = 3$$

$$A_{21} = (-1)^{2+1} M_{21} = (-1)^3 (-4) = 4$$

$$A_{22} = (-1)^{2+2} M_{22} = (-1)^4 (2) = 2$$

$$A_{23} = (-1)^{2+3} M_{23} = (-1)^5 (1) = -1$$

$$A_{31} = (-1)^{3+1} M_{31} = (-1)^4 (-20) = -20$$

$$A_{32} = (-1)^{3+2} M_{32} = (-1)^5 (-13) = 13$$

$$A_{33} = (-1)^{3+3} M_{33} = (-1)^6 (5) = 5$$

### Question 3:

$$\Delta = \begin{vmatrix} 5 & 3 & 8 \\ 2 & 0 & 1 \\ 1 & 2 & 3 \end{vmatrix}$$

Using Cofactors of elements of second row, evaluate

### Solution:

$$\text{The given determinant is } \begin{vmatrix} 5 & 3 & 8 \\ 2 & 0 & 1 \\ 1 & 2 & 3 \end{vmatrix}$$

$$M_{21} = \text{minor of element } a_{21} = \begin{vmatrix} 3 & 8 \\ 2 & 3 \end{vmatrix} = -7$$

$$A_{21} = (-1)^{2+1} M_{21} = (-1)^3 (-7) = 7$$

$$M_{22} = \text{minor of element } a_{22} = \begin{vmatrix} 5 & 8 \\ 1 & 3 \end{vmatrix} = 15 - 8 = 7$$

$$A_{22} = (-1)^{2+2} M_{22} = (-1)^4 (7) = 7$$

$$M_{23} = \text{minor of element } a_{23} = \begin{vmatrix} 5 & 3 \\ 1 & 2 \end{vmatrix} = 7$$

$$A_{23} = (-1)^{2+3} M_{23} = (-1)^5 (7) = -7$$

We know that  $\Delta$  is equal to the sum of the product of the elements of the second row with their corresponding cofactors.

Therefore,

$$\begin{aligned} \Delta &= a_{21}A_{21} + a_{22}A_{22} + a_{23}A_{23} \\ &= 2(7) + 0(7) + 1(-7) \\ &= 14 - 7 \\ &= 7 \end{aligned}$$

#### Question 4:

$$\Delta = \begin{vmatrix} 1 & x & yz \\ 1 & y & zx \\ 1 & z & xy \end{vmatrix}$$

Using Cofactors of elements of third column, evaluate

#### Solution:

The given determinant is  $\begin{vmatrix} 1 & x & yz \\ 1 & y & zx \\ 1 & z & xy \end{vmatrix}$

Therefore,

$$M_{13} = \begin{vmatrix} 1 & y \\ 1 & z \end{vmatrix} = z - y$$

$$M_{23} = \begin{vmatrix} 1 & x \\ 1 & z \end{vmatrix} = z - x$$

$$M_{33} = \begin{vmatrix} 1 & x \\ 1 & y \end{vmatrix} = y - x$$

$$A_{13} = (-1)^{1+3} M_{13} = (-1)^4 (z - y) = z - y$$

$$A_{23} = (-1)^{2+3} M_{23} = (-1)^5 (z - x) = -(z - x) = x - z$$

$$A_{33} = (-1)^{3+3} M_{33} = (-1)^6 (y - x) = y - x$$

We know that  $\Delta$  is equal to the sum of the product of the elements of the third column with their corresponding cofactors.

Therefore,

$$\begin{aligned}\Delta &= a_{13}A_{13} + a_{23}A_{23} + a_{33}A_{33} \\ &= yz(z - y) + zx(x - z) + xy(y - x) \\ &= yz^2 - y^2z + x^2z - xz^2 + xy^2 - x^2y \\ &= (x^2z - y^2z) + (yz^2 - xz^2) + (xy^2 - x^2y) \\ &= z(x^2 - y^2) + z^2(y - x) + xy(y - x) \\ &= z(x - y)(x + y) + z^2(y - x) + xy(y - x) \\ &= (x - y)[zx + zy - z^2 - xy] \\ &= (x - y)[z(x - z) + y(z - x)] \\ &= (x - y)(z - x)[-z + y] \\ &= (x - y)(y - z)(z - x)\end{aligned}$$

Hence,

$$\Delta = (x - y)(y - z)(z - x)$$

### Question 5:

$$\Delta = \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}$$

If  $A_{ij}$  is the cofactor of  $a_{ij}$ , then the value of  $\Delta$  is given by:

- A.  $a_{11}A_{31} + a_{12}A_{32} + a_{13}A_{33}$
- B.  $a_{11}A_{11} + a_{12}A_{21} + a_{13}A_{31}$
- C.  $a_{21}A_{11} + a_{22}A_{12} + a_{23}A_{13}$
- D.  $a_{11}A_{11} + a_{21}A_{21} + a_{31}A_{31}$

### Solution:

We know that  $\Delta$  is equal to the sum of the product of the elements of a column or row with their corresponding cofactors.

$$\Delta = a_{11}A_{11} + a_{21}A_{21} + a_{31}A_{31}$$

Thus, the correct option is D.

## EXERCISE 4.5

### Question 1:

Find the adjoint of the matrix  $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$

### Solution:

Let  $A = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$

Then,

$$\begin{aligned} A_{11} &= 4 & A_{12} &= -3 \\ A_{21} &= -2 & A_{22} &= 1 \end{aligned}$$

Therefore,

$$\begin{aligned} \text{adj}A &= \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \\ &= \begin{pmatrix} 4 & -2 \\ -3 & 1 \end{pmatrix} \end{aligned}$$

### Question 2:

Find the adjoint of the matrix  $\begin{pmatrix} 1 & -1 & 2 \\ 2 & 3 & 5 \\ -2 & 0 & 1 \end{pmatrix}$

### Solution:

Let  $A = \begin{pmatrix} 1 & -1 & 2 \\ 2 & 3 & 5 \\ -2 & 0 & 1 \end{pmatrix}$

Then,

$$\begin{aligned} A_{11} &= \begin{vmatrix} 3 & 5 \\ 0 & 1 \end{vmatrix} = 3 & A_{12} &= -\begin{vmatrix} 2 & 5 \\ -2 & 1 \end{vmatrix} = -12 & A_{13} &= \begin{vmatrix} 2 & 3 \\ -2 & 0 \end{vmatrix} = 6 \\ A_{21} &= -\begin{vmatrix} -1 & 2 \\ 0 & 1 \end{vmatrix} = 1 & A_{22} &= \begin{vmatrix} 1 & 2 \\ -2 & 1 \end{vmatrix} = 5 & A_{23} &= -\begin{vmatrix} 1 & -1 \\ -2 & 0 \end{vmatrix} = 2 \\ A_{31} &= \begin{vmatrix} -1 & 2 \\ 3 & 5 \end{vmatrix} = -11 & A_{32} &= -\begin{vmatrix} 1 & 2 \\ 2 & 5 \end{vmatrix} = -1 & A_{33} &= \begin{vmatrix} 1 & -1 \\ 2 & 3 \end{vmatrix} = 5 \end{aligned}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} 3 & 1 & -11 \\ -12 & 5 & -1 \\ 6 & 2 & 5 \end{pmatrix}$$

### Question 3:

Verify  $A(\text{adj}A) = (\text{adj}A)A = |A|I$  for

$$\begin{pmatrix} 2 & 3 \\ -4 & -6 \end{pmatrix}$$

### Solution:

Let  $A = \begin{pmatrix} 2 & 3 \\ -4 & -6 \end{pmatrix}$

Then,

$$\begin{aligned} |A| &= -12 - (-12) \\ &= 0 \end{aligned}$$

Also,

$$\begin{aligned} |A|I &= 0 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{aligned}$$

Now,

$$\begin{aligned} A_{11} &= -6 & A_{12} &= 4 \\ A_{21} &= -3 & A_{22} &= 2 \end{aligned}$$

Hence,

$$\text{adj}A = \begin{pmatrix} -6 & -3 \\ 4 & 2 \end{pmatrix}$$

Now,

$$\begin{aligned} A(\text{adj}A) &= \begin{pmatrix} 2 & 3 \\ -4 & -6 \end{pmatrix} \begin{pmatrix} -6 & -3 \\ 4 & 2 \end{pmatrix} \\ &= \begin{pmatrix} -12+12 & -6+6 \\ 24-24 & 12-12 \end{pmatrix} \\ &= \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{aligned}$$

Also,

$$\begin{aligned}(\operatorname{adj} A) A &= \begin{pmatrix} -6 & -3 \\ 4 & 2 \end{pmatrix} \begin{pmatrix} 2 & 3 \\ -4 & -6 \end{pmatrix} \\&= \begin{pmatrix} -12+12 & -18+18 \\ 8-8 & 12-12 \end{pmatrix} \\&= \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}\end{aligned}$$

Hence,  $A(\operatorname{adj} A) = (\operatorname{adj} A) A = |A|I$ .

#### Question 4:

Verify  $A(\operatorname{adj} A) = (\operatorname{adj} A) A = |A|I$  for

$$\begin{pmatrix} 1 & -1 & 2 \\ 3 & 0 & -2 \\ 1 & 0 & 3 \end{pmatrix}$$

**Solution:**

Let  $A = \begin{pmatrix} 1 & -1 & 2 \\ 3 & 0 & -2 \\ 1 & 0 & 3 \end{pmatrix}$

Then,

$$\begin{aligned}|A| &= 1(0-0) + 1(9+2) + 2(0-0) \\&= 11\end{aligned}$$

Also,

$$\begin{aligned}|A|I &= 11 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\&= \begin{pmatrix} 11 & 0 & 0 \\ 0 & 11 & 0 \\ 0 & 0 & 11 \end{pmatrix}\end{aligned}$$

Now,

$$\begin{array}{lll}A_{11} = 0 & A_{12} = -11 & A_{13} = 0 \\A_{21} = 3 & A_{22} = 1 & A_{23} = -1 \\A_{31} = 2 & A_{32} = 8 & A_{33} = 3\end{array}$$

Hence,

$$\text{adj}A = \begin{pmatrix} 0 & 3 & 2 \\ -11 & 1 & 8 \\ 0 & -1 & 3 \end{pmatrix}$$

Now,

$$\begin{aligned} A(\text{adj}A) &= \begin{pmatrix} 1 & -1 & 2 \\ 3 & 0 & -2 \\ 1 & 0 & 3 \end{pmatrix} \begin{pmatrix} 0 & 3 & 2 \\ -11 & 1 & 8 \\ 0 & -1 & 3 \end{pmatrix} \\ &= \begin{pmatrix} 0+11+0 & 3-1-2 & 2-8+6 \\ 0+0+0 & 9+0+2 & 6+0-6 \\ 0+0+0 & 3+0-3 & 2+0+9 \end{pmatrix} = \begin{pmatrix} 11 & 0 & 0 \\ 0 & 11 & 0 \\ 0 & 0 & 11 \end{pmatrix} \end{aligned}$$

Also,

$$\begin{aligned} (\text{adj}A)A &= \begin{pmatrix} 0 & 3 & 2 \\ -11 & 1 & 8 \\ 0 & -1 & 3 \end{pmatrix} \begin{pmatrix} 1 & -1 & 2 \\ 3 & 0 & -2 \\ 1 & 0 & 3 \end{pmatrix} \\ &= \begin{pmatrix} 0+9+2 & 0+0+0 & 0-6+6 \\ -11+3+8 & 11+0+0 & -22-2+24 \\ 0-3+3 & 0+0+0 & 2+0+9 \end{pmatrix} \\ &= \begin{pmatrix} 11 & 0 & 0 \\ 0 & 11 & 0 \\ 0 & 0 & 11 \end{pmatrix} \end{aligned}$$

Hence,  $A(\text{adj}A) = (\text{adj}A)A = |A|I$ .

### Question 5:

Find the inverse of each of the matrix  $\begin{pmatrix} 2 & -2 \\ 4 & 3 \end{pmatrix}$  (if it exists).

