

# Exercise 16:

## Foundations of Mathematical, WS24

Zichao Wei

This is **exercise** 16 for Foundations of Mathematical, WS24. Generated on 2025-03-10 with 10 problems per section.

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# 1. Problems

## 1.1. Vector Arithmetic

### 1.1.1. Addition

Find the sum of the following vectors  $\mathbf{u}$  and  $\mathbf{v}$

1.  $\mathbf{u} = \begin{bmatrix} 6 \\ 8 \\ 2 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -5 \\ -9 \\ -4 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
2.  $\mathbf{u} = \begin{bmatrix} 5 \\ -2 \\ -6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 7 \\ 3 \\ -9 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
3.  $\mathbf{u} = \begin{bmatrix} -1 \\ 2 \\ 9 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 7 \\ 7 \\ -9 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
4.  $\mathbf{u} = \begin{bmatrix} -2 \\ -3 \\ 6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 10 \\ 1 \\ -6 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
5.  $\mathbf{u} = \begin{bmatrix} 1 \\ -10 \\ -7 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 9 \\ 6 \\ 4 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
6.  $\mathbf{u} = \begin{bmatrix} 0 \\ 5 \\ -9 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 8 \\ -8 \\ 9 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
7.  $\mathbf{u} = \begin{bmatrix} 6 \\ -4 \\ -3 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 1 \\ 9 \\ 1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
8.  $\mathbf{u} = \begin{bmatrix} 4 \\ 4 \\ 2 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -9 \\ -9 \\ 8 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
9.  $\mathbf{u} = \begin{bmatrix} 1 \\ 5 \\ 0 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -9 \\ 2 \\ 5 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
10.  $\mathbf{u} = \begin{bmatrix} -7 \\ 5 \\ -1 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -5 \\ -10 \\ 8 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .

### 1.1.2. Subtraction

Find the difference of the following vectors  $\mathbf{u}$  and  $\mathbf{v}$

1.  $\mathbf{u} = \begin{bmatrix} -8 \\ -2 \\ -6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -7 \\ 9 \\ 0 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
2.  $\mathbf{u} = \begin{bmatrix} 7 \\ 1 \\ 5 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -10 \\ -8 \\ 4 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
3.  $\mathbf{u} = \begin{bmatrix} -4 \\ 3 \\ 6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 1 \\ 2 \\ 8 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
4.  $\mathbf{u} = \begin{bmatrix} -3 \\ 10 \\ -2 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -3 \\ 9 \\ -5 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
5.  $\mathbf{u} = \begin{bmatrix} 9 \\ 2 \\ 6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -5 \\ -3 \\ 0 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .

6.  $\mathbf{u} = \begin{bmatrix} 5 \\ -7 \\ 5 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -5 \\ 3 \\ -5 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
7.  $\mathbf{u} = \begin{bmatrix} 7 \\ -9 \\ -3 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 1 \\ 8 \\ 5 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
8.  $\mathbf{u} = \begin{bmatrix} 6 \\ 1 \\ -7 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -3 \\ -5 \\ 8 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
9.  $\mathbf{u} = \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -10 \\ 1 \\ -3 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .
10.  $\mathbf{u} = \begin{bmatrix} -4 \\ -1 \\ 10 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 5 \\ -7 \\ -3 \end{bmatrix}$   $\mathbf{u} - \mathbf{v}$ .

### 1.1.3. Scalar Multiplication

Find the scalar product of the following vector  $\mathbf{u}$  and scalar  $k$

1.  $\mathbf{u} = \begin{bmatrix} 3 \\ 2 \\ 9 \end{bmatrix} - 2\mathbf{v}$ .
2.  $\mathbf{u} = \begin{bmatrix} -8 \\ -8 \\ 9 \end{bmatrix} - 4\mathbf{v}$ .
3.  $\mathbf{u} = \begin{bmatrix} -8 \\ -4 \\ 2 \end{bmatrix} - 3\mathbf{v}$ .
4.  $\mathbf{u} = \begin{bmatrix} -5 \\ 6 \\ -3 \end{bmatrix} 3\mathbf{v}$ .
5.  $\mathbf{u} = \begin{bmatrix} -1 \\ 3 \\ 6 \end{bmatrix} 8\mathbf{v}$ .
6.  $\mathbf{u} = \begin{bmatrix} -1 \\ 10 \\ -10 \end{bmatrix} - 2\mathbf{v}$ .
7.  $\mathbf{u} = \begin{bmatrix} -9 \\ -5 \\ -3 \end{bmatrix} - 3\mathbf{v}$ .
8.  $\mathbf{u} = \begin{bmatrix} 3 \\ 8 \\ 9 \end{bmatrix} - 2\mathbf{v}$ .
9.  $\mathbf{u} = \begin{bmatrix} 0 \\ 6 \\ -9 \end{bmatrix} 1\mathbf{v}$ .
10.  $\mathbf{u} = \begin{bmatrix} 7 \\ 4 \\ 6 \end{bmatrix} 6\mathbf{v}$ .

## 1.2. Matrix Arithmetic

### 1.2.1. Addition

Find the sum of the following matrices  $A$  and  $B$

1. 
$$A = \begin{bmatrix} 9 & -10 & 8 \\ -8 & -2 & -6 \\ -1 & 5 & -2 \end{bmatrix} \quad (1)$$

and

$$B = \begin{bmatrix} 6 & -1 & 9 \\ 1 & 0 & -3 \\ 2 & -4 & 0 \end{bmatrix} \quad (2)$$

2. 
$$A = \begin{bmatrix} 0 & -1 & -7 \\ 4 & -1 & -2 \\ 7 & 7 & -8 \end{bmatrix} \quad (3)$$

and

$$B = \begin{bmatrix} 0 & 4 & -4 \\ -3 & -8 & 0 \\ -6 & -5 & 6 \end{bmatrix} \quad (4)$$

3. 
$$A = \begin{bmatrix} 1 & 9 & -4 \\ -9 & -8 & 9 \\ 4 & 6 & 3 \end{bmatrix} \quad (5)$$

and

$$B = \begin{bmatrix} 2 & 7 & 6 \\ -9 & 3 & -9 \\ -8 & 7 & -3 \end{bmatrix} \quad (6)$$

4. 
$$A = \begin{bmatrix} 9 & 4 & -3 \\ -9 & -8 & 4 \\ 6 & 5 & 0 \end{bmatrix} \quad (7)$$

and

$$B = \begin{bmatrix} 1 & -5 & 7 \\ 3 & 5 & 3 \\ 7 & 6 & -9 \end{bmatrix} \quad (8)$$