**Solution:**

Let  $A = \begin{pmatrix} 2 & -2 \\ 4 & 3 \end{pmatrix}$

Then,

$$\begin{aligned}|A| &= 6 + 8 \\ &= 14\end{aligned}$$

Now,

$$\begin{aligned}A_{11} &= 3 & A_{12} &= -4 \\ A_{21} &= 2 & A_{22} &= 2\end{aligned}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} 3 & 2 \\ -4 & 2 \end{pmatrix}$$

Hence,

$$\begin{aligned}A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= \frac{1}{14} \begin{pmatrix} 3 & 2 \\ -4 & 2 \end{pmatrix}\end{aligned}$$

### Question 6:

Find the inverse of each of the matrix  $\begin{pmatrix} -1 & 5 \\ -3 & 2 \end{pmatrix}$  (if it exists)

**Solution:**

Let  $A = \begin{pmatrix} -1 & 5 \\ -3 & 2 \end{pmatrix}$

Then,

$$|A| = -2 + 15 = 13$$

Now,

$$\begin{aligned}A_{11} &= 2 & A_{12} &= 3 \\ A_{21} &= -5 & A_{22} &= -1\end{aligned}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} 2 & -5 \\ 3 & -1 \end{pmatrix}$$

Hence,



$$\begin{aligned}
 A^{-1} &= \frac{1}{|A|} \text{adj}A \\
 &= \frac{1}{13} \begin{pmatrix} 2 & -5 \\ 3 & -1 \end{pmatrix}
 \end{aligned}$$

### Question 7:

Find the inverse of each of the matrix  $\begin{pmatrix} 1 & 2 & 3 \\ 0 & 2 & 4 \\ 0 & 0 & 5 \end{pmatrix}$  (if it exists)

### Solution:

$$\text{Let } A = \begin{pmatrix} 1 & 2 & 3 \\ 0 & 2 & 4 \\ 0 & 0 & 5 \end{pmatrix}$$

Then,

$$\begin{aligned}
 |A| &= 1(10-0) - 2(0-0) + 3(0-0) \\
 &= 10
 \end{aligned}$$

Now,

$$\begin{array}{lll}
 A_{11} = 10 & A_{12} = 0 & A_{13} = 0 \\
 A_{21} = -10 & A_{22} = 5 & A_{23} = 0 \\
 A_{31} = 2 & A_{32} = -4 & A_{33} = 2
 \end{array}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} 10 & -10 & 2 \\ 0 & 5 & -4 \\ 0 & 0 & 2 \end{pmatrix}$$

Hence,

$$\begin{aligned}
 A^{-1} &= \frac{1}{|A|} \text{adj}A \\
 &= \frac{1}{10} \begin{pmatrix} 10 & -10 & 2 \\ 0 & 5 & -4 \\ 0 & 0 & 2 \end{pmatrix}
 \end{aligned}$$

**Question 8:**

Find the inverse of each of the matrix  $\begin{pmatrix} 1 & 0 & 0 \\ 3 & 3 & 0 \\ 5 & 2 & -1 \end{pmatrix}$  (if it exists)

**Solution:**

Let  $A = \begin{pmatrix} 1 & 0 & 0 \\ 3 & 3 & 0 \\ 5 & 2 & -1 \end{pmatrix}$

Then,

$$|A| = 1(-3 - 0) - 0 + 0 = -3$$

Now,

$$\begin{array}{lll} A_{11} = -3 & A_{12} = 3 & A_{13} = -9 \\ A_{21} = 0 & A_{22} = -1 & A_{23} = -2 \\ A_{31} = 0 & A_{32} = 0 & A_{33} = 3 \end{array}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} -3 & 0 & 0 \\ 3 & -1 & 0 \\ -9 & -2 & 3 \end{pmatrix}$$

Hence,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= \frac{-1}{3} \begin{pmatrix} -3 & 0 & 0 \\ 3 & -1 & 0 \\ -9 & -2 & 3 \end{pmatrix} \end{aligned}$$

**Question 9:**

Find the inverse of each of the matrix  $\begin{pmatrix} 2 & 1 & 3 \\ 4 & -1 & 0 \\ -7 & 2 & 1 \end{pmatrix}$  (if it exists)

**Solution:**

Let  $A = \begin{pmatrix} 2 & 1 & 3 \\ 4 & -1 & 0 \\ -7 & 2 & 1 \end{pmatrix}$

Then,

$$\begin{aligned} |A| &= 2(-1-0) - 1(4-0) + 3(8-7) \\ &= 2(-1) - 1(4) + 3(1) \\ &= -3 \end{aligned}$$

Now,

$$\begin{array}{lll} A_{11} = -1 & A_{12} = -4 & A_{13} = 1 \\ A_{21} = 5 & A_{22} = 23 & A_{23} = -11 \\ A_{31} = 3 & A_{32} = 12 & A_{33} = -6 \end{array}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} -1 & 5 & 3 \\ -4 & 23 & 12 \\ 1 & -11 & -6 \end{pmatrix}$$

Hence,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= -\frac{1}{3} \begin{pmatrix} -1 & 5 & 3 \\ -4 & 23 & 12 \\ 1 & -11 & -6 \end{pmatrix} \end{aligned}$$

**Question 10:**

Find the inverse of each of the matrix  $\begin{pmatrix} 1 & -1 & 2 \\ 0 & 2 & -3 \\ 3 & -2 & 4 \end{pmatrix}$  (if it exists)

**Solution:**

Let  $A = \begin{pmatrix} 1 & -1 & 2 \\ 0 & 2 & -3 \\ 3 & -2 & 4 \end{pmatrix}$

Then, expanding along  $C_1$ ,

$$|A| = 1(8-6) - 0 + 3(3-4) = 2-3 \\ = -1$$

Now,

$$\begin{array}{lll} A_{11} = 2 & A_{12} = -9 & A_{13} = -6 \\ A_{21} = 0 & A_{22} = -2 & A_{23} = -1 \\ A_{31} = -1 & A_{32} = 3 & A_{33} = 2 \end{array}$$

Therefore,

$$\text{adj}A = \begin{pmatrix} 2 & 0 & -1 \\ -9 & -2 & 3 \\ -6 & -1 & 2 \end{pmatrix}$$

Hence,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= -1 \begin{pmatrix} 2 & 0 & -1 \\ -9 & -2 & 3 \\ -6 & -1 & 2 \end{pmatrix} \\ &= \begin{pmatrix} -2 & 0 & 1 \\ 9 & 2 & -3 \\ 6 & 1 & -2 \end{pmatrix} \end{aligned}$$

### Question 11:

Find the inverse of each of the matrix  $\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & \sin \alpha \\ 0 & \sin \alpha & -\cos \alpha \end{pmatrix}$  (if it exists)

**Solution:**

$$\text{Let } A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & \sin \alpha \\ 0 & \sin \alpha & -\cos \alpha \end{pmatrix}$$

Then,

$$|A| = 1(-\cos^2 \alpha - \sin^2 \alpha) = -(\cos^2 \alpha + \sin^2 \alpha) \\ = -1$$

Now,

$$\begin{array}{lll}
A_{11} = -\cos^2 \alpha - \sin^2 \alpha = -1 & A_{12} = 0 & A_{13} = 0 \\
A_{21} = 0 & A_{22} = -\cos \alpha & A_{23} = -\sin \alpha \\
A_{31} = 0 & A_{32} = -\sin \alpha & A_{33} = \cos \alpha
\end{array}$$

Therefore,

$$adj A = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -\cos \alpha & -\sin \alpha \\ 0 & -\sin \alpha & \cos \alpha \end{pmatrix}$$

Hence,

$$\begin{aligned}
A^{-1} &= \frac{1}{|A|} adj A \\
&= -1 \begin{pmatrix} -1 & 0 & 0 \\ 0 & -\cos \alpha & -\sin \alpha \\ 0 & -\sin \alpha & \cos \alpha \end{pmatrix} \\
&= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & \sin \alpha \\ 0 & \sin \alpha & -\cos \alpha \end{pmatrix}
\end{aligned}$$

### Question 12:

Let  $A = \begin{pmatrix} 3 & 7 \\ 2 & 5 \end{pmatrix}$  and  $B = \begin{pmatrix} 6 & 8 \\ 7 & 9 \end{pmatrix}$ . Verify that  $(AB)^{-1} = B^{-1}A^{-1}$ .

### Solution:

Let  $A = \begin{pmatrix} 3 & 7 \\ 2 & 5 \end{pmatrix}$

Then,

$$\begin{aligned}
|A| &= 15 - 14 \\
&= 1
\end{aligned}$$

Now,

$$\begin{array}{ll}
A_{11} = 5 & A_{12} = -2 \\
A_{21} = -7 & A_{22} = 3
\end{array}$$

Then,

$$adj A = \begin{pmatrix} 5 & -7 \\ -2 & 3 \end{pmatrix}$$

Therefore,

$$\begin{aligned}A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= \begin{pmatrix} 5 & -7 \\ -2 & 3 \end{pmatrix}\end{aligned}$$

Now,

Let  $B = \begin{pmatrix} 6 & 8 \\ 7 & 9 \end{pmatrix}$

Then,

$$\begin{aligned}|B| &= 54 - 56 \\ &= -2\end{aligned}$$

Now,

$$\begin{aligned}A_{11} &= 9 & A_{12} &= -7 \\ A_{21} &= -8 & A_{22} &= 6\end{aligned}$$

Then,

$$\text{adj}B = \begin{pmatrix} 9 & -8 \\ -7 & 6 \end{pmatrix}$$

Therefore,

$$\begin{aligned}B^{-1} &= \frac{1}{|B|} \text{adj}B \\ &= -\frac{1}{2} \begin{pmatrix} 9 & -8 \\ -7 & 6 \end{pmatrix} \\ &= \begin{pmatrix} -\frac{9}{2} & 4 \\ \frac{7}{2} & -3 \end{pmatrix}\end{aligned}$$

Now,

$$\begin{aligned}
B^{-1}A^{-1} &= \begin{pmatrix} -\frac{9}{2} & 4 \\ \frac{7}{2} & -3 \end{pmatrix} \begin{pmatrix} 5 & -7 \\ -2 & 3 \end{pmatrix} \\
&= \begin{pmatrix} -\frac{45}{2}-8 & \frac{63}{2}+12 \\ \frac{35}{2}+6 & -\frac{49}{2}-9 \end{pmatrix} \\
&= \begin{pmatrix} -\frac{61}{2} & \frac{87}{2} \\ \frac{47}{2} & -\frac{67}{2} \end{pmatrix} \quad \dots(1)
\end{aligned}$$

Also,

$$\begin{aligned}
AB &= \begin{pmatrix} 3 & 7 \\ 2 & 5 \end{pmatrix} \begin{pmatrix} 6 & 8 \\ 7 & 9 \end{pmatrix} \\
&= \begin{pmatrix} 18+49 & 24+63 \\ 12+35 & 16+45 \end{pmatrix} \\
&= \begin{pmatrix} 67 & 87 \\ 47 & 61 \end{pmatrix}
\end{aligned}$$

Then, we have

$$\begin{aligned}
|AB| &= 67(61) - 87(47) \\
&= 4087 - 4089 \\
&= -2
\end{aligned}$$

Therefore,

$$adj(AB) = \begin{pmatrix} 61 & -87 \\ -47 & 67 \end{pmatrix}$$

Thus,

$$\begin{aligned}
(AB)^{-1} &= \frac{1}{|AB|} adj(AB) \\
&= -\frac{1}{2} \begin{pmatrix} 61 & -87 \\ -47 & 67 \end{pmatrix} \\
&= \begin{pmatrix} -\frac{61}{2} & \frac{87}{2} \\ \frac{47}{2} & -\frac{67}{2} \end{pmatrix} \quad \dots(2)
\end{aligned}$$

From (1) and (2),

$$(AB)^{-1} = B^{-1}A^{-1}$$

Hence, proved.

### Question 13:

If  $A = \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix}$ , show that  $A^2 - 5A + 7I = 0$ . Hence find  $A^{-1}$ .

### Solution:

Let  $A = \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix}$

Therefore,

$$\begin{aligned} A^2 &= A.A = \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix} \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix} \\ &= \begin{pmatrix} 9-1 & 3+2 \\ -3-2 & -1+4 \end{pmatrix} \\ &= \begin{pmatrix} 8 & 5 \\ -5 & 3 \end{pmatrix} \end{aligned}$$

Now,

$$\begin{aligned} A^2 - 5A + 7I &= \begin{pmatrix} 8 & 5 \\ -5 & 3 \end{pmatrix} - 5 \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix} + 7 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} 8 & 5 \\ -5 & 3 \end{pmatrix} - \begin{pmatrix} 15 & 5 \\ -5 & 10 \end{pmatrix} + \begin{pmatrix} 7 & 0 \\ 0 & 7 \end{pmatrix} \\ &= \begin{pmatrix} -7 & 0 \\ 0 & -7 \end{pmatrix} + \begin{pmatrix} 7 & 0 \\ 0 & 7 \end{pmatrix} \\ &= \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \end{aligned}$$

Hence,  $A^2 - 5A + 7I = 0$ .

Now,



$$\begin{aligned}
&\Rightarrow A.A - 5A = -7I \\
&\Rightarrow A.A(A^{-1}) - 5A.A^{-1} = -7IA^{-1} \quad \left[ \text{post-multiplying by } A^{-1} \text{ as } |A| \neq 0 \right] \\
&\Rightarrow A(AA^{-1}) - 5I = -7A^{-1} \\
&\Rightarrow AI - 5I = -7A^{-1} \\
&\Rightarrow A^{-1} = -\frac{1}{7}(A - 5I) \\
&\Rightarrow A^{-1} = \frac{1}{7}(5I - A) \\
&\Rightarrow A^{-1} = \frac{1}{7} \left[ \begin{pmatrix} 5 & 0 \\ 0 & 5 \end{pmatrix} - \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix} \right] \\
&\Rightarrow A^{-1} = \frac{1}{7} \begin{pmatrix} 2 & -1 \\ 1 & 3 \end{pmatrix}
\end{aligned}$$

Thus,

$$A^{-1} = \frac{1}{7} \begin{pmatrix} 2 & -1 \\ 1 & 3 \end{pmatrix}$$

#### Question 14:

For the matrix  $A = \begin{pmatrix} 3 & 2 \\ 1 & 1 \end{pmatrix}$ , find the numbers  $a$  and  $b$  such that  $A^2 + aA + bI = 0$ .

#### Solution:

Let  $A = \begin{pmatrix} 3 & 2 \\ 1 & 1 \end{pmatrix}$

Therefore,

$$\begin{aligned}
A^2 &= A.A = \begin{pmatrix} 3 & 2 \\ 1 & 1 \end{pmatrix} \begin{pmatrix} 3 & 2 \\ 1 & 1 \end{pmatrix} \\
&= \begin{pmatrix} 9+2 & 6+2 \\ 3+1 & 2+1 \end{pmatrix} = \begin{pmatrix} 11 & 8 \\ 4 & 3 \end{pmatrix}
\end{aligned}$$

Now,  $A^2 + aA + bI = 0$ .

Hence,

$$\begin{aligned}
&\Rightarrow (A.A)A^{-1} + aA.A^{-1} + bIA^{-1} = 0 && [\text{post-multiplying by } A^{-1} \text{ as } |A| \neq 0] \\
&\Rightarrow A(AA^{-1}) + aI + b(IA^{-1}) = 0 \\
&\Rightarrow AI + aI + bA^{-1} = 0 \\
&\Rightarrow A + aI = -bA^{-1} \\
&\Rightarrow A^{-1} = -\frac{1}{b}(A + aI) \quad \dots(1)
\end{aligned}$$

Now,

$$\begin{aligned}
A^{-1} &= \frac{1}{|A|} \text{adj}A \\
&= \frac{1}{1} \begin{pmatrix} 1 & -2 \\ -1 & 3 \end{pmatrix} \\
&= \begin{pmatrix} 1 & -2 \\ -1 & 3 \end{pmatrix} \quad \dots(2)
\end{aligned}$$

From (1) and (2), we have,

$$\begin{aligned}
&\Rightarrow \begin{pmatrix} 1 & -2 \\ -1 & 3 \end{pmatrix} = \frac{1}{b} \left[ \begin{pmatrix} 3 & 2 \\ 1 & 1 \end{pmatrix} + \begin{pmatrix} a & 0 \\ 0 & a \end{pmatrix} \right] \\
&\Rightarrow \begin{pmatrix} 1 & -2 \\ -1 & 3 \end{pmatrix} = -\frac{1}{b} \begin{pmatrix} 3+a & 2 \\ 1 & a \end{pmatrix} \\
&\Rightarrow \begin{pmatrix} 1 & -2 \\ -1 & 3 \end{pmatrix} = \begin{pmatrix} \frac{-3-a}{b} & -\frac{2}{b} \\ -\frac{1}{b} & \frac{-1-a}{b} \end{pmatrix}
\end{aligned}$$

Comparing the corresponding elements of the two matrices, we have:

$$\begin{aligned}
&\Rightarrow -\frac{1}{b} = -1 \\
&\Rightarrow b = 1
\end{aligned}$$

Also,

$$\Rightarrow \frac{-3-a}{b} = 1$$

$$\Rightarrow -3-a=1$$

$$\Rightarrow a = -4$$

Thus,  $a = -4$  and  $b = 1$ .

### Question 15:

$$A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix}$$

For the matrix  $A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix}$ , show that  $A^3 - 6A^2 + 5A + 11I = 0$ . Hence, find  $A^{-1}$ .

### Solution:

$$A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix}$$

Let

Therefore,

$$\begin{aligned} A^2 &= A.A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix} \\ &= \begin{pmatrix} 1+1+2 & 1+2-1 & 1-3+3 \\ 1+2-6 & 1+4+3 & 1-6-9 \\ 2-1+6 & 2-2-3 & 2+3+9 \end{pmatrix} = \begin{pmatrix} 4 & 2 & 1 \\ -3 & 8 & -14 \\ 7 & -3 & 14 \end{pmatrix} \end{aligned}$$

And,

$$\begin{aligned} A^3 &= A^2.A = \begin{pmatrix} 4 & 2 & 1 \\ -3 & 8 & -14 \\ 7 & -3 & 14 \end{pmatrix} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix} \\ &= \begin{pmatrix} 4+2+2 & 4+4-1 & 4-6+3 \\ -3+8-28 & -3+16+14 & -3-24-42 \\ 7-3+28 & 7-6-14 & 7+9+42 \end{pmatrix} = \begin{pmatrix} 8 & 7 & 1 \\ -23 & 27 & -69 \\ 32 & -13 & 58 \end{pmatrix} \end{aligned}$$

Hence,

$$\begin{aligned}
 A^3 - 6A^2 + 5A + 11I &= \begin{pmatrix} 8 & 7 & 1 \\ -23 & 27 & -69 \\ 32 & -13 & 58 \end{pmatrix} - 6 \begin{pmatrix} 4 & 2 & 1 \\ -3 & 8 & -14 \\ 7 & -3 & 14 \end{pmatrix} + 5 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix} + 11 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\
 &= \begin{pmatrix} 8 & 7 & 1 \\ -23 & 27 & -69 \\ 32 & -13 & 58 \end{pmatrix} - \begin{pmatrix} 24 & 12 & 6 \\ -18 & 48 & -84 \\ 42 & -18 & 84 \end{pmatrix} + \begin{pmatrix} 5 & 5 & 5 \\ 5 & 10 & -15 \\ 10 & -5 & 15 \end{pmatrix} + \begin{pmatrix} 11 & 0 & 0 \\ 0 & 11 & 0 \\ 0 & 0 & 11 \end{pmatrix} \\
 &= \begin{pmatrix} 24 & 12 & 6 \\ -18 & 48 & -84 \\ 42 & -18 & 84 \end{pmatrix} - \begin{pmatrix} 24 & 12 & 6 \\ -18 & 48 & -84 \\ 42 & -18 & 84 \end{pmatrix} \\
 &= \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \\
 &= 0
 \end{aligned}$$

Thus,  $A^3 - 6A^2 + 5A + 11I = 0$

Now,

$$\begin{aligned}
 &\Rightarrow A^3 - 6A^2 + 5A + 11I = 0 \\
 &\Rightarrow (AAA)A^{-1} - 6(AA)A^{-1} + 5AA^{-1} + 11IA^{-1} = 0 \quad \left[ \text{post-multiplying by } A^{-1} \text{ as } |A| \neq 0 \right] \\
 &\Rightarrow AA(AA^{-1}) - 6A(AA^{-1}) + 5(AA^{-1}) = -11(IA^{-1}) \\
 &\Rightarrow A^2 - 6A + 5I = -11A^{-1} \\
 &\Rightarrow A^{-1} = -\frac{1}{11}(A^2 - 6A + 5I) \quad \dots(1)
 \end{aligned}$$

Now,

$$\begin{aligned}
A^2 - 6A + 5I &= \begin{pmatrix} 4 & 2 & 1 \\ -3 & 8 & -14 \\ 7 & -3 & 14 \end{pmatrix} - 6 \begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & -3 \\ 2 & -1 & 3 \end{pmatrix} + 5 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\
&= \begin{pmatrix} 4 & 2 & 1 \\ -3 & 8 & -14 \\ 7 & -3 & 14 \end{pmatrix} - \begin{pmatrix} 6 & 6 & 6 \\ 6 & 12 & -18 \\ 12 & -6 & 18 \end{pmatrix} + \begin{pmatrix} 5 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 5 \end{pmatrix} \\
&= \begin{pmatrix} 9 & 2 & 1 \\ -3 & 13 & -14 \\ 7 & -3 & 19 \end{pmatrix} - \begin{pmatrix} 6 & 6 & 6 \\ 6 & 12 & -18 \\ 12 & -6 & 18 \end{pmatrix} \\
&= \begin{pmatrix} 3 & -4 & -5 \\ -9 & 1 & 4 \\ -5 & 3 & 1 \end{pmatrix} \quad \dots(2)
\end{aligned}$$

From equation (1) and (2)

$$\begin{aligned}
A^{-1} &= -\frac{1}{11} \begin{pmatrix} 3 & -4 & -5 \\ -9 & 1 & 4 \\ -5 & 3 & 1 \end{pmatrix} \\
&= \frac{1}{11} \begin{pmatrix} -3 & 4 & 5 \\ 9 & -1 & -4 \\ 5 & -3 & -1 \end{pmatrix}
\end{aligned}$$

### Question 16:

If  $A = \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix}$ , verify that  $A^3 - 6A^2 + 9A - 4I = 0$ . Hence, find  $A^{-1}$ .

### Solution:

$$A = \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix}$$

Let

Therefore,

$$\begin{aligned}
A^2 &= A.A \\
&= \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix} \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix} \\
&= \begin{pmatrix} 4+1+1 & -2-2-1 & 2+1+2 \\ -2-2-1 & 1+4+1 & -1-2-2 \\ 2+1+2 & -1-2-2 & 1+1+4 \end{pmatrix} \\
&= \begin{pmatrix} 6 & -5 & 5 \\ -5 & 6 & -5 \\ 5 & -5 & 6 \end{pmatrix}
\end{aligned}$$

And

$$\begin{aligned}
A^3 &= A^2.A \\
&= \begin{pmatrix} 6 & -5 & 5 \\ -5 & 6 & -5 \\ 5 & -5 & 6 \end{pmatrix} \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix} \\
&= \begin{pmatrix} 12+5+5 & -6-10-5 & 6+5+10 \\ -10-6-5 & 5+12+5 & -5-6-10 \\ 10+5+6 & -5-10-6 & 5+5+12 \end{pmatrix} \\
&= \begin{pmatrix} 22 & -21 & 21 \\ -21 & 22 & -21 \\ 21 & -21 & 22 \end{pmatrix}
\end{aligned}$$

Now,

$$\begin{aligned}
A^3 - 6A^2 + 9A - 4I &= \begin{pmatrix} 22 & -21 & 21 \\ -21 & 22 & -21 \\ 21 & -21 & 22 \end{pmatrix} - 6 \begin{pmatrix} 6 & -5 & 5 \\ -5 & 6 & -5 \\ 5 & -5 & 6 \end{pmatrix} + 9 \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix} - 4 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\
&= \begin{pmatrix} 22 & -21 & 21 \\ -21 & 22 & -21 \\ 21 & -21 & 22 \end{pmatrix} - \begin{pmatrix} 36 & -30 & 30 \\ -30 & 36 & -30 \\ 30 & -30 & 36 \end{pmatrix} + \begin{pmatrix} 18 & -9 & 9 \\ -9 & 18 & -9 \\ 9 & -9 & 18 \end{pmatrix} - \begin{pmatrix} 4 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 4 \end{pmatrix} \\
&= \begin{pmatrix} 40 & -30 & 30 \\ -30 & 40 & -30 \\ 30 & -30 & 40 \end{pmatrix} - \begin{pmatrix} 40 & -30 & 30 \\ -30 & 40 & -30 \\ 30 & -30 & 40 \end{pmatrix} \\
&= \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \\
&= 0
\end{aligned}$$

Thus,

$$A^3 - 6A^2 + 9A - 4I = 0$$

Now,

$$\Rightarrow A^3 - 6A^2 + 9A - 4I = 0$$

$$\Rightarrow (AAA)A^{-1} - 6(AA)A^{-1} + 9AA^{-1} - 4IA^{-1} = 0 \quad \left[ \text{post-multiplying by } A^{-1} \text{ as } |A| \neq 0 \right]$$

$$\Rightarrow AA(AA^{-1}) - 6A(AA^{-1}) + 9(AA^{-1}) = 4(AA^{-1})$$

$$\Rightarrow AAI - 6AI + 9I = 4A^{-1}$$

$$\Rightarrow A^2 - 6A + 9I = 4A^{-1}$$

$$\Rightarrow A^{-1} = \frac{1}{4}(A^2 - 6A + 9I) \quad \dots(1)$$

Now,

$$\begin{aligned} A^2 - 6A + 9I &= \begin{pmatrix} 6 & -5 & 5 \\ -5 & 6 & -5 \\ 5 & -5 & 6 \end{pmatrix} - 6 \begin{pmatrix} 2 & -1 & 1 \\ -1 & 2 & -1 \\ 1 & -1 & 2 \end{pmatrix} + 9 \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \\ &= \begin{pmatrix} 6 & -5 & 5 \\ -5 & 6 & -5 \\ 5 & -5 & 6 \end{pmatrix} - \begin{pmatrix} 12 & -6 & 6 \\ -6 & 12 & -6 \\ 6 & -6 & 12 \end{pmatrix} + \begin{pmatrix} 9 & 0 & 0 \\ 0 & 9 & 0 \\ 0 & 0 & 9 \end{pmatrix} \\ &= \begin{pmatrix} 3 & 1 & -1 \\ 1 & 3 & 1 \\ -1 & 1 & 3 \end{pmatrix} \quad \dots(2) \end{aligned}$$

From equations (1) and (2),

$$A^{-1} = \frac{1}{4} \begin{pmatrix} 3 & 1 & -1 \\ 1 & 3 & 1 \\ -1 & 1 & 3 \end{pmatrix}$$

### Question 17:

Let  $A$  be a non-singular square matrix of order  $3 \times 3$ . Then  $|adj A|$  is equal to:

- (A)  $|A|$       (B)  $|A|^2$       (C)  $|A|^3$       (D)  $3|A|$

### Solution:

Since  $A$  be a non-singular square matrix of order  $3 \times 3$

$$\begin{aligned}
 (\text{adj}A)A &= |A|I \\
 &= \begin{pmatrix} |A| & 0 & 0 \\ 0 & |A| & 0 \\ 0 & 0 & |A| \end{pmatrix}
 \end{aligned}$$

Therefore,

$$\begin{aligned}
 |(\text{adj}A)A| &= \begin{vmatrix} |A| & 0 & 0 \\ 0 & |A| & 0 \\ 0 & 0 & |A| \end{vmatrix} \\
 |\text{adj}A||A| &= |A|^3 \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} \\
 &= |A|^3 I \\
 |\text{adj}A| &= |A|^2
 \end{aligned}$$

Thus, the correct option is B.