5. 
$$A = \begin{bmatrix} -9 & 1 & -1 \\ 3 & -2 & -5 \\ -1 & -10 & -8 \end{bmatrix} \quad (9)$$

and

$$B = \begin{bmatrix} -5 & 4 & 0 \\ -9 & 2 & -6 \\ 5 & 1 & 3 \end{bmatrix} \quad (10)$$

6. 
$$A = \begin{bmatrix} 9 & 1 & -1 \\ -3 & -3 & 0 \\ 5 & 0 & 8 \end{bmatrix} \quad (11)$$

and

$$B = \begin{bmatrix} -5 & 2 & 5 \\ -2 & 2 & 9 \\ -1 & -3 & 7 \end{bmatrix} \quad (12)$$

7.

$$A = \begin{bmatrix} -6 & -6 & 4 \\ -8 & 8 & 9 \\ -10 & -1 & 3 \end{bmatrix} \quad (13)$$

and

$$B = \begin{bmatrix} 1 & -10 & 4 \\ -1 & 2 & -1 \\ -8 & -8 & -9 \end{bmatrix} \quad (14)$$

8.

$$A = \begin{bmatrix} -10 & 1 & -9 \\ 9 & 8 & -5 \\ -10 & -7 & -10 \end{bmatrix} \quad (15)$$

and

$$B = \begin{bmatrix} -9 & -10 & -9 \\ 3 & 0 & -4 \\ -4 & 4 & 2 \end{bmatrix} \quad (16)$$

9.

$$A = \begin{bmatrix} 6 & 1 & -1 \\ 3 & -2 & -4 \\ -7 & 0 & 8 \end{bmatrix} \quad (17)$$

and

$$B = \begin{bmatrix} 8 & 3 & 0 \\ 7 & -9 & 5 \\ -10 & -10 & 1 \end{bmatrix} \quad (18)$$

10.

$$A = \begin{bmatrix} 6 & 1 & 3 \\ -2 & 7 & 0 \\ 5 & -5 & -10 \end{bmatrix} \quad (19)$$

and

$$B = \begin{bmatrix} 5 & 4 & 4 \\ -8 & -6 & -8 \\ 0 & -1 & -5 \end{bmatrix} \quad (20)$$

### 1.2.2. Subtraction

Find the difference of the following matrices  $A$  and  $B$

$$1. \quad A = \begin{bmatrix} 4 & 9 & 3 \\ 1 & -6 & 1 \\ -8 & -3 & 7 \end{bmatrix} \quad (21)$$

and

$$B = \begin{bmatrix} 6 & -1 & -6 \\ -2 & -9 & 6 \\ -1 & 3 & -8 \end{bmatrix} \quad (22)$$

$$2. \quad A = \begin{bmatrix} 4 & -8 & 6 \\ 0 & -4 & 2 \\ -1 & -7 & -4 \end{bmatrix} \quad (23)$$

and

$$B = \begin{bmatrix} 5 & -3 & 1 \\ -1 & -3 & -5 \\ -4 & -6 & -4 \end{bmatrix} \quad (24)$$

$$3. \quad A = \begin{bmatrix} -7 & 1 & -4 \\ 1 & -3 & -9 \\ -6 & -8 & -5 \end{bmatrix} \quad (25)$$

and

$$B = \begin{bmatrix} -7 & 1 & 4 \\ 3 & 6 & -10 \\ 6 & 6 & 7 \end{bmatrix} \quad (26)$$

$$4. \quad A = \begin{bmatrix} -8 & 3 & 7 \\ -5 & -2 & 9 \\ 8 & 6 & -1 \end{bmatrix} \quad (27)$$

and

$$B = \begin{bmatrix} 4 & -3 & -9 \\ 0 & 9 & -7 \\ -10 & -6 & -8 \end{bmatrix} \quad (28)$$

$$5. \quad A = \begin{bmatrix} -10 & -1 & 9 \\ 6 & -10 & -2 \\ -1 & -1 & -4 \end{bmatrix} \quad (29)$$

and

$$B = \begin{bmatrix} -4 & -7 & 4 \\ 5 & -7 & -8 \\ -2 & 8 & 7 \end{bmatrix} \quad (30)$$

$$6. \quad A = \begin{bmatrix} 2 & -6 & 7 \\ -10 & -7 & 4 \\ 9 & 8 & 1 \end{bmatrix} \quad (31)$$

and

$$B = \begin{bmatrix} 1 & 3 & -7 \\ 4 & -4 & -7 \\ 7 & -3 & 7 \end{bmatrix} \quad (32)$$

7.

$$A = \begin{bmatrix} 7 & 9 & -7 \\ 8 & 4 & -3 \\ 0 & -5 & -5 \end{bmatrix} \quad (33)$$

and

$$B = \begin{bmatrix} -2 & 1 & 9 \\ 6 & 8 & 9 \\ 1 & -4 & 4 \end{bmatrix} \quad (34)$$

8.

$$A = \begin{bmatrix} -2 & -10 & -6 \\ -7 & 8 & -8 \\ 9 & 9 & 2 \end{bmatrix} \quad (35)$$

and

$$B = \begin{bmatrix} -10 & -2 & -5 \\ -8 & 1 & 2 \\ -9 & -8 & 1 \end{bmatrix} \quad (36)$$

9.

$$A = \begin{bmatrix} 7 & -9 & 9 \\ -2 & -9 & -1 \\ 3 & 5 & 6 \end{bmatrix} \quad (37)$$

and

$$B = \begin{bmatrix} -3 & 3 & 6 \\ -7 & 1 & -6 \\ 1 & -5 & 6 \end{bmatrix} \quad (38)$$

10.

$$A = \begin{bmatrix} 0 & -5 & -6 \\ -9 & -7 & -8 \\ 0 & 3 & -9 \end{bmatrix} \quad (39)$$

and

$$B = \begin{bmatrix} 7 & 4 & -6 \\ -8 & -8 & 2 \\ -10 & 1 & 5 \end{bmatrix} \quad (40)$$