### Question 18:

If  $A$  is an invertible matrix of order 2, the  $\det(A^{-1})$  is equal to:

- (A)  $\det(A)$       (B)  $\frac{1}{\det(A)}$       (C) 1      (D) 0

### Solution:

Since  $A$  is an invertible matrix,  $A^{-1}$  exists and  $A^{-1} = \frac{1}{|A|} \text{adj}A$ .

As matrix  $A$  is of order 2, let  $A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$



Then,

$$|A| = ad - bc$$

And

$$\text{adj}A = \begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$$

Now,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} \text{adj}A \\ &= \begin{pmatrix} \frac{d}{|A|} & \frac{-b}{|A|} \\ \frac{-c}{|A|} & \frac{a}{|A|} \end{pmatrix} \end{aligned}$$

Hence,

$$\begin{aligned} |A^{-1}| &= \begin{vmatrix} \frac{d}{|A|} & \frac{-b}{|A|} \\ \frac{-c}{|A|} & \frac{a}{|A|} \end{vmatrix} \\ |A^{-1}| &= \frac{1}{|A|^2} \begin{vmatrix} d & -b \\ -c & a \end{vmatrix} \\ &= \frac{1}{|A|^2} (ad - bc) \\ &= \frac{1}{|A|^2} \cdot |A| \\ &= \frac{1}{|A|} \end{aligned}$$

Hence,

$$\det(A^{-1}) = \frac{1}{\det(A)}$$

Thus, the correct option is B.

## **EXERCISE 4.6**

### **Question 1:**

Examine the consistency of the system of equations:

$$x + 2y = 2$$

$$2x + 3y = 3$$

### **Solution:**

$$x + 2y = 2$$

The given system of equations is:  $2x + 3y = 3$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 1 & 2 \\ 2 & 3 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 2 \\ 3 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 1(3) - 2(2) \\ &= 3 - 4 \\ &= -1 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Thus, the given system of equations is consistent.

### **Question 2:**

Examine the consistency of the system of equations:

$$2x - y = 5$$

$$x + y = 4$$

### **Solution:**

$$2x - y = 5$$

The given system of equations is:  $x + y = 4$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 2 & -1 \\ 1 & 1 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 5 \\ 4 \end{bmatrix}$$

Hence,

$$\begin{aligned}|A| &= 2(1) - 1(-1) \\ &= 2 + 1 \\ &= 3 \\ &\neq 0\end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Hence, the given system of equations is consistent.

### Question 3:

Examine the consistency of the system of equations:

$$x + 3y = 5$$

$$2x + 6y = 8$$

**Solution:**

$$x + 3y = 5$$

The given system of equations is:  $2x + 6y = 8$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 1 & 3 \\ 2 & 6 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 5 \\ 8 \end{bmatrix}$$

Hence,

$$\begin{aligned}|A| &= 1(6) - 3(2) \\ &= 6 - 6 \\ &= 0\end{aligned}$$

So,  $A$  is a singular matrix.

Now,

$$(adj A) = \begin{pmatrix} 6 & -3 \\ -2 & 1 \end{pmatrix}$$

Therefore,

$$\begin{aligned}
 (\text{adj}A)B &= \begin{pmatrix} 6 & -5 \\ -2 & 1 \end{pmatrix} \begin{bmatrix} 5 \\ 8 \end{bmatrix} \\
 &= \begin{pmatrix} 30-24 \\ -10+8 \end{pmatrix} \\
 &= \begin{bmatrix} 6 \\ -2 \end{bmatrix} \\
 &\neq 0
 \end{aligned}$$

Thus, the solution of the given system of equations does not exist.

Hence, the system of equations is inconsistent.

#### Question 4:

Examine the consistency of the system of equations:

$$x + y + z = 1$$

$$2x + 3y + 2z = 2$$

$$ax + ay + 2az = 4$$

#### Solution:

$$x + y + z = 1$$

$$2x + 3y + 2z = 2$$

The given system of equations is:  $ax + ay + 2az = 4$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 1 & 1 & 1 \\ 2 & 3 & 2 \\ a & a & 2a \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 \\ 2 \\ 4 \end{bmatrix}$$

Hence,

$$\begin{aligned}
 |A| &= 1(6a - 2a) - 1(4a - 2a) + 1(2a - 3a) \\
 &= 4a - 2a - a \\
 &= 4a - 3a \\
 &= a \neq 0
 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Thus, the given system of equations is consistent.

**Question 5:**

Examine the consistency of the system of equations:

$$3x - y - 2z = 2$$

$$2y - z = -1$$

$$3x - 5y = 3$$

**Solution:**

$$3x - y - 2z = 2$$

$$2y - z = -1$$

The given system of equations is:  $3x - 5y = 3$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 3 & -1 & -2 \\ 0 & 2 & -1 \\ 3 & -5 & 0 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 2 \\ -1 \\ 3 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 3(0-5) - 0 + 3(1+4) \\ &= -15 + 15 \\ &= 0 \end{aligned}$$

So,  $A$  is a singular matrix.

Now,

$$(adjA) = \begin{pmatrix} -5 & 10 & 5 \\ -3 & 6 & 3 \\ -6 & 12 & 6 \end{pmatrix}$$

Therefore,

$$\begin{aligned}
 (\text{adj}A)B &= \begin{pmatrix} -5 & 10 & 5 \\ -3 & 6 & 3 \\ -6 & 12 & 6 \end{pmatrix} \begin{bmatrix} 2 \\ -1 \\ 3 \end{bmatrix} \\
 &= \begin{bmatrix} -10 - 10 + 15 \\ -6 - 6 + 9 \\ -12 - 12 + 18 \end{bmatrix} \\
 &= \begin{bmatrix} -5 \\ -3 \\ -6 \end{bmatrix} \\
 &\neq 0
 \end{aligned}$$

Thus, the solution of the given system of equations does not exist.

Hence, the system of equations is inconsistent.

#### Question 6:

Examine the consistency of the system of equations:

$$5x - y + 4z = 5$$

$$2x + 3y + 5z = 2$$

$$5x - 2y + 6z = -1$$

#### Solution:

$$5x - y + 4z = 5$$

$$2x + 3y + 5z = 2$$

The given system of equations is:  $5x - 2y + 6z = -1$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 5 & -1 & 4 \\ 2 & 3 & 5 \\ 5 & -2 & 6 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 5 \\ 2 \\ -1 \end{bmatrix}$$

Hence,

$$\begin{aligned}
 |A| &= 5(18 + 10) + 1(12 - 25) + 4(-4 - 15) \\
 &= 5(28) + 1(-13) + 4(-19) \\
 &= 140 - 13 - 76 \\
 &= 51 \neq 0
 \end{aligned}$$

So,  $A$  is nonsingular.

Therefore,  $A^{-1}$  exists.

Hence, the given system of equations is consistent.

**Question 7:**

Solve system of linear equations, using matrix method.

$$5x + 2y = 4$$

$$7x + 3y = 5$$

**Solution:**

$$5x + 2y = 4$$

The given system of equations is:  $7x + 3y = 5$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 5 & 2 \\ 7 & 3 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 4 \\ 5 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 15 - 14 \\ &= 1 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj}A) \\ &= \begin{pmatrix} 3 & -2 \\ -7 & 5 \end{pmatrix} \end{aligned}$$

Then,

$$\begin{aligned}\Rightarrow X &= A^{-1}B \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{pmatrix} 3 & -2 \\ -7 & 5 \end{pmatrix} \begin{bmatrix} 4 \\ 5 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{bmatrix} 12-10 \\ -28+25 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{bmatrix} 2 \\ -3 \end{bmatrix}\end{aligned}$$

Hence,  $x = 2$  and  $y = -3$

### Question 8:

Solve system of linear equations, using matrix method.

$$2x - y = -2$$

$$3x + 4y = 3$$

**Solution:**

$$2x - y = -2$$

The given system of equations is:  $3x + 4y = 3$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 2 & -1 \\ 3 & 4 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} -2 \\ 3 \end{bmatrix}$$

Hence,

$$\begin{aligned}|A| &= 8 + 3 \\ &= 11 \\ &\neq 0\end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{aligned}A^{-1} &= \frac{1}{|A|}(\text{adj}A) \\ &= \frac{1}{11} \begin{pmatrix} 4 & 1 \\ -3 & 2 \end{pmatrix}\end{aligned}$$



Therefore,

$$\begin{aligned}\Rightarrow X &= A^{-1}B \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{pmatrix} 4 & 1 \\ -3 & 2 \end{pmatrix} \begin{bmatrix} -2 \\ 3 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{bmatrix} -8+3 \\ 6+6 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{bmatrix} -5 \\ 12 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{bmatrix} \frac{-5}{11} \\ \frac{12}{11} \end{bmatrix}\end{aligned}$$

Hence,  $x = \frac{-5}{11}$  and  $y = \frac{12}{11}$

### Question 9:

Solve system of linear equations, using matrix method.

$$4x - 3y = 3$$

$$3x - 5y = 7$$

**Solution:**

$$4x - 3y = 3$$

The given system of equations is:  $3x - 5y = 7$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 4 & -3 \\ 3 & -5 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 \\ 7 \end{bmatrix}$$

Hence,

$$\begin{aligned}|A| &= -20 + 9 \\ &= -11 \\ &\neq 0\end{aligned}$$

So,  $A$  is nonsingular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj}A) \\ &= -\frac{1}{11} \begin{pmatrix} -5 & 3 \\ -3 & 4 \end{pmatrix} = \frac{1}{11} \begin{pmatrix} 5 & -3 \\ 3 & -4 \end{pmatrix} \end{aligned}$$

Therefore,

$$\begin{aligned} \Rightarrow X &= A^{-1}B \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{pmatrix} 5 & -3 \\ 3 & -4 \end{pmatrix} \begin{bmatrix} 3 \\ 7 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{pmatrix} 5 & -3 \\ 3 & -4 \end{pmatrix} \begin{bmatrix} 3 \\ 7 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{bmatrix} 15 - 21 \\ 9 - 28 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{11} \begin{bmatrix} -6 \\ -19 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{bmatrix} \frac{-6}{11} \\ \frac{-19}{11} \end{bmatrix} \end{aligned}$$

Hence,  $x = \frac{-6}{11}$  and  $y = \frac{-19}{11}$

### Question 10:

Solve system of linear equations, using matrix method.

$$5x + 2y = 3$$

$$3x + 2y = 5$$

**Solution:**

$$5x + 2y = 3$$

The given system of equations is:  $3x + 2y = 5$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 5 & 2 \\ 3 & 2 \end{pmatrix}, X = \begin{bmatrix} x \\ y \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 \\ 5 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 10 - 6 \\ &= 4 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj} A) \\ &= \frac{1}{4} \begin{pmatrix} 2 & -2 \\ -3 & 5 \end{pmatrix} \end{aligned}$$

Therefore,

$$\begin{aligned} \Rightarrow X &= A^{-1} B \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{4} \begin{pmatrix} 2 & -2 \\ -3 & 5 \end{pmatrix} \begin{bmatrix} 3 \\ 5 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{4} \begin{pmatrix} 2 & -2 \\ -3 & 5 \end{pmatrix} \begin{bmatrix} 3 \\ 5 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{4} \begin{bmatrix} 6 - 10 \\ -9 + 25 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \frac{1}{4} \begin{bmatrix} -4 \\ 16 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \end{bmatrix} &= \begin{bmatrix} -1 \\ 4 \end{bmatrix} \end{aligned}$$

Hence,  $x = -1$  and  $y = 4$

### Question 11:

Solve system of linear equations, using matrix method.

$$2x + y + z = 1$$

$$x - 2y - z = \frac{3}{2}$$

$$3y - 5z = 9$$

**Solution:**

$$2x + y + z = 1$$

$$x - 2y - z = \frac{3}{2}$$

The given system of equations is:  $3y - 5z = 9$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 2 & 1 & 1 \\ 1 & -2 & -1 \\ 0 & 3 & -5 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 \\ \frac{3}{2} \\ 9 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 2(10 + 3) - 1(-5 - 3) + 0 \\ &= 2(13) - 1(-8) \\ &= 26 + 8 \\ &= 34 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll} A_{11} = 13 & A_{12} = 5 & A_{13} = 3 \\ A_{21} = 8 & A_{22} = -10 & A_{23} = -6 \\ A_{31} = 1 & A_{32} = 3 & A_{33} = -5 \end{array}$$

Hence,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj} A) \\ &= \frac{1}{34} \begin{pmatrix} 13 & 8 & 1 \\ 5 & -10 & 3 \\ 3 & -6 & -5 \end{pmatrix} \end{aligned}$$

Therefore,

$$\Rightarrow X = A^{-1}B$$

$$\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{34} \begin{pmatrix} 13 & 8 & 1 \\ 5 & -10 & 3 \\ 3 & -6 & -5 \end{pmatrix} \begin{bmatrix} 1 \\ \frac{3}{2} \\ 9 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{34} \begin{pmatrix} 13 & 8 & 1 \\ 5 & -10 & 3 \\ 3 & -6 & -5 \end{pmatrix} \begin{bmatrix} 1 \\ \frac{3}{2} \\ 9 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{34} \begin{bmatrix} 13+12+9 \\ 5-15+27 \\ 3-9-45 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{34} \begin{bmatrix} 34 \\ 17 \\ -51 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 \\ \frac{1}{2} \\ -\frac{3}{2} \end{bmatrix}$$

Hence,  $x=1, y=\frac{1}{2}$  and  $z=-\frac{3}{2}$

### Question 12:

Solve system of linear equations, using matrix method.

$$x - y + z = 4$$

$$2x + y - 3z = 0$$

$$x + y + z = 2$$

### Solution:

$$x - y + z = 4$$

$$2x + y - 3z = 0$$

The given system of equations is:  $x + y + z = 2$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 1 & -1 & 1 \\ 2 & 1 & -3 \\ 1 & 1 & 1 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 4 \\ 0 \\ 2 \end{bmatrix}$$

Hence,

$$\begin{aligned}|A| &= 1(1+3) + 1(2+3) + 1(2-1) \\ &= 4 + 5 + 1 \\ &= 10 \\ &\neq 0\end{aligned}$$

So,  $A$  is nonsingular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll}A_{11} = 4 & A_{12} = -5 & A_{13} = 1 \\ A_{21} = 2 & A_{22} = 0 & A_{23} = -2 \\ A_{31} = 2 & A_{32} = 5 & A_{33} = 3\end{array}$$

Hence,

$$\begin{aligned}A^{-1} &= \frac{1}{|A|}(\text{adj}A) \\ &= \frac{1}{10} \begin{pmatrix} 4 & 2 & 2 \\ -5 & 0 & 5 \\ 1 & -2 & 3 \end{pmatrix}\end{aligned}$$

Therefore,

$$\begin{aligned}\Rightarrow X &= A^{-1}B \\ \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{10} \begin{pmatrix} 4 & 2 & 2 \\ -5 & 0 & 5 \\ 1 & -2 & 3 \end{pmatrix} \begin{bmatrix} 4 \\ 0 \\ 2 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{10} \begin{pmatrix} 4 & 2 & 2 \\ -5 & 0 & 5 \\ 1 & -2 & 3 \end{pmatrix} \begin{bmatrix} 4 \\ 0 \\ 2 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{10} \begin{bmatrix} 16+0+4 \\ -20+0+10 \\ 4+0+6 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{10} \begin{bmatrix} 20 \\ -10 \\ 10 \end{bmatrix} \\ \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \begin{bmatrix} 2 \\ -1 \\ 1 \end{bmatrix}\end{aligned}$$

Hence,  $x=2, y=-1$  and  $z=1$

### Question 13:

Solve system of linear equations, using matrix method.

$$2x+3y+3z=5$$

$$x-2y+z=-4$$

$$3x-y-2z=3$$

**Solution:**

$$2x+3y+3z=5$$

$$x-2y+z=-4$$

The given system of equations is:  $3x-y-2z=3$

The given system of equations can be written in the form of  $AX=B$ , where

$$A = \begin{pmatrix} 2 & 3 & 3 \\ 1 & -2 & 1 \\ 3 & -1 & -2 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 5 \\ -4 \\ 3 \end{bmatrix}$$

Hence,

$$\begin{aligned}
 |A| &= 2(4+1) - 3(-2-3) + 3(-1+6) \\
 &= 10 + 15 + 15 \\
 &= 40 \\
 &\neq 0
 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll}
 A_{11} = 5 & A_{12} = 5 & A_{13} = 5 \\
 A_{21} = 3 & A_{22} = -13 & A_{23} = 11 \\
 A_{31} = 9 & A_{32} = 1 & A_{33} = -7
 \end{array}$$

Hence,

$$\begin{aligned}
 A^{-1} &= \frac{1}{|A|} (\text{adj}A) \\
 &= \frac{1}{40} \begin{pmatrix} 5 & 3 & 9 \\ 5 & -13 & 1 \\ 5 & 11 & -7 \end{pmatrix}
 \end{aligned}$$

Therefore,

$$\begin{aligned}
 &\Rightarrow X = A^{-1}B \\
 &\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{40} \begin{pmatrix} 5 & 3 & 9 \\ 5 & -13 & 1 \\ 5 & 11 & -7 \end{pmatrix} \begin{bmatrix} 5 \\ -4 \\ 3 \end{bmatrix} \\
 &\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{40} \begin{pmatrix} 5 & 3 & 9 \\ 5 & -13 & 1 \\ 5 & 11 & -7 \end{pmatrix} \begin{bmatrix} 5 \\ -4 \\ 3 \end{bmatrix} \\
 &\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{40} \begin{bmatrix} 25 - 12 + 27 \\ 25 + 52 + 3 \\ 25 - 44 - 21 \end{bmatrix} \\
 &\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{40} \begin{bmatrix} 40 \\ 80 \\ -40 \end{bmatrix} \\
 &\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ -1 \end{bmatrix}
 \end{aligned}$$



Hence,  $x = 1, y = 2$  and  $z = -1$

**Question 14:**

Solve system of linear equations, using matrix method.

$$x - y + 2z = 7$$

$$3x + 4y - 5z = -5$$

$$2x - y + 3z = 12$$

**Solution:**

$$x - y + 2z = 7$$

$$3x + 4y - 5z = -5$$

The given system of equations is:  $2x - y + 3z = 12$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 1 & -1 & 2 \\ 3 & 4 & -5 \\ 2 & -1 & 3 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 7 \\ -5 \\ 12 \end{bmatrix}$$

Hence,

$$\begin{aligned} |A| &= 1(12 - 5) + 1(9 + 10) + 2(-3 - 8) \\ &= 7 + 19 - 22 \\ &= 4 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll} A_{11} = 7 & A_{12} = -19 & A_{13} = -11 \\ A_{21} = 1 & A_{22} = -1 & A_{23} = -1 \\ A_{31} = -3 & A_{32} = 11 & A_{33} = 7 \end{array}$$

Hence,

$$\begin{aligned}
 A^{-1} &= \frac{1}{|A|}(\text{adj}A) \\
 &= \frac{1}{4} \begin{pmatrix} 7 & 1 & -3 \\ -19 & -1 & 11 \\ -11 & -1 & 7 \end{pmatrix}
 \end{aligned}$$

Therefore,

$$\begin{aligned}
 \Rightarrow X &= A^{-1}B \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{4} \begin{pmatrix} 7 & 1 & -3 \\ -19 & -1 & 11 \\ -11 & -1 & 7 \end{pmatrix} \begin{bmatrix} 7 \\ -5 \\ 12 \end{bmatrix} \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{4} \begin{pmatrix} 7 & 1 & -3 \\ -19 & -1 & 11 \\ -11 & -1 & 7 \end{pmatrix} \begin{bmatrix} 7 \\ -5 \\ 12 \end{bmatrix} \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{4} \begin{bmatrix} 49-5-36 \\ -133+5+132 \\ -77+5+84 \end{bmatrix} \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{4} \begin{bmatrix} 49-5-36 \\ -133+5+132 \\ -77+5+84 \end{bmatrix} \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \frac{1}{4} \begin{bmatrix} 8 \\ 4 \\ 12 \end{bmatrix} \\
 \Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} &= \begin{bmatrix} 2 \\ 1 \\ 3 \end{bmatrix}
 \end{aligned}$$

Hence,  $x = 2, y = 1$  and  $z = 3$

### Question 15:

$$A = \begin{pmatrix} 2 & -3 & 5 \\ 3 & 2 & -4 \\ 1 & 1 & -2 \end{pmatrix}$$

If  $\begin{pmatrix} 2 & -3 & 5 \\ 3 & 2 & -4 \\ 1 & 1 & -2 \end{pmatrix}$ , find  $A^{-1}$ . Using  $A^{-1}$  solve the system of equations

$$2x - 3y + 5z = 11$$

$$3x + 2y - 4z = -5$$

$$x + y - 2z = -3$$

**Solution:**

$$A = \begin{pmatrix} 2 & -3 & 5 \\ 3 & 2 & -4 \\ 1 & 1 & -2 \end{pmatrix}$$

It is given that

Therefore,

$$\begin{aligned} |A| &= 2(-4+4) + 3(-6+4) + 5(3-2) \\ &= 0 - 6 + 5 \\ &= -1 \\ &\neq 0 \end{aligned}$$

Now,

$$\begin{array}{lll} A_{11} = 0 & A_{12} = 2 & A_{13} = 1 \\ A_{21} = -1 & A_{22} = -9 & A_{23} = -5 \\ A_{31} = 2 & A_{32} = 23 & A_{33} = 13 \end{array}$$

Hence,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj}A) \\ &= - \begin{pmatrix} 0 & -1 & 2 \\ 2 & -9 & 23 \\ 1 & -5 & 13 \end{pmatrix} = \begin{pmatrix} 0 & 1 & -2 \\ -2 & 9 & -23 \\ -1 & 5 & -13 \end{pmatrix} \end{aligned}$$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 2 & -3 & 5 \\ 3 & 2 & -4 \\ 1 & 1 & -2 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 11 \\ -5 \\ -3 \end{bmatrix}$$

The solution of the system of equations is given by  $X = A^{-1}B$ .

Therefore,

$$\begin{aligned}
&\Rightarrow X = A^{-1}B \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{pmatrix} 0 & 1 & -2 \\ -2 & 9 & -23 \\ -1 & 5 & -13 \end{pmatrix} \begin{bmatrix} 11 \\ -5 \\ -3 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{pmatrix} 0 & 1 & -2 \\ -2 & 9 & -23 \\ -1 & 5 & -13 \end{pmatrix} \begin{bmatrix} 11 \\ -5 \\ -3 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0-5+6 \\ -22-45+69 \\ -11-25+39 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}
\end{aligned}$$

Hence,  $x = 1, y = 2$  and  $z = 3$

### Question 16:

The cost of 4 kg onion, 3 kg wheat and 2 kg rice is ₹60. The cost of 2 kg onion, 4 kg wheat and 6 kg rice is ₹90. The cost of 6 kg onion 2 kg wheat and 3 kg rice is ₹70. Find cost of each item per kg by matrix method.

### Solution:

Let the cost of onions, wheat, and rice per kg in ₹ be  $x, y$  and  $z$  respectively.