### 1.2.3. Multiplication

Find the product of the following matrices  $A$  and  $B$

$$1. \quad A = \begin{bmatrix} -7 & 3 & -10 \\ -4 & 8 & 5 \\ -6 & -2 & 3 \end{bmatrix} \quad (41)$$

and

$$B = \begin{bmatrix} -4 & 5 & -3 \\ 7 & 6 & 0 \\ 9 & 0 & 3 \end{bmatrix} \quad (42)$$

$$2. \quad A = \begin{bmatrix} 7 & 0 & -9 \\ -3 & -8 & 6 \\ -8 & -5 & -8 \end{bmatrix} \quad (43)$$

and

$$B = \begin{bmatrix} -7 & 2 & 8 \\ -6 & 3 & -6 \\ -9 & -4 & 2 \end{bmatrix} \quad (44)$$

$$3. \quad A = \begin{bmatrix} -7 & 3 & 5 \\ -8 & 2 & -10 \\ 7 & 0 & 6 \end{bmatrix} \quad (45)$$

and

$$B = \begin{bmatrix} -1 & 6 & -9 \\ -7 & 0 & 8 \\ -3 & 5 & 3 \end{bmatrix} \quad (46)$$

$$4. \quad A = \begin{bmatrix} 0 & -3 & 1 \\ -8 & 7 & -2 \\ -7 & -8 & -2 \end{bmatrix} \quad (47)$$

and

$$B = \begin{bmatrix} 4 & 7 & -7 \\ -10 & 2 & -1 \\ 0 & -8 & 9 \end{bmatrix} \quad (48)$$

$$5. \quad A = \begin{bmatrix} -5 & -8 & 3 \\ 9 & 0 & -8 \\ 6 & -8 & 8 \end{bmatrix} \quad (49)$$

and

$$B = \begin{bmatrix} -8 & -2 & -2 \\ -6 & 9 & -7 \\ 0 & -8 & 1 \end{bmatrix} \quad (50)$$

$$6. \quad A = \begin{bmatrix} 9 & 2 & 3 \\ -9 & 8 & -9 \\ -8 & 6 & 8 \end{bmatrix} \quad (51)$$



and

$$B = \begin{bmatrix} 8 & 6 & -5 \\ -6 & -4 & -8 \\ -9 & 7 & 0 \end{bmatrix} \quad (52)$$

7.

$$A = \begin{bmatrix} -2 & 2 & 9 \\ 8 & -8 & 4 \\ 4 & -9 & 0 \end{bmatrix} \quad (53)$$

and

$$B = \begin{bmatrix} 8 & 5 & 8 \\ 8 & 2 & 8 \\ -10 & 1 & -3 \end{bmatrix} \quad (54)$$

8.

$$A = \begin{bmatrix} 5 & -9 & -9 \\ -7 & -10 & -10 \\ 1 & 3 & -5 \end{bmatrix} \quad (55)$$

and

$$B = \begin{bmatrix} -8 & -7 & 6 \\ -1 & -5 & -6 \\ -6 & -6 & -3 \end{bmatrix} \quad (56)$$

9.

$$A = \begin{bmatrix} 1 & -10 & 3 \\ -8 & 6 & 8 \\ -1 & -3 & -1 \end{bmatrix} \quad (57)$$

and

$$B = \begin{bmatrix} 1 & -1 & 4 \\ -4 & -1 & 2 \\ 1 & -7 & -9 \end{bmatrix} \quad (58)$$

10.

$$A = \begin{bmatrix} -3 & 2 & -8 \\ 9 & -8 & -7 \\ 5 & -6 & 3 \end{bmatrix} \quad (59)$$

and

$$B = \begin{bmatrix} -2 & -1 & -8 \\ -1 & 6 & 8 \\ -1 & 2 & 2 \end{bmatrix} \quad (60)$$

## 1.3. Matrix Properties

### 1.3.1. Properties

For each matrix  $A$ , find:

a)  $\text{rank}(A)$

- b) nullity( $A$ )
- c)  $\det(A)$
- d)  $A^{-1}$  (if exists)
- e) basis of  $\ker(A)$

1. 
$$A = \begin{bmatrix} -1 & 1 & 0 \\ -6 & 7 & -1 \\ 2 & -2 & 0 \end{bmatrix} \quad (61)$$

2. 
$$A = \begin{bmatrix} 1 & 1 & -2 \\ -2 & -1 & 2 \\ 0 & -1 & 3 \end{bmatrix} \quad (62)$$

3. 
$$A = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & -2 \\ 1 & 1 & 0 \end{bmatrix} \quad (63)$$

4. 
$$A = \begin{bmatrix} 1 & -2 & -2 \\ -1 & 3 & 1 \\ 0 & 0 & 1 \end{bmatrix} \quad (64)$$

5. 
$$A = \begin{bmatrix} 5 & 12 & 0 \\ 2 & 5 & 0 \\ 2 & 4 & 1 \end{bmatrix} \quad (65)$$

6. 
$$A = \begin{bmatrix} 1 & -4 & 4 \\ 1 & -3 & 2 \\ 0 & -2 & 5 \end{bmatrix} \quad (66)$$

7. 
$$A = \begin{bmatrix} 1 & 0 & 2 \\ 0 & -1 & -1 \\ 0 & 2 & 2 \end{bmatrix} \quad (67)$$

8. 
$$A = \begin{bmatrix} 1 & 1 & 3 \\ 0 & 1 & 1 \\ 0 & -2 & -1 \end{bmatrix} \quad (68)$$

9. 
$$A = \begin{bmatrix} 1 & -1 & 1 \\ -2 & 3 & -1 \\ 1 & -1 & 1 \end{bmatrix} \quad (69)$$

10. 
$$A = \begin{bmatrix} -1 & 2 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix} \quad (70)$$

### 1.3.2. RREF

Find the Reduced Row Echelon Form of the following matrix  $A$

1. 
$$A = \begin{bmatrix} 1 & -2 & 4 \\ 0 & 1 & -2 \\ 0 & -2 & 4 \end{bmatrix} \quad (71)$$

$$2. \quad A = \begin{bmatrix} -3 & 4 & -2 \\ 0 & 1 & 0 \\ 2 & -2 & 1 \end{bmatrix} \quad (72)$$

$$3. \quad A = \begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & -2 & 0 \end{bmatrix} \quad (73)$$

$$4. \quad A = \begin{bmatrix} 1 & 3 & 2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (74)$$

$$5. \quad A = \begin{bmatrix} 1 & 3 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \quad (75)$$

$$6. \quad A = \begin{bmatrix} -3 & 5 & -4 \\ -2 & 3 & -2 \\ -2 & 2 & 0 \end{bmatrix} \quad (76)$$

$$7. \quad A = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 2 & -2 \\ 0 & 0 & 1 \end{bmatrix} \quad (77)$$

$$8. \quad A = \begin{bmatrix} 1 & 1 & -1 \\ 0 & 3 & -2 \\ 0 & -1 & 1 \end{bmatrix} \quad (78)$$

$$9. \quad A = \begin{bmatrix} 1 & -1 & 0 \\ 4 & -3 & 1 \\ 2 & -2 & 0 \end{bmatrix} \quad (79)$$

$$10. \quad A = \begin{bmatrix} 1 & 3 & -2 \\ 1 & 4 & -3 \\ 0 & 0 & 0 \end{bmatrix} \quad (80)$$

## 1.4. Calculus

### 1.4.1. Limit

Calculate the following limits

1. Calculate the limit of the following expression:

$$\lim_{x \rightarrow -2} x^2 + x + 5 \quad (81)$$

2. Calculate the limit of the following expression:

$$\lim_{x \rightarrow \infty} \left( 1 + \frac{1}{x} \right)^x \quad (82)$$

3. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (83)$$

4. Calculate the limit of the following expression:

$$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x \quad (84)$$

5. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (85)$$

6. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 1} \frac{x^2 - 1}{x - 1} \quad (86)$$

7. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 3} -4x^3 - 4x^2 - 3x - 1 \quad (87)$$

8. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 2} -2x^2 + 3x + 5 \quad (88)$$

9. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (89)$$

10. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 1} \frac{x^2 - 1}{x - 1} \quad (90)$$

### 1.4.2. Derivative

Calculate the derivatives of the following expressions

1. Calculate the derivative of the following expression:

$$\frac{x^3}{x^2 + 1} \quad (91)$$

2. Calculate the derivative of the following expression:

$$\frac{x^3}{x^2 + 1} \quad (92)$$

3. Calculate the derivative of the following expression:

$$\log(x+1) + \log(x^2 + 1) \quad (93)$$

4. Calculate the derivative of the following expression:

$$x^2 e^x \quad (94)$$

5. Calculate the derivative of the following expression:

$$\log(x+1) + \log(x^2+1) \quad (95)$$

6. Calculate the derivative of the following expression:

$$e^{2x} + e^{x^2} \quad (96)$$

7. Calculate the derivative of the following expression:

$$x e^x \quad (97)$$

8. Calculate the derivative of the following expression:

$$\frac{x^2}{x^2+1} \quad (98)$$

9. Calculate the derivative of the following expression:

$$x e^x \quad (99)$$

10. Calculate the derivative of the following expression:

$$e^{x^2-3} \quad (100)$$

### 1.4.3. Integral

Calculate the indefinite and definite integrals of the following expressions

1. the indefinite integral and evaluate from 1 to 5:

$$\int \frac{3x+2}{x^2-4} dx \quad (101)$$

2. the indefinite integral and evaluate from 3 to 5:

$$\int \frac{e^x}{x} dx \quad (102)$$

3. the indefinite integral and evaluate from 1 to 5:

$$\int \frac{1}{x \log(x)} dx \quad (103)$$

4. the indefinite integral and evaluate from 3 to 5:

$$\int \frac{1}{x \log(x)} dx \quad (104)$$

5. the indefinite integral and evaluate from 1 to 3:

$$\int e^{\sin(x)} \cos(x) dx \quad (105)$$

6. Evaluate the improper integral:

$$\int_1^{\infty} e^{-x} dx \quad (106)$$

7. the indefinite integral and evaluate from 1 to 3:

$$\int \frac{e^x}{x} dx \quad (107)$$

8. the indefinite integral and evaluate from 2 to 4:

$$\int 5x^2 + 4x - 3 dx \quad (108)$$

9. Evaluate the improper integral:

$$\int_1^{\infty} \frac{1}{\sqrt{x}} dx \quad (109)$$

10. Evaluate the improper integral:

$$\int_1^{\infty} \frac{1}{x^2} dx \quad (110)$$

#### 1.4.4. Partial Derivative

Calculate the partial derivatives of the following expressions

1. the mixed partial derivative of:

$$f(x, y) = x^3 y^2 + x y^4 \quad (111)$$

$$\frac{\partial^2 f}{\partial x \partial y}$$

2. the third order partial derivative of:

$$f(x, y) = x^4 y^3 + 3x^2 y^4 \quad (112)$$

$$\frac{\partial^3 f}{\partial y^3}$$

3. the partial derivatives of the function:

$$f(x, y) = x^3 y^2 - 3x^2 y + 2xy^3 \quad (113)$$

$$\frac{\partial f}{\partial x} \text{ and } \frac{\partial f}{\partial y}$$

4. Given  $u = u(x, y)$  and  $v = v(x, y)$ , use the chain rule to find:

$$\frac{\partial f}{\partial x} \quad (114)$$

where  $f = f(u, v)$

5. Given  $u = u(x, y)$  and  $v = v(x, y)$ , use the chain rule to find:

$$\frac{\partial f}{\partial x} \quad (115)$$

where  $f = f(u, v)$

6. the mixed partial derivative of:

$$f(x, y) = x^3y^2 + xy^4 \quad (116)$$

$$\frac{\partial^2 f}{\partial x \partial y}$$

7. the mixed partial derivative of:

$$f(x, y) = x^3y^2 + xy^4 \quad (117)$$

$$\frac{\partial^2 f}{\partial x \partial y}$$

8. Given  $u = u(x, y)$  and  $v = v(x, y)$ , use the chain rule to find:

$$\frac{\partial f}{\partial x} \quad (118)$$

where  $f = f(u, v)$

9. the second order partial derivative of:

$$f(x, y) = x^4y^3 + 3x^2y^4 \quad (119)$$

$$\frac{\partial^2 f}{\partial x^2}$$

10. the third order partial derivative of:

$$f(x, y) = x^4y^3 + 3x^2y^4 \quad (120)$$

$$\frac{\partial^3 f}{\partial y^3}$$

## 2. Solutions

### 2.1. Vector Arithmetic

#### 2.1.1. Addition

$$\begin{bmatrix} 1 \\ -1 \\ -2 \end{bmatrix} + \begin{bmatrix} 12 \\ 1 \\ -15 \end{bmatrix} + \begin{bmatrix} 6 \\ 9 \\ 0 \end{bmatrix} + \begin{bmatrix} 8 \\ -2 \\ 0 \end{bmatrix} + \begin{bmatrix} 10 \\ -4 \\ -3 \end{bmatrix}$$

$$\begin{bmatrix} 8 \\ -3 \\ 0 \end{bmatrix} + \begin{bmatrix} 7 \\ 5 \\ -2 \end{bmatrix} + \begin{bmatrix} -5 \\ -5 \\ 10 \end{bmatrix} + \begin{bmatrix} -8 \\ 7 \\ 5 \end{bmatrix} + \begin{bmatrix} -12 \\ -5 \\ 7 \end{bmatrix}$$