Then, the given situation can be represented by a system of equations as:

$$4x + 3y + 2z = 60$$

$$2x + 4y + 6z = 90$$

$$6x + 2y + 3z = 70$$

The given system of equations can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 4 & 3 & 2 \\ 2 & 4 & 6 \\ 6 & 2 & 3 \end{pmatrix}, X = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \text{ and } B = \begin{bmatrix} 60 \\ 90 \\ 70 \end{bmatrix}$$

Therefore,

$$\begin{aligned} |A| &= 4(12 - 12) - 3(6 - 36) + 2(4 - 24) \\ &= 0 + 90 - 40 \\ &= 50 \\ &\neq 0 \end{aligned}$$

So,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll} A_{11} = 0 & A_{12} = 30 & A_{13} = -20 \\ A_{21} = -5 & A_{22} = 0 & A_{23} = 10 \\ A_{31} = 10 & A_{32} = -20 & A_{33} = 10 \end{array}$$

Therefore,

$$\begin{aligned} A^{-1} &= \frac{1}{|A|} (\text{adj} A) \\ &= \frac{1}{50} \begin{pmatrix} 0 & -5 & 10 \\ 30 & 0 & -20 \\ -20 & 10 & 10 \end{pmatrix} \end{aligned}$$

Hence,

$$\begin{aligned}
&\Rightarrow X = A^{-1}B \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{50} \begin{pmatrix} 0 & -5 & 10 \\ 30 & 0 & -20 \\ -20 & 10 & 10 \end{pmatrix} \begin{bmatrix} 60 \\ 90 \\ 70 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{50} \begin{pmatrix} 0 & -5 & 10 \\ 30 & 0 & -20 \\ -20 & 10 & 10 \end{pmatrix} \begin{bmatrix} 60 \\ 90 \\ 70 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{50} \begin{bmatrix} 0 - 450 + 700 \\ 1800 + 0 - 1400 \\ -1200 + 900 + 700 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \frac{1}{50} \begin{bmatrix} 250 \\ 400 \\ 400 \end{bmatrix} \\
&\Rightarrow \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 5 \\ 8 \\ 8 \end{bmatrix}
\end{aligned}$$

Thus,  $x = 5, y = 8$  and  $z = 8$

Hence, the cost of onions is ₹ 5 per kg the cost of wheat is ₹ 8 per kg, and the cost of rice is ₹ 8 per kg.

## MISCELLANEOUS EXERCISE

### Question 1:

Prove that the determinant  $\begin{vmatrix} x & \sin \theta & \cos \theta \\ -\sin \theta & -x & 1 \\ \cos \theta & 1 & x \end{vmatrix}$  is independent of  $\theta$ .

### Solution:

$$\begin{aligned}\Delta &= \begin{vmatrix} x & \sin \theta & \cos \theta \\ -\sin \theta & -x & 1 \\ \cos \theta & 1 & x \end{vmatrix} \\ &= x(-x^2 - 1) - \sin \theta(-x \sin \theta - \cos \theta) + \cos \theta(-\sin \theta + x \cos \theta) \\ &= -x^3 - x + x \sin^2 \theta + \sin \theta \cos \theta - \sin \theta \cos \theta + x \cos^2 \theta \\ &= -x^3 - x + x(\sin^2 \theta + \cos^2 \theta) \\ &= -x^3 - x + x \\ &= -x^3\end{aligned}$$

Hence,  $\Delta$  is independent of  $\theta$ .

### Question 2:

Without expanding the determinant, prove that  $\begin{vmatrix} a & a^2 & bc \\ b & b^2 & ca \\ c & c^2 & ab \end{vmatrix} = \begin{vmatrix} 1 & a^2 & a^3 \\ 1 & b^2 & b^3 \\ 1 & c^2 & c^3 \end{vmatrix}$ .

**Solution:**

$$\begin{aligned}
 LHS &= \begin{vmatrix} a & a^2 & bc \\ b & b^2 & ca \\ c & c^2 & ab \end{vmatrix} \\
 &= \frac{1}{abc} \begin{vmatrix} a^2 & a^3 & abc \\ b^2 & b^3 & abc \\ c^2 & c^3 & abc \end{vmatrix} && [R_1 \rightarrow aR_1, R_2 \rightarrow bR_2, R_3 \rightarrow cR_3] \\
 &= \frac{1}{abc} \cdot abc \begin{vmatrix} a^2 & a^3 & 1 \\ b^2 & b^3 & 1 \\ c^2 & c^3 & 1 \end{vmatrix} && [\text{Taking out factor } abc \text{ from } C_3] \\
 &= \begin{vmatrix} a^2 & a^3 & 1 \\ b^2 & b^3 & 1 \\ c^2 & c^3 & 1 \end{vmatrix} \\
 &= \begin{vmatrix} 1 & a^2 & a^3 \\ 1 & b^2 & b^3 \\ 1 & c^2 & c^3 \end{vmatrix} && [C_1 \leftrightarrow C_3 \text{ and } C_2 \leftrightarrow C_3] \\
 &= RHS
 \end{aligned}$$

Hence, proved.

**Question 3:**

Evaluate  $\begin{vmatrix} \cos \alpha \cos \beta & \cos \alpha \sin \beta & -\sin \alpha \\ -\sin \beta & \cos \beta & 0 \\ \sin \alpha \cos \beta & \sin \alpha \sin \beta & \cos \alpha \end{vmatrix}.$

**Solution:**

Let  $\Delta = \begin{vmatrix} \cos \alpha \cos \beta & \cos \alpha \sin \beta & -\sin \alpha \\ -\sin \beta & \cos \beta & 0 \\ \sin \alpha \cos \beta & \sin \alpha \sin \beta & \cos \alpha \end{vmatrix}$

Expanding along  $C_3$ ,

$$\begin{aligned}
 \Delta &= -\sin \alpha (-\sin \alpha \sin^2 \beta - \cos^2 \beta \sin \alpha) + \cos \alpha (\cos \alpha \cos^2 \beta + \cos \alpha \sin^2 \beta) \\
 &= \sin^2 \alpha (\sin^2 \beta + \cos^2 \beta) + \cos^2 \alpha (\cos^2 \beta + \sin^2 \beta) \\
 &= \sin^2 \alpha (1) + \cos^2 \alpha (1) \\
 &= 1
 \end{aligned}$$



#### Question 4:

$$\Delta = \begin{vmatrix} b+c & c+a & a+b \\ c+a & a+b & b+c \\ a+b & b+c & c+a \end{vmatrix} = 0$$

If  $a, b, c$  are real numbers and  $\begin{vmatrix} b+c & c+a & a+b \\ c+a & a+b & b+c \\ a+b & b+c & c+a \end{vmatrix} = 0$ , show that either  $a+b+c=0$  or  $a=b=c$ .

#### Solution:

$$\begin{aligned} \Delta &= \begin{vmatrix} b+c & c+a & a+b \\ c+a & a+b & b+c \\ a+b & b+c & c+a \end{vmatrix} \\ &= \begin{vmatrix} 2(a+b+c) & 2(a+b+c) & 2(a+b+c) \\ c+a & a+b & b+c \\ a+b & b+c & c+a \end{vmatrix} & [R_1 \rightarrow R_1 + R_2 + R_3] \\ &= 2(a+b+c) \begin{vmatrix} 1 & 1 & 1 \\ c+a & a+b & b+c \\ a+b & b+c & c+a \end{vmatrix} \\ &= 2(a+b+c) \begin{vmatrix} 1 & 0 & 0 \\ c+a & b-c & b-a \\ a+b & c-a & c-b \end{vmatrix} & [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1] \end{aligned}$$

Expanding  $R_1$ ,

$$\begin{aligned} \Delta &= 2(a+b+c)(1)[(b-c)(c-b) - (b-a)(c-a)] \\ &= 2(a+b+c)[-b^2 - c^2 + 2bc - bc + ba + ac - a^2] \\ &= 2(a+b+c)[ab + bc + ca - a^2 - b^2 - c^2] \end{aligned}$$

It is given that  $\Delta = 0$ .

Hence,

$$2(a+b+c)[ab + bc + ca - a^2 - b^2 - c^2] = 0$$

Either  $(a+b+c)=0$  or  $[ab + bc + ca - a^2 - b^2 - c^2] = 0$

Now,

$$\begin{aligned}
&\Rightarrow ab + bc + ca - a^2 - b^2 - c^2 = 0 \\
&\Rightarrow -2ab - 2ac - 2ca + 2a^2 + 2b^2 + 2c^2 = 0 \\
&\Rightarrow (a-b)^2 + (b-c)^2 + (c-a)^2 = 0 \\
&\Rightarrow (a-b)^2 = (b-c)^2 = (c-a)^2 = 0 \quad \left[ (a-b)^2, (b-c)^2, (c-a)^2 \text{ are non-negative} \right] \\
&\Rightarrow (a-b) = (b-c) = (c-a) = 0 \\
&\Rightarrow a = b = c
\end{aligned}$$

Hence, if  $\Delta = 0$ , then either  $(a+b+c) = 0$  or  $a = b = c$ .

### Question 5:

Solve the equations 
$$\begin{vmatrix} x+a & x & x \\ x & x+a & x \\ x & x & x+a \end{vmatrix} = 0, a \neq 0$$
.

**Solution:**

$$\begin{aligned}
&\Rightarrow \begin{vmatrix} x+a & x & x \\ x & x+a & x \\ x & x & x+a \end{vmatrix} = 0 \\
&\Rightarrow \begin{vmatrix} 3x+a & 3x+a & 3x+a \\ x & x+a & x \\ x & x & x+a \end{vmatrix} = 0 \quad [R_1 \rightarrow R_1 + R_2 + R_3] \\
&\Rightarrow (3x+a) \begin{vmatrix} 1 & 1 & 1 \\ x & x+a & x \\ x & x & x+a \end{vmatrix} = 0 \\
&\Rightarrow (3x+a) \begin{vmatrix} 1 & 0 & 0 \\ x & a & 0 \\ x & 0 & a \end{vmatrix} = 0 \quad [C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1]
\end{aligned}$$

Expanding along  $R_1$ ,

$$\begin{aligned}
&\Rightarrow (3x+a) [1 \times a^2] = 0 \\
&\Rightarrow a^2 (3x+a) = 0
\end{aligned}$$

Since  $a \neq 0$

Therefore,

$$\Rightarrow 3x + a = 0$$

$$\Rightarrow x = -\frac{a}{3}$$

### Question 6:

Prove that  $\begin{vmatrix} a^2 & bc & ac+c^2 \\ a^2+ab & b^2 & ac \\ ab & b^2+bc & c^2 \end{vmatrix} = 4a^2b^2c^2$ .

### Solution:

$$\Delta = \begin{vmatrix} a^2 & bc & ac+c^2 \\ a^2+ab & b^2 & ac \\ ab & b^2+bc & c^2 \end{vmatrix}$$

$$= abc \begin{vmatrix} a & c & a+c \\ a+b & b & a \\ b & b+c & c \end{vmatrix}$$

[Taking out common factors  $a, b$  and  $c$  from  $C_1, C_2$  and  $C_3$ ]

$$= abc \begin{vmatrix} a & c & a+c \\ b & b-c & -c \\ b-a & b & -a \end{vmatrix}$$

[ $R_2 \rightarrow R_2 - R_1$  and  $R_3 \rightarrow R_3 - R_1$ ]

$$= abc \begin{vmatrix} a & c & a+c \\ a+b & b & a \\ b-a & b & -a \end{vmatrix}$$

[ $R_2 \rightarrow R_2 + R_1$ ]

$$= abc \begin{vmatrix} a & c & a+c \\ a+b & b & a \\ 2b & 2b & 0 \end{vmatrix}$$

[ $R_3 \rightarrow R_3 + R_2$ ]

$$= 2ab^2c \begin{vmatrix} a & c & a+c \\ a+b & b & a \\ 1 & 1 & 0 \end{vmatrix}$$

$$\Delta = 2ab^2c \begin{vmatrix} a & c-a & a+c \\ a+b & -a & a \\ 1 & 0 & 0 \end{vmatrix}$$

[ $C_2 \rightarrow C_2 - C_1$ ]

Expanding along  $R_3$ ,

$$\begin{aligned}
\Delta &= 2ab^2c[a(c-a) + a(a+c)] \\
&= 2ab^2c[ac - a^2 + a^2 + ac] \\
&= 2ab^2c(2ac) \\
&= 4a^2b^2c^2
\end{aligned}$$

Hence, proved.

### Question 7:

If  $A^{-1} = \begin{vmatrix} 3 & -1 & 1 \\ -15 & 6 & -5 \\ 5 & -2 & 2 \end{vmatrix}$  and  $B = \begin{vmatrix} 1 & 2 & -2 \\ -1 & 3 & 0 \\ 0 & -2 & 1 \end{vmatrix}$ , find  $(AB)^{-1}$ .