#### 2.1.2. Subtraction

$$\begin{bmatrix} -1 \\ -11 \\ -6 \end{bmatrix} - \begin{bmatrix} 17 \\ 9 \\ 1 \end{bmatrix} - \begin{bmatrix} -5 \\ 1 \\ -2 \end{bmatrix} - \begin{bmatrix} 0 \\ 1 \\ 3 \end{bmatrix} - \begin{bmatrix} 14 \\ 5 \\ 6 \end{bmatrix}$$

$$\begin{bmatrix} 10 \\ -10 \\ 10 \end{bmatrix} - \begin{bmatrix} 6 \\ -17 \\ -8 \end{bmatrix} - \begin{bmatrix} 9 \\ 6 \\ -15 \end{bmatrix} - \begin{bmatrix} 12 \\ -3 \\ 4 \end{bmatrix} - \begin{bmatrix} -9 \\ 6 \\ 13 \end{bmatrix}$$

#### 2.1.3. Scalar Multiplication

$$1: \begin{bmatrix} -6 \\ -4 \\ -18 \end{bmatrix} \quad 2: \begin{bmatrix} 32 \\ 32 \\ -36 \end{bmatrix} \quad 3: \begin{bmatrix} 24 \\ 12 \\ -6 \end{bmatrix} \quad 4: \begin{bmatrix} -15 \\ 18 \\ -9 \end{bmatrix} \quad 5: \begin{bmatrix} -8 \\ 24 \\ 48 \end{bmatrix}$$

$$6: \begin{bmatrix} 2 \\ -20 \\ 20 \end{bmatrix} \quad 7: \begin{bmatrix} 27 \\ 15 \\ 9 \end{bmatrix} \quad 8: \begin{bmatrix} -6 \\ -16 \\ -18 \end{bmatrix} \quad 9: \begin{bmatrix} 0 \\ 6 \\ -9 \end{bmatrix} \quad 10: \begin{bmatrix} 42 \\ 24 \\ 36 \end{bmatrix}$$

## 2.2. Matrix Arithmetic

### 2.2.1. Addition

1:

$$\begin{bmatrix} 15 & -11 & 17 \\ -7 & -2 & -9 \\ 1 & 1 & -2 \end{bmatrix} \quad (121)$$

1:

$$\begin{bmatrix} 0 & 3 & -11 \\ 1 & -9 & -2 \\ 1 & 2 & -2 \end{bmatrix} \quad (122)$$

1:

$$\begin{bmatrix} 3 & 16 & 2 \\ -18 & -5 & 0 \\ -4 & 13 & 0 \end{bmatrix} \quad (123)$$

1:

$$\begin{bmatrix} 10 & -1 & 4 \\ -6 & -3 & 7 \\ 13 & 11 & -9 \end{bmatrix} \quad (124)$$



1:

$$\begin{bmatrix} -14 & 5 & -1 \\ -6 & 0 & -11 \\ 4 & -9 & -5 \end{bmatrix} \quad (125)$$

1:

$$\begin{bmatrix} 4 & 3 & 4 \\ -5 & -1 & 9 \\ 4 & -3 & 15 \end{bmatrix} \quad (126)$$

1:

$$\begin{bmatrix} -5 & -16 & 8 \\ -9 & 10 & 8 \\ -18 & -9 & -6 \end{bmatrix} \quad (127)$$

1:

$$\begin{bmatrix} -19 & -9 & -18 \\ 12 & 8 & -9 \\ -14 & -3 & -8 \end{bmatrix} \quad (128)$$

1:

$$\begin{bmatrix} 14 & 4 & -1 \\ 10 & -11 & 1 \\ -17 & -10 & 9 \end{bmatrix} \quad (129)$$

1:

$$\begin{bmatrix} 11 & 5 & 7 \\ -10 & 1 & -8 \\ 5 & -6 & -15 \end{bmatrix} \quad (130)$$

### 2.2.2. Subtraction

1:

$$\begin{bmatrix} -2 & 10 & 9 \\ 3 & 3 & -5 \\ -7 & -6 & 15 \end{bmatrix} \quad (131)$$

1:

$$\begin{bmatrix} -1 & -5 & 5 \\ 1 & -1 & 7 \\ 3 & -1 & 0 \end{bmatrix} \quad (132)$$

1:

$$\begin{bmatrix} 0 & 0 & -8 \\ -2 & -9 & 1 \\ -12 & -14 & -12 \end{bmatrix} \quad (133)$$

1:

$$\begin{bmatrix} -12 & 6 & 16 \\ -5 & -11 & 16 \\ 18 & 12 & 7 \end{bmatrix} \quad (134)$$

1:

$$\begin{bmatrix} -6 & 6 & 5 \\ 1 & -3 & 6 \\ 1 & -9 & -11 \end{bmatrix} \quad (135)$$

1:

$$\begin{bmatrix} 1 & -9 & 14 \\ -14 & -3 & 11 \\ 2 & 11 & -6 \end{bmatrix} \quad (136)$$

1:

$$\begin{bmatrix} 9 & 8 & -16 \\ 2 & -4 & -12 \\ -1 & -1 & -9 \end{bmatrix} \quad (137)$$

1:

$$\begin{bmatrix} 8 & -8 & -1 \\ 1 & 7 & -10 \\ 18 & 17 & 1 \end{bmatrix} \quad (138)$$

1:

$$\begin{bmatrix} 10 & -12 & 3 \\ 5 & -10 & 5 \\ 2 & 10 & 0 \end{bmatrix} \quad (139)$$

1:

$$\begin{bmatrix} -7 & -9 & 0 \\ -1 & 1 & -10 \\ 10 & 2 & -14 \end{bmatrix} \quad (140)$$

### 2.2.3. Multiplication

1:

$$\begin{bmatrix} -41 & -17 & -9 \\ 117 & 28 & 27 \\ 37 & -42 & 27 \end{bmatrix} \quad (141)$$

1:

$$\begin{bmatrix} 32 & 50 & 38 \\ 15 & -54 & 36 \\ 158 & 1 & -50 \end{bmatrix} \quad (142)$$

1:

$$\begin{bmatrix} -29 & -17 & 102 \\ 24 & -98 & 58 \\ -25 & 72 & -45 \end{bmatrix} \quad (143)$$

1:

$$\begin{bmatrix} 30 & -14 & 12 \\ -102 & -26 & 31 \\ 52 & -49 & 39 \end{bmatrix} \quad (144)$$

1:

$$\begin{bmatrix} 88 & -86 & 69 \\ -72 & 46 & -26 \\ 0 & -148 & 52 \end{bmatrix} \quad (145)$$

1:

$$\begin{bmatrix} 33 & 67 & -61 \\ -39 & -149 & -19 \\ -172 & -16 & -8 \end{bmatrix} \quad (146)$$

1:

$$\begin{bmatrix} -90 & 3 & -27 \\ -40 & 28 & -12 \\ -40 & 2 & -40 \end{bmatrix} \quad (147)$$

1:

$$\begin{bmatrix} 23 & 64 & 111 \\ 126 & 159 & 48 \\ 19 & 8 & 3 \end{bmatrix} \quad (148)$$

1:

$$\begin{bmatrix} 44 & -12 & -43 \\ -24 & -54 & -92 \\ 10 & 11 & -1 \end{bmatrix} \quad (149)$$

1:

$$\begin{bmatrix} 12 & -1 & 24 \\ -3 & -71 & -150 \\ -7 & -35 & -82 \end{bmatrix} \quad (150)$$

## 2.3. Matrix Properties

### 2.3.1. Properties

#### Solution

#### Row Operations:

$$\text{Step 1: } r_1 := -1r_1 \quad \begin{bmatrix} 1 & -1 & 0 & | & -1 & 0 & 0 \\ -6 & 7 & -1 & | & 0 & 1 & 0 \\ 2 & -2 & 0 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 2: } r_2 := r_2 - (-6)r_1 \quad \begin{bmatrix} 1 & -1 & 0 & | & -1 & 0 & 0 \\ 0 & 1 & -1 & | & -6 & 1 & 0 \\ 2 & -2 & 0 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 3: } r_3 := r_3 - (2)r_1 \quad \begin{bmatrix} 1 & -1 & 0 & | & -1 & 0 & 0 \\ 0 & 1 & -1 & | & -6 & 1 & 0 \\ 0 & 0 & 0 & | & 2 & 0 & 1 \end{bmatrix}$$

$$\text{Step 4: } r_1 := r_1 - (-1)r_2 \quad \begin{bmatrix} 1 & 0 & -1 & | & -7 & 1 & 0 \\ 0 & 1 & -1 & | & -6 & 1 & 0 \\ 0 & 0 & 0 & | & 2 & 0 & 1 \end{bmatrix}$$

#### Results:

a)  $\text{rank}(A) = 2$

b)  $\text{nullity}(A) = 1$

c)  $\det(A) = 0$

d)  $A^{-1}$  = does not exist

e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \right\}$

#### Solution

#### Row Operations:

$$\text{Step 1: } r_2 := r_2 - (-2)r_1 \quad \begin{bmatrix} 1 & 1 & -2 & | & 1 & 0 & 0 \\ 0 & 1 & -2 & | & 2 & 1 & 0 \\ 0 & -1 & 3 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 2: } r_1 := r_1 - r_2 \quad \begin{bmatrix} 1 & 0 & 0 & | & -1 & -1 & 0 \\ 0 & 1 & -2 & | & 2 & 1 & 0 \\ 0 & -1 & 3 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 3: } r_3 := r_3 - (-1)r_2 \quad \begin{bmatrix} 1 & 0 & 0 & | & -1 & -1 & 0 \\ 0 & 1 & -2 & | & 2 & 1 & 0 \\ 0 & 0 & 1 & | & 2 & 1 & 1 \end{bmatrix}$$

$$\text{Step 4: } r_2 := r_2 - (-2)r_3 \quad \begin{bmatrix} 1 & 0 & 0 & | & -1 & -1 & 0 \\ 0 & 1 & 0 & | & 6 & 3 & 2 \\ 0 & 0 & 1 & | & 2 & 1 & 1 \end{bmatrix}$$

#### Results:

- a)  $\text{rank}(A) = 3$
- b)  $\text{nullity}(A) = 0$
- c)  $\det(A) = 0$
- d)  $A^{-1} = \begin{bmatrix} -3 & -2 & 0 \\ 2 & 1 & 0 \\ 2 & 1 & 1 \end{bmatrix}$
- e)  $\ker(A) = \{\mathbf{0}\}$

**Solution**

**Row Operations:**

$$\text{Step 1: } r_3 := r_3 - r_1 \quad \left[ \begin{array}{ccc|ccc} 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & -2 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_1 := r_1 - r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 1 & -1 & 0 \\ 0 & 1 & -2 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \end{array} \right]$$

**Results:**

- a)  $\text{rank}(A) = 2$
- b)  $\text{nullity}(A) = 1$
- c)  $\det(A) = 0$
- d)  $A^{-1} =$  does not exist
- e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} -2 \\ 2 \\ 1 \end{bmatrix} \right\}$

**Solution**

**Row Operations:**

$$\text{Step 1: } r_2 := r_2 - (-1)r_1 \quad \left[ \begin{array}{ccc|ccc} 1 & -2 & -2 & 1 & 0 & 0 \\ 0 & 1 & -1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_1 := r_1 - (-2)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & -4 & 3 & 2 & 0 \\ 0 & 1 & -1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 3: } r_1 := r_1 - (-4)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 3 & 2 & 4 \\ 0 & 1 & -1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 4: } r_2 := r_2 - (-1)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 3 & 2 & 4 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{array} \right]$$

**Results:**

- a)  $\text{rank}(A) = 3$
- b)  $\text{nullity}(A) = 0$

c)  $\det(A) = 0$

d)  $A^{-1} = \begin{bmatrix} 1 & 0 & 2 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

e)  $\ker(A) = \{\mathbf{0}\}$

### Solution

#### Row Operations:

Step 1:  $r_1 := 1/5r_1$   $\left[ \begin{array}{ccc|ccc} 1 & 12/5 & 0 & 1/5 & 0 & 0 \\ 2 & 5 & 0 & 0 & 1 & 0 \\ 2 & 4 & 1 & 0 & 0 & 1 \end{array} \right]$

Step 2:  $r_2 := r_2 - (2)r_1$   $\left[ \begin{array}{ccc|ccc} 1 & 12/5 & 0 & 1/5 & 0 & 0 \\ 0 & 1/5 & 0 & -2/5 & 1 & 0 \\ 2 & 4 & 1 & 0 & 0 & 1 \end{array} \right]$