### Solution:

We know that  $(AB)^{-1} = B^{-1}A^{-1}$ .

$$B = \begin{vmatrix} 1 & 2 & -2 \\ -1 & 3 & 0 \\ 0 & -2 & 1 \end{vmatrix}$$

It is given that

Therefore,

$$\begin{aligned}
|B| &= 1(3) - 2(-1) - 2(-2) \\
&= 3 + 2 - 4 \\
&= 5 - 4 \\
&= 1
\end{aligned}$$

Now,

$$\begin{array}{lll}
B_{11} = 3 & B_{12} = 1 & B_{13} = 2 \\
B_{21} = 2 & B_{22} = 1 & B_{23} = 2 \\
B_{31} = 6 & B_{32} = 2 & B_{33} = 5
\end{array}$$

Hence,

$$adj B = \begin{pmatrix} 3 & 2 & 6 \\ 1 & 1 & 2 \\ 2 & 2 & 5 \end{pmatrix}$$

Now,

$$\begin{aligned}
B^{-1} &= \frac{1}{|B|} adj B \\
&= \begin{pmatrix} 3 & 2 & 6 \\ 1 & 1 & 2 \\ 2 & 2 & 5 \end{pmatrix}
\end{aligned}$$

Therefore,

$$\begin{aligned}(AB)^{-1} &= B^{-1}A^{-1} \\&= \begin{pmatrix} 3 & 2 & 6 \\ 1 & 1 & 2 \\ 2 & 2 & 5 \end{pmatrix} \begin{pmatrix} 3 & -1 & 1 \\ -15 & 6 & -5 \\ 5 & -2 & 2 \end{pmatrix} \\&= \begin{pmatrix} 9-30+30 & -3+12-12 & 3-10+12 \\ 3-15+10 & -1+6-4 & 1-5+4 \\ 6-30+25 & -2+12-10 & 2-10+10 \end{pmatrix} \\&= \begin{pmatrix} 9 & -3 & 5 \\ -2 & 1 & 0 \\ 1 & 0 & 2 \end{pmatrix}\end{aligned}$$

Thus,  $(AB)^{-1} = \begin{pmatrix} 9 & -3 & 5 \\ -2 & 1 & 0 \\ 1 & 0 & 2 \end{pmatrix}.$

### Question 8:

Let  $A = \begin{pmatrix} 1 & -2 & 1 \\ -2 & 3 & 1 \\ 1 & 1 & 5 \end{pmatrix}$  verify that

- (i)  $[adj A]^{-1} = adj(A)^{-1}$
- (ii)  $(A^{-1})^{-1} = A$

### Solution:

$$A = \begin{pmatrix} 1 & -2 & 1 \\ -2 & 3 & 1 \\ 1 & 1 & 5 \end{pmatrix}$$

It is given that  
Therefore,

$$\begin{aligned}|A| &= 1(15-1) + 2(-10-1) + 1(-2-3) \\&= 14 - 22 - 5 \\&= -13\end{aligned}$$

Now,

$$\begin{array}{lll}
A_{11} = 14 & A_{12} = 11 & A_{13} = -5 \\
A_{21} = 11 & A_{22} = 4 & A_{23} = -3 \\
A_{31} = -5 & A_{32} = -3 & A_{33} = -1
\end{array}$$

Hence,

$$adjA = \begin{pmatrix} 14 & 11 & -5 \\ 11 & 4 & -3 \\ -5 & -3 & -1 \end{pmatrix}$$

Now,

$$\begin{aligned}
A^{-1} &= \frac{1}{|A|} (adjA) \\
&= -\frac{1}{13} \begin{pmatrix} 14 & 11 & -5 \\ 11 & 4 & -3 \\ -5 & -3 & -1 \end{pmatrix} \\
&= \frac{1}{13} \begin{pmatrix} -14 & -11 & 5 \\ -11 & -4 & 3 \\ 5 & 3 & 1 \end{pmatrix}
\end{aligned}$$

(i)

$$\begin{aligned}
|adjA| &= 14(-4-9) - 11(-11-15) - 5(-33+20) \\
&= 14(-13) - 11(-26) - 5(-13) \\
&= -182 + 286 + 65 \\
&= 169
\end{aligned}$$

We have,

$$adj(adjA) = \begin{pmatrix} -13 & 26 & -13 \\ 26 & -39 & -13 \\ -13 & -13 & -65 \end{pmatrix}$$

Therefore,

$$\begin{aligned}
[adj A]^{-1} &= \frac{1}{|adj A|} (adj(adj A)) \\
&= \frac{1}{169} \begin{pmatrix} -13 & 26 & -13 \\ 26 & -39 & -13 \\ -13 & -13 & -65 \end{pmatrix} \\
&= \begin{pmatrix} \frac{-1}{13} & \frac{2}{13} & \frac{-1}{13} \\ \frac{2}{13} & \frac{-3}{13} & \frac{-1}{13} \\ \frac{-1}{13} & \frac{-1}{13} & \frac{-5}{13} \end{pmatrix}
\end{aligned}$$

Now,

$$A^{-1} = -\frac{1}{13} \begin{pmatrix} 14 & 11 & -5 \\ 11 & 4 & -3 \\ -5 & -3 & -1 \end{pmatrix} = \begin{pmatrix} \frac{-14}{13} & \frac{-11}{13} & \frac{5}{13} \\ \frac{-11}{13} & \frac{-4}{13} & \frac{3}{13} \\ \frac{5}{13} & \frac{3}{13} & \frac{1}{13} \end{pmatrix}$$

Therefore,

$$\begin{aligned} \text{adj}(A)^{-1} &= \begin{pmatrix} \frac{-13}{169} & \frac{26}{169} & \frac{-13}{169} \\ \frac{26}{169} & \frac{-39}{169} & \frac{-13}{169} \\ \frac{-13}{169} & \frac{-13}{169} & \frac{-65}{169} \end{pmatrix} \\ &= \begin{pmatrix} \frac{-1}{13} & \frac{2}{13} & \frac{-1}{13} \\ \frac{2}{13} & \frac{-3}{13} & \frac{-1}{13} \\ \frac{-1}{13} & \frac{-1}{13} & \frac{-5}{13} \end{pmatrix} \end{aligned}$$

Hence,  $[\text{adj}A]^{-1} = \text{adj}(A)^{-1}$  proved.

(ii)  $A^{-1} = \frac{1}{13} \begin{pmatrix} -14 & -11 & 5 \\ -11 & -4 & 3 \\ 5 & 3 & 1 \end{pmatrix}$

Hence,

$$\text{adj}(A)^{-1} = \begin{pmatrix} \frac{-1}{13} & \frac{2}{13} & \frac{-1}{13} \\ \frac{2}{13} & \frac{-3}{13} & \frac{-1}{13} \\ \frac{-1}{13} & \frac{-1}{13} & \frac{-5}{13} \end{pmatrix}$$

Now,

$$\begin{aligned} |A^{-1}| &= \left(\frac{1}{13}\right)^3 [-14(-4-9) + 11(-11-26) + 5(-33+20)] \\ &= \left(\frac{1}{13}\right)^3 [-169] \\ &= -\frac{1}{13} \end{aligned}$$

Therefore,



$$\begin{aligned}(A^{-1})^{-1} &= \frac{\text{adj}A^{-1}}{|A|} = \frac{1}{\left(-\frac{1}{13}\right)} \times \begin{pmatrix} \frac{-1}{13} & \frac{2}{13} & \frac{-1}{13} \\ \frac{2}{13} & \frac{-3}{13} & \frac{-1}{13} \\ \frac{-1}{13} & \frac{-1}{13} & \frac{-5}{13} \end{pmatrix} \\ &= \begin{pmatrix} 1 & -2 & 1 \\ -2 & 3 & 1 \\ 1 & 1 & 5 \end{pmatrix} = A\end{aligned}$$

Hence,  $(A^{-1})^{-1} = A$  proved.

### Question 9:

Evaluate  $\begin{vmatrix} x & y & x+y \\ y & x+y & x \\ x+y & x & y \end{vmatrix}$ .

### Solution:

$$\begin{aligned}\Delta &= \begin{vmatrix} x & y & x+y \\ y & x+y & x \\ x+y & x & y \end{vmatrix} \\ &= \begin{vmatrix} 2(x+y) & 2(x+y) & 2(x+y) \\ y & x+y & x \\ x+y & x & y \end{vmatrix}\end{aligned}$$

$$[R_1 \rightarrow R_1 + R_2 + R_3]$$

$$= 2(x+y) \begin{vmatrix} 1 & 1 & 1 \\ y & x+y & x \\ x+y & x & y \end{vmatrix}$$

$$= 2(x+y) \begin{vmatrix} 1 & 0 & 0 \\ y & x & x-y \\ x+y & -y & -x \end{vmatrix}$$

$$[C_2 \rightarrow C_2 - C_1 \text{ and } C_3 \rightarrow C_3 - C_1]$$

$$= 2(x+y) [-x^2 + y(x-y)]$$

$$[\text{Expanding along } R_1]$$

$$= -2(x+y)(x^2 + y^2 - yx)$$

$$= -2(x^3 + y^3)$$

**Question 10:**

Evaluate  $\begin{vmatrix} 1 & x & y \\ 1 & x+y & y \\ 1 & x & x+y \end{vmatrix}$ .

**Solution:**

$$\begin{aligned}
 \Delta &= \begin{vmatrix} 1 & x & y \\ 1 & x+y & y \\ 1 & x & x+y \end{vmatrix} \\
 &= \begin{vmatrix} 1 & x & y \\ 0 & y & 0 \\ 0 & 0 & x \end{vmatrix} && [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\
 &= 1(xy - 0) && [\text{Expanding along } C_1] \\
 &= xy
 \end{aligned}$$

**Question 11:**

Using properties of determinants prove that:

$$\begin{vmatrix} \alpha & \alpha^2 & \beta + \gamma \\ \beta & \beta^2 & \gamma + \alpha \\ \gamma & \gamma^2 & \alpha + \beta \end{vmatrix} = (\beta - \gamma)(\gamma - \alpha)(\alpha - \beta)(\alpha + \beta + \gamma)$$

**Solution:**

$$\begin{aligned}
 \Delta &= \begin{vmatrix} \alpha & \alpha^2 & \beta + \gamma \\ \beta & \beta^2 & \gamma + \alpha \\ \gamma & \gamma^2 & \alpha + \beta \end{vmatrix} \\
 &= \begin{vmatrix} \alpha & \alpha^2 & \beta + \gamma \\ \beta - \alpha & \beta^2 - \alpha^2 & \alpha - \beta \\ \gamma - \alpha & \gamma^2 - \alpha^2 & \alpha - \gamma \end{vmatrix} && [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\
 &= (\beta - \alpha)(\gamma - \alpha) \begin{vmatrix} \alpha & \alpha^2 & \beta + \gamma \\ 1 & \beta + \alpha & -1 \\ 1 & \gamma + \alpha & -1 \end{vmatrix} \\
 &= (\beta - \alpha)(\gamma - \alpha) \begin{vmatrix} \alpha & \alpha^2 & \beta + \gamma \\ 1 & \beta + \alpha & -1 \\ 0 & \gamma - \beta & 0 \end{vmatrix} && [R_3 \rightarrow R_3 - R_2] \\
 &= (\beta - \alpha)(\gamma - \alpha) [-(\gamma - \beta)(-\alpha - \beta - \gamma)] \\
 &= (\beta - \alpha)(\gamma - \alpha)(\gamma - \beta)(\alpha + \beta + \gamma) \\
 &= (\alpha - \beta)(\beta - \gamma)(\gamma - \alpha)(\alpha + \beta + \gamma) && [\text{Expanding along } R_3]
 \end{aligned}$$

Hence, proved.

### Question 12:

Using properties of determinants prove that:

$$\begin{vmatrix} x & x^2 & 1 + px^3 \\ y & y^2 & 1 + py^3 \\ z & z^2 & 1 + pz^3 \end{vmatrix} = (1 + pxyz)(x - y)(y - z)(z - x)$$

**Solution:**

$$\Delta = \begin{vmatrix} x & x^2 & 1+px^3 \\ y & y^2 & 1+py^3 \\ z & z^2 & 1+pz^3 \end{vmatrix}$$

$$\Delta = \begin{vmatrix} x & x^2 & 1+px^3 \\ y-x & y^2-x^2 & p(y^3-x^3) \\ z-x & z^2-x^2 & p(z^3-x^3) \end{vmatrix}$$

$$[R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1]$$

$$\Delta = (y-x)(z-x) \begin{vmatrix} x & x^2 & 1+px^3 \\ 1 & y+x & p(y^2+x^2+xy) \\ 1 & z+x & p(z^2+x^2+xz) \end{vmatrix}$$

$$\Delta = (y-x)(z-x) \begin{vmatrix} x & x^2 & 1+px^3 \\ 1 & y+x & p(y^2+x^2+xy) \\ 0 & z-y & p(z-y)(x+y+z) \end{vmatrix}$$

$$[R_3 \rightarrow R_3 - R_2]$$

$$\Delta = (y-x)(z-x)(z-y) \begin{vmatrix} x & x^2 & 1+px^3 \\ 1 & y+x & p(y^2+x^2+xy) \\ 0 & 1 & p(x+y+z) \end{vmatrix}$$

$$\begin{aligned} \Delta &= (x-y)(z-y)(z-x) \left[ (-1)(p)(xy^2+x^3+x^2y) + 1+px^3 + p(x+y+z)(xy) \right] \quad [\text{Expanding along } R_3] \\ &= (x-y)(y-z)(z-x) \left[ -pxy^2 - px^3 - px^2y + 1+px^3 + px^2y + pxy^2 + pxyz \right] \\ &= (x-y)(y-z)(z-x)(1+pxyz) \end{aligned}$$

Hence, proved.