Step 3:  $r_3 := r_3 - (2)r_1$   $\left[ \begin{array}{ccc|ccc} 1 & 12/5 & 0 & 1/5 & 0 & 0 \\ 0 & 1/5 & 0 & -2/5 & 1 & 0 \\ 0 & -4/5 & 1 & -2/5 & 0 & 1 \end{array} \right]$

Step 4:  $r_2 := 5r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 12/5 & 0 & 1/5 & 0 & 0 \\ 0 & 1 & 0 & -2 & 5 & 0 \\ 0 & -4/5 & 1 & -2/5 & 0 & 1 \end{array} \right]$

Step 5:  $r_1 := r_1 - (12/5)r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 5 & -12 & 0 \\ 0 & 1 & 0 & -2 & 5 & 0 \\ 0 & -4/5 & 1 & -2/5 & 0 & 1 \end{array} \right]$

Step 6:  $r_3 := r_3 - (-4/5)r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 5 & -12 & 0 \\ 0 & 1 & 0 & -2 & 5 & 0 \\ 0 & 0 & 1 & -2 & 4 & 1 \end{array} \right]$

### Results:

a)  $\text{rank}(A) = 3$

b)  $\text{nullity}(A) = 0$

c)  $\det(A) = 0$

d)  $A^{-1} = \begin{bmatrix} 1 & -2 & 0 \\ 2 & -3 & -2 \\ -2 & 4 & 0 \end{bmatrix}$

e)  $\ker(A) = \{\mathbf{0}\}$

### Solution

#### Row Operations:

Step 1:  $r_2 := r_2 - r_1$   $\left[ \begin{array}{ccc|ccc} 1 & -4 & 4 & 1 & 0 & 0 \\ 0 & 1 & -2 & -1 & 1 & 0 \\ 0 & -2 & 5 & 0 & 0 & 1 \end{array} \right]$

Step 2:  $r_1 := r_1 - (-4)r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & -4 & -3 & 4 & 0 \\ 0 & 1 & -2 & -1 & 1 & 0 \\ 0 & -2 & 5 & 0 & 0 & 1 \end{array} \right]$

$$\text{Step 3: } r_3 := r_3 - (-2)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & -4 & -3 & 4 & 0 \\ 0 & 1 & -2 & -1 & 1 & 0 \\ 0 & 0 & 1 & -2 & 2 & 1 \end{array} \right]$$

$$\text{Step 4: } r_1 := r_1 - (-4)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & -11 & 12 & 4 \\ 0 & 1 & -2 & -1 & 1 & 0 \\ 0 & 0 & 1 & -2 & 2 & 1 \end{array} \right]$$

$$\text{Step 5: } r_2 := r_2 - (-2)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & -11 & 12 & 4 \\ 0 & 1 & 0 & -5 & 5 & 2 \\ 0 & 0 & 1 & -2 & 2 & 1 \end{array} \right]$$

### Results:

a)  $\text{rank}(A) = 3$

b)  $\text{nullity}(A) = 0$

c)  $\det(A) = 0$

d)  $A^{-1} = \begin{bmatrix} 3 & -2 & -2 \\ -1 & 1 & 0 \\ -2 & 2 & 1 \end{bmatrix}$

e)  $\ker(A) = \{\mathbf{0}\}$

### Solution

#### Row Operations:

$$\text{Step 1: } r_2 := -1r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & -1 & 0 \\ 0 & 2 & 2 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_3 := r_3 - (2)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 2 & 1 \end{array} \right]$$

### Results:

a)  $\text{rank}(A) = 2$

b)  $\text{nullity}(A) = 1$

c)  $\det(A) = 0$

d)  $A^{-1}$  = does not exist

e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} -2 \\ -1 \\ 1 \end{bmatrix} \right\}$

### Solution

#### Row Operations:

$$\text{Step 1: } r_1 := r_1 - r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 1 & -1 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & -2 & -1 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_3 := r_3 - (-2)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 1 & -1 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 2 & 1 \end{array} \right]$$

$$\text{Step 3: } r_1 := r_1 - (2)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 1 & -5 & -2 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 2 & 1 \end{array} \right]$$

$$\text{Step 4: } r_2 := r_2 - r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 1 & -5 & -2 \\ 0 & 1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & 0 & 2 & 1 \end{array} \right]$$

**Results:**

a)  $\text{rank}(A) = 3$

b)  $\text{nullity}(A) = 0$

c)  $\det(A) = 0$

d)  $A^{-1} = \begin{bmatrix} 1 & -2 & 0 \\ 0 & 3 & 1 \\ 0 & 2 & 1 \end{bmatrix}$

e)  $\ker(A) = \{\mathbf{0}\}$

**Solution**

**Row Operations:**

$$\text{Step 1: } r_2 := r_2 - (-2)r_1 \quad \left[ \begin{array}{ccc|ccc} 1 & -1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 2 & 1 & 0 \\ 1 & -1 & 1 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_3 := r_3 - r_1 \quad \left[ \begin{array}{ccc|ccc} 1 & -1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 2 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \end{array} \right]$$

$$\text{Step 3: } r_1 := r_1 - (-1)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & 3 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \end{array} \right]$$

**Results:**

a)  $\text{rank}(A) = 2$

b)  $\text{nullity}(A) = 1$

c)  $\det(A) = 0$

d)  $A^{-1} = \text{does not exist}$

e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} -1 \\ -1 \\ 1 \end{bmatrix} \right\}$

**Solution**

**Row Operations:**

$$\text{Step 1: } r_1 := -1r_1 \quad \left[ \begin{array}{ccc|ccc} 1 & -2 & 0 & -1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_1 := r_1 - (-2)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 2 & -1 & 2 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$



**Results:**

- a)  $\text{rank}(A) = 2$
- b)  $\text{nullity}(A) = 1$
- c)  $\det(A) = 0$
- d)  $A^{-1}$  does not exist
- e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} 0 \\ -1 \\ 1 \end{bmatrix} \right\}$

**2.3.2. RREF****Solution****Elementary Row Operations:**

$$(1) \ r_3 := r_3 - (2)r_2$$

$$\begin{bmatrix} 1 & -2 & 4 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

$$(2) \ r_1 := r_1 - (2)r_2$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

$$(3) \ r_1 := r_1 - (2)r_3$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

**Solution****Elementary Row Operations:**

$$(1) \ r_1 := r_1 - (2)r_3$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 2 & -2 & 1 \end{bmatrix}$$

$$(2) \ r_3 := r_3 - (2)r_2$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 2 & 0 & 1 \end{bmatrix}$$

$$(3) \ r_3 := r_3 + (-2)r_1$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

(1)  $r_3 := r_3 - r_2$

$$\begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix}$$

(2)  $r_3 := r_3 - r_2$

$$\begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

(3)  $r_2 := r_2 + (-1)r_3$

$$\begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 0 & -2 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

(1)  $r_2 := r_2 - r_1$

$$\begin{bmatrix} 1 & 3 & 2 \\ 1 & 4 & 2 \\ 0 & 0 & 1 \end{bmatrix}$$

(2)  $r_2 := r_2 + (-1)r_1$

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

(3)  $r_1 := r_1 + (-1)r_2$

$$\begin{bmatrix} 1 & 2 & 2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 2 & 2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

$$(1) \ r_1 := r_1 + (-1)r_2$$

$$\begin{bmatrix} 1 & 2 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$$

$$(2) \ r_3 := r_3 - r_2$$

$$\begin{bmatrix} 1 & 2 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$(3) \ r_1 := r_1 + (-2)r_2$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

$$(1) \ r_1 := r_1 + (-2)r_2$$

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

$$(2) \ r_3 := r_3 - (2)r_1$$

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

$$(3) \ r_2 := r_2 - (2)r_1$$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 0 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

$$(1) \ r_2 := r_2 + (-1)r_1$$

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & -2 \\ 0 & 0 & 1 \end{bmatrix}$$

$$(2) \ r_2 := r_2 - (2)r_3$$

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

(1)  $r_2 := r_2 - (2)r_3$

$$\begin{bmatrix} 1 & 1 & -1 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$$

(2)  $r_3 := r_3 - r_2$

$$\begin{bmatrix} 1 & 1 & -1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

(3)  $r_1 := r_1 - r_3$

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

(1)  $r_2 := r_2 + (-2)r_3$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & 1 \\ 2 & -2 & 0 \end{bmatrix}$$

(2)  $r_3 := r_3 + (-2)r_1$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

(3)  $r_2 := r_2 + (-1)r_3$

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

**Solution**

**Elementary Row Operations:**

$$(1) \ r_2 := r_2 + (-1)r_1$$

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

$$(2) \ r_1 := r_1 + (-2)r_2$$

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

$$(3) \ r_2 := r_2 - r_3$$

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

**Result:**

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \end{bmatrix}$$

## 2.4. Calculus

### 2.4.1. Limit

The limit is:

$$7 \tag{151}$$

The limit is:

$$e \tag{152}$$

The limit is:

$$1 \tag{153}$$

The limit is:

$$e \tag{154}$$

The limit is:

$$1 \tag{155}$$

The limit is:

$$2 \tag{156}$$

The limit is:

$$-154 \tag{157}$$

The limit is:

$$3 \tag{158}$$

The limit is:

$$1 \tag{159}$$

The limit is:

$$2 \quad (160)$$

### 2.4.2. Derivative

The derivative is:

$$-\frac{2x^4}{(x^2+1)^2} + \frac{3x^2}{x^2+1} \quad (161)$$

The derivative is:

$$-\frac{2x^4}{(x^2+1)^2} + \frac{3x^2}{x^2+1} \quad (162)$$

The derivative is:

$$\frac{2x}{x^2+1} + \frac{1}{x+1} \quad (163)$$

The derivative is:

$$x^2e^x + 2xe^x \quad (164)$$

The derivative is:

$$\frac{2x}{x^2+1} + \frac{1}{x+1} \quad (165)$$

The derivative is:

$$2xe^{x^2} + 2e^{2x} \quad (166)$$

The derivative is:

$$xe^x + e^x \quad (167)$$

The derivative is:

$$-\frac{2x^3}{(x^2+1)^2} + \frac{2x}{x^2+1} \quad (168)$$

The derivative is:

$$xe^x + e^x \quad (169)$$

The derivative is:

$$2xe^{x^2-3} \quad (170)$$

### 2.4.3. Integral

The indefinite integral is:

$$2 \log(x-2) + \log(x+2) \quad (171)$$

Definite integral from 1 to 5:

$$\text{NaN} \quad (172)$$

The indefinite integral is:

$$\text{Ei}(x) \quad (173)$$

Definite integral from 3 to 5:

$$-\text{Ei}(3) + \text{Ei}(5) \quad (174)$$

The indefinite integral is:

$$\log(\log(x)) \quad (175)$$

Definite integral from 1 to 5:

$$\infty \quad (176)$$

The indefinite integral is:

$$\log(\log(x)) \quad (177)$$

Definite integral from 3 to 5:

$$-\log(\log(3)) + \log(\log(5)) \quad (178)$$

The indefinite integral is:

$$e^{\sin(x)} \quad (179)$$

Definite integral from 1 to 3:

$$-e^{\sin(1)} + e^{\sin(3)} \quad (180)$$

The improper integral converges to:

$$e^{-1} \quad (181)$$

The indefinite integral is:

$$\text{Ei}(x) \quad (182)$$

Definite integral from 1 to 3:

$$-\text{Ei}(1) + \text{Ei}(3) \quad (183)$$

The indefinite integral is:

$$\frac{5x^3}{3} + 2x^2 - 3x \quad (184)$$

Definite integral from 2 to 4:

$$\frac{334}{3} \quad (185)$$

The improper integral converges to:

$$\infty \quad (186)$$

The improper integral converges to:

$$1 \quad (187)$$

#### 2.4.4. Partial Derivative

$$\frac{\partial^2 f}{\partial x \partial y} = 2y(3x^2 + 2y^2) \quad (188)$$

$$\frac{\partial^3 f}{\partial y^3} = 6x^2(x^2 + 12y) \quad (189)$$

$$\frac{\partial f}{\partial x} = 3x^2y^2 - 6xy + 2y^3 \quad (190)$$

$$\frac{\partial f}{\partial y} = 2x^3y - 3x^2 + 6xy^2 \quad (191)$$

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (192)$$

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (193)$$

$$\frac{\partial^2 f}{\partial x \partial y} = 2y(3x^2 + 2y^2) \quad (194)$$

$$\frac{\partial^2 f}{\partial x \partial y} = 2y(3x^2 + 2y^2) \quad (195)$$

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (196)$$

$$\frac{\partial^2 f}{\partial x^2} = 6y^3(2x^2 + y) \quad (197)$$

$$\frac{\partial^3 f}{\partial y^3} = 6x^2(x^2 + 12y) \quad (198)$$