### Question 13:

Using properties of determinants prove that:

$$\begin{vmatrix} 3a & -a+b & -a+c \\ -b+a & 3b & -b+c \\ -c+a & -c+b & 3c \end{vmatrix} = 3(a+b+c)(ab+bc+ca)$$

**Solution:**

$$\begin{aligned}\Delta &= \begin{vmatrix} 3a & -a+b & -a+c \\ -b+a & 3b & -b+c \\ -c+a & -c+b & 3c \end{vmatrix} \\ &= \begin{vmatrix} a+b+c & -a+b & -a+c \\ a+b+c & 3b & -b+c \\ a+b+c & -c+b & 3c \end{vmatrix} && [C_1 \rightarrow C_1 + C_2 + C_3] \\ &= (a+b+c) \begin{vmatrix} 1 & -a+b & -a+c \\ 1 & 3b & -b+c \\ 1 & -c+b & 3c \end{vmatrix} \\ &= (a+b+c) \begin{vmatrix} 1 & -a+b & -a+c \\ 0 & 2b+a & a-b \\ 0 & a-c & 2c+a \end{vmatrix} && [R_2 \rightarrow R_2 - R_1 \text{ and } R_3 \rightarrow R_3 - R_1] \\ &= (a+b+c) [(2b+a)(2c+a) - (a-b)(a-c)] && [\text{Expanding along } C_1] \\ &= (a+b+c) [4bc + 2ab + 2ac + a^2 - a^2 + ac + ba - bc] \\ &= (a+b+c)(3ab + 3bc + 3ac) \\ &= 3(a+b+c)(ab + bc + ca)\end{aligned}$$

Hence, proved.

**Question 14:**

Using properties of determinants prove that:

$$\begin{vmatrix} 1 & 1+p & 1+p+q \\ 2 & 3+2p & 4+3p+2q \\ 3 & 6+3p & 10+6p+3q \end{vmatrix} = 1$$

**Solution:**

$$\begin{aligned}
 \Delta &= \begin{vmatrix} 1 & 1+p & 1+p+q \\ 2 & 3+2p & 4+3p+2q \\ 3 & 6+3p & 10+6p+3q \end{vmatrix} \\
 &= \begin{vmatrix} 1 & 1+p & 1+p+q \\ 0 & 1 & 2+p \\ 0 & 3 & 7+3p \end{vmatrix} && [R_2 \rightarrow R_2 - 2R_1 \text{ and } R_3 \rightarrow R_3 - 3R_1] \\
 &= \begin{vmatrix} 1 & 1+p & 1+p+q \\ 0 & 1 & 2+p \\ 0 & 0 & 1 \end{vmatrix} && [R_3 \rightarrow R_3 - 3R_2] \\
 &= 1 \begin{vmatrix} 1 & 2+p \\ 0 & 1 \end{vmatrix} && [\text{Expanding along } C_1] \\
 &= 1(1-0) = 1
 \end{aligned}$$

Hence, proved.

### Question 15:

Using properties of determinants prove that:

$$\begin{vmatrix} \sin \alpha & \cos \alpha & \cos(\alpha + \delta) \\ \sin \beta & \cos \beta & \cos(\beta + \delta) \\ \sin \gamma & \cos \gamma & \cos(\gamma + \delta) \end{vmatrix} = 0$$

**Solution:**

$$\begin{aligned}
 \Delta &= \begin{vmatrix} \sin \alpha & \cos \alpha & \cos(\alpha + \delta) \\ \sin \beta & \cos \beta & \cos(\beta + \delta) \\ \sin \gamma & \cos \gamma & \cos(\gamma + \delta) \end{vmatrix} \\
 &= \frac{1}{\sin \delta \cos \delta} \begin{vmatrix} \sin \alpha \sin \delta & \cos \alpha \cos \delta & \cos \alpha \cos \delta - \sin \alpha \sin \delta \\ \sin \beta \sin \delta & \cos \beta \cos \delta & \cos \beta \cos \delta - \sin \beta \sin \delta \\ \sin \gamma \sin \delta & \cos \gamma \cos \delta & \cos \gamma \cos \delta - \sin \gamma \sin \delta \end{vmatrix} \\
 &= \frac{1}{\sin \delta \cos \delta} \begin{vmatrix} \cos \alpha \cos \delta & \cos \alpha \cos \delta & \cos \alpha \cos \delta - \sin \alpha \sin \delta \\ \cos \beta \cos \delta & \cos \beta \cos \delta & \cos \beta \cos \delta - \sin \beta \sin \delta \\ \cos \gamma \cos \delta & \cos \gamma \cos \delta & \cos \gamma \cos \delta - \sin \gamma \sin \delta \end{vmatrix} && [C_1 \rightarrow C_1 + C_3]
 \end{aligned}$$

Here, two columns  $C_1$  and  $C_2$  are identical.

Therefore,  $\Delta = 0$

Hence, proved.

**Question 16:**

Solve the system of the following equations:

$$\frac{2}{x} + \frac{3}{y} + \frac{10}{z} = 4$$

$$\frac{4}{x} - \frac{6}{y} + \frac{5}{z} = 1$$

$$\frac{6}{x} + \frac{9}{y} - \frac{20}{z} = 2$$

**Solution:**

Let  $\frac{1}{x} = p, \frac{1}{y} = q$  and  $\frac{1}{z} = r$ .

Then the given system of equations is as follows:

$$2p + 3q + 10r = 4$$

$$4p - 6q + 5r = 1$$

$$6p + 9q - 20r = 2$$

This system can be written in the form of  $AX = B$ , where

$$A = \begin{pmatrix} 2 & 3 & 10 \\ 4 & -6 & 5 \\ 6 & 9 & -20 \end{pmatrix}, X = \begin{bmatrix} p \\ q \\ r \end{bmatrix} \text{ and } B = \begin{bmatrix} 4 \\ 1 \\ 2 \end{bmatrix}$$

Therefore,

$$\begin{aligned} |A| &= 2(120 - 45) - 3(-80 - 30) + 10(36 + 36) \\ &= 150 + 330 + 720 \\ &= 1200 \end{aligned}$$

Thus,  $A$  is non-singular.

Therefore,  $A^{-1}$  exists.

Now,

$$\begin{array}{lll} A_{11} = 75 & A_{12} = 110 & A_{13} = 72 \\ A_{21} = 150 & A_{22} = -100 & A_{23} = 0 \\ A_{31} = 75 & A_{32} = 30 & A_{33} = -24 \end{array}$$

Hence,

$$A^{-1} = \frac{1}{|A|} (\text{adj}A)$$

$$= \frac{1}{1200} \begin{pmatrix} 75 & 150 & 75 \\ 110 & -100 & 30 \\ 72 & 0 & -24 \end{pmatrix}$$

Now,

$$\Rightarrow X = A^{-1}B$$

$$\Rightarrow \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \frac{1}{1200} \begin{pmatrix} 75 & 150 & 75 \\ 110 & -100 & 30 \\ 72 & 0 & -24 \end{pmatrix} \begin{bmatrix} 4 \\ 1 \\ 2 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \frac{1}{1200} \begin{bmatrix} 300 + 150 + 150 \\ 440 - 100 + 60 \\ 288 + 0 - 48 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \frac{1}{1200} \begin{bmatrix} 600 \\ 400 \\ 240 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \frac{1}{2} \\ \frac{1}{3} \\ \frac{1}{5} \end{bmatrix}$$

Therefore,

$$p = \frac{1}{2}, q = \frac{1}{3} \text{ and } r = \frac{1}{5}$$

Hence,  $x = 2, y = 3$  and  $z = 5$ .

### Question 17:

If  $a, b, c$  are in A.P, then the determinant  $\begin{vmatrix} x+2 & x+3 & x+2a \\ x+3 & x+4 & x+2b \\ x+4 & x+5 & x+2c \end{vmatrix}$  is

- (A) 0                      (B) 1                      (C)  $x$                       (D)  $2x$



**Solution:**

$$\begin{aligned}
 \Delta &= \begin{vmatrix} x+2 & x+3 & x+2a \\ x+3 & x+4 & x+2b \\ x+4 & x+5 & x+2c \end{vmatrix} \\
 &= \begin{vmatrix} x+2 & x+3 & x+2a \\ x+3 & x+4 & x+(a+c) \\ x+4 & x+5 & x+2c \end{vmatrix} && (2b = a+c \text{ as } a, b, c \text{ are in A.P}) \\
 &= \begin{vmatrix} -1 & -1 & a-c \\ x+3 & x+4 & x+(a+c) \\ 1 & 1 & c-a \end{vmatrix} && [R_1 \rightarrow R_1 - R_2 \text{ and } R_3 \rightarrow R_3 - R_2] \\
 &= \begin{vmatrix} 0 & 0 & 0 \\ x+3 & x+4 & x+a+c \\ 1 & 1 & c-a \end{vmatrix} && [R_1 \rightarrow R_1 + R_3]
 \end{aligned}$$

Here, all the elements of the first row are zero.

Hence, we have  $\Delta = 0$

Thus, the correct option is A.

**Question 18:**

If  $x, y, z$  are non-zero real numbers, then the inverse of matrix  $A = \begin{pmatrix} x & 0 & 0 \\ 0 & y & 0 \\ 0 & 0 & z \end{pmatrix}$  is

- (A)  $\begin{pmatrix} x^{-1} & 0 & 0 \\ 0 & y^{-1} & 0 \\ 0 & 0 & z^{-1} \end{pmatrix}$
- (B)  $xyz \begin{pmatrix} x^{-1} & 0 & 0 \\ 0 & y^{-1} & 0 \\ 0 & 0 & z^{-1} \end{pmatrix}$
- (C)  $\frac{1}{xyz} \begin{pmatrix} x & 0 & 0 \\ 0 & y & 0 \\ 0 & 0 & z \end{pmatrix}$
- (D)  $\frac{1}{xyz} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

**Solution:**

$$A = \begin{pmatrix} x & 0 & 0 \\ 0 & y & 0 \\ 0 & 0 & z \end{pmatrix}$$

It is given that

Hence,

$$\begin{aligned}
 |A| &= x(yz - 0) \\
 &= xyz \\
 &\neq 0
 \end{aligned}$$

Now,

$$\begin{array}{lll}
 A_{11} = yz & A_{12} = 0 & A_{13} = 0 \\
 A_{21} = 0 & A_{22} = xz & A_{23} = 0 \\
 A_{31} = 0 & A_{32} = 0 & A_{33} = xy
 \end{array}$$

Therefore,

$$\begin{aligned}
 A^{-1} &= \frac{1}{|A|} (\text{adj} A) \\
 &= \frac{1}{xyz} \begin{pmatrix} yz & 0 & 0 \\ 0 & xz & 0 \\ 0 & 0 & xy \end{pmatrix} \\
 &= \begin{pmatrix} \frac{yz}{xyz} & 0 & 0 \\ 0 & \frac{xz}{xyz} & 0 \\ 0 & 0 & \frac{xy}{xyz} \end{pmatrix} \\
 &= \begin{pmatrix} \frac{1}{x} & 0 & 0 \\ 0 & \frac{1}{y} & 0 \\ 0 & 0 & \frac{1}{z} \end{pmatrix} \\
 &= \begin{pmatrix} x^{-1} & 0 & 0 \\ 0 & y^{-1} & 0 \\ 0 & 0 & z^{-1} \end{pmatrix}
 \end{aligned}$$

Thus, the correct option is A.

### Question 19:

$$\text{Let } A = \begin{pmatrix} 1 & \sin \theta & 1 \\ -\sin \theta & 1 & \sin \theta \\ -1 & -\sin \theta & 1 \end{pmatrix}, \text{ where } 0 \leq \theta \leq 2\pi, \text{ then:}$$

$$(A) \text{ } \text{Det}(A) = 0$$

$$(B) \text{ } \text{Det}(A) \in (2, \infty)$$

$$(C) \operatorname{Det}(A) \in (2, 4)$$

$$(D) \operatorname{Det}(A) \in [2, 4]$$

**Solution:**

$$A = \begin{pmatrix} 1 & \sin \theta & 1 \\ -\sin \theta & 1 & \sin \theta \\ -1 & -\sin \theta & 1 \end{pmatrix}$$

It is given that

Hence,

$$\begin{aligned} |A| &= 1(1 + \sin^2 \theta) - \sin \theta(-\sin \theta + \sin \theta) + 1(\sin^2 \theta + 1) \\ &= 1 + \sin^2 \theta + \sin^2 \theta + 1 \\ &= 2 + 2\sin^2 \theta \\ &= 2(1 + \sin^2 \theta) \end{aligned}$$

Now,

$$\begin{aligned} &\Rightarrow 0 \leq \theta \leq 2\pi \\ &\Rightarrow -1 \leq \sin \theta \leq 1 \\ &\Rightarrow 0 \leq \sin^2 \theta \leq 1 \\ &\Rightarrow 1 \leq 1 + \sin^2 \theta \leq 2 \\ &\Rightarrow 2 \leq 2(1 + \sin^2 \theta) \leq 4 \end{aligned}$$

Therefore,

$$\operatorname{Det}(A) \in [2, 4]$$

Thus, the correct option is D.