

Exercise 30:

Foundations of Mathematical, WS24

Zichao Wei

This is **exercise** 30 for Foundations of Mathematical, WS24. Generated on 2025-06-16 with 10 problems per section.

2025-06-30

1. Problems

1.1. Vector Arithmetic

1.1.1. Addition

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

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

1.1.2. Subtraction

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

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

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

1.1.3. Scalar Multiplication

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

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

1.2. Matrix Arithmetic

1.2.1. Addition

Find the sum of the following matrices A and B

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

and

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

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

and

$$B = \begin{bmatrix} -7 & -8 & -3 \\ 8 & 0 & -10 \\ -8 & 9 & 5 \end{bmatrix} \quad (4)$$

3.
$$A = \begin{bmatrix} 0 & 2 & -7 \\ -7 & -4 & -6 \\ 5 & -1 & -8 \end{bmatrix} \quad (5)$$

and

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

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

and

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

5.
$$A = \begin{bmatrix} 4 & -7 & 2 \\ 0 & 7 & -2 \\ -5 & 0 & 6 \end{bmatrix} \quad (9)$$

and

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

6.
$$A = \begin{bmatrix} 1 & -9 & -1 \\ 4 & -10 & -7 \\ 4 & 5 & -2 \end{bmatrix} \quad (11)$$

and

$$B = \begin{bmatrix} -4 & 6 & -5 \\ -10 & 5 & -10 \\ -1 & 1 & 1 \end{bmatrix} \quad (12)$$

7.

$$A = \begin{bmatrix} 9 & -2 & 9 \\ -10 & -10 & -3 \\ -1 & 5 & -4 \end{bmatrix} \quad (13)$$

and

$$B = \begin{bmatrix} 9 & 7 & 9 \\ 7 & 1 & 2 \\ 9 & -7 & 7 \end{bmatrix} \quad (14)$$

8.

$$A = \begin{bmatrix} -1 & -9 & -9 \\ 9 & 7 & -7 \\ 2 & -10 & -2 \end{bmatrix} \quad (15)$$

and

$$B = \begin{bmatrix} -1 & -2 & 8 \\ 6 & 9 & -4 \\ 6 & 8 & 3 \end{bmatrix} \quad (16)$$

9.

$$A = \begin{bmatrix} -6 & -5 & 7 \\ -2 & 5 & -1 \\ 1 & 8 & 0 \end{bmatrix} \quad (17)$$

and

$$B = \begin{bmatrix} -7 & 3 & -7 \\ 8 & -9 & 1 \\ 2 & 6 & -2 \end{bmatrix} \quad (18)$$

10.

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

and

$$B = \begin{bmatrix} 2 & 6 & -4 \\ -7 & 6 & -7 \\ 0 & 3 & -2 \end{bmatrix} \quad (20)$$

1.2.2. Subtraction

Find the difference of the following matrices A and B

$$1. \quad A = \begin{bmatrix} -1 & -10 & -7 \\ -6 & 6 & -5 \\ -5 & 3 & -3 \end{bmatrix} \quad (21)$$

and

$$B = \begin{bmatrix} 5 & -1 & 0 \\ -8 & -3 & -7 \\ 1 & 4 & -10 \end{bmatrix} \quad (22)$$

$$2. \quad A = \begin{bmatrix} -8 & 8 & 6 \\ -10 & -3 & -1 \\ 7 & -2 & -6 \end{bmatrix} \quad (23)$$

and

$$B = \begin{bmatrix} 3 & 9 & 1 \\ -6 & 4 & 1 \\ -8 & -4 & 4 \end{bmatrix} \quad (24)$$

$$3. \quad A = \begin{bmatrix} 8 & -5 & -6 \\ 0 & 8 & -10 \\ 8 & -5 & -6 \end{bmatrix} \quad (25)$$

and

$$B = \begin{bmatrix} 5 & -7 & 2 \\ -1 & -1 & -1 \\ -7 & 5 & 5 \end{bmatrix} \quad (26)$$

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

and

$$B = \begin{bmatrix} 8 & 6 & 5 \\ -7 & -4 & 0 \\ 7 & 6 & -5 \end{bmatrix} \quad (28)$$

$$5. \quad A = \begin{bmatrix} 6 & -9 & -1 \\ 9 & -1 & 0 \\ -1 & 8 & -1 \end{bmatrix} \quad (29)$$

and

$$B = \begin{bmatrix} 4 & 2 & -5 \\ -10 & 0 & 7 \\ -10 & -2 & 1 \end{bmatrix} \quad (30)$$

$$6. \quad A = \begin{bmatrix} -2 & 3 & 0 \\ 0 & -1 & -4 \\ -4 & 3 & 7 \end{bmatrix} \quad (31)$$

and

$$B = \begin{bmatrix} -8 & 3 & 2 \\ -9 & -2 & -7 \\ -4 & -5 & -9 \end{bmatrix} \quad (32)$$

7.

$$A = \begin{bmatrix} -1 & 0 & 8 \\ 5 & -8 & 2 \\ -4 & 1 & 0 \end{bmatrix} \quad (33)$$

and

$$B = \begin{bmatrix} 1 & -3 & 8 \\ -8 & -7 & -8 \\ -3 & 9 & -1 \end{bmatrix} \quad (34)$$

8.

$$A = \begin{bmatrix} -3 & -6 & -8 \\ -6 & -7 & -8 \\ 0 & -9 & -7 \end{bmatrix} \quad (35)$$

and

$$B = \begin{bmatrix} -7 & 5 & 7 \\ 4 & -1 & 1 \\ -6 & 6 & -2 \end{bmatrix} \quad (36)$$

9.

$$A = \begin{bmatrix} 7 & -5 & 3 \\ -5 & -2 & 1 \\ 9 & 8 & 8 \end{bmatrix} \quad (37)$$

and

$$B = \begin{bmatrix} -3 & 9 & -6 \\ 4 & -10 & 4 \\ 2 & -6 & 9 \end{bmatrix} \quad (38)$$

10.

$$A = \begin{bmatrix} -4 & 8 & 2 \\ 1 & 1 & 0 \\ -9 & 3 & 4 \end{bmatrix} \quad (39)$$

and

$$B = \begin{bmatrix} -10 & 3 & 5 \\ -9 & -3 & 3 \\ 1 & -6 & -2 \end{bmatrix} \quad (40)$$

1.2.3. Multiplication

Find the product of the following matrices A and B

$$1. \quad A = \begin{bmatrix} -9 & 8 & -6 \\ -5 & -10 & 6 \\ -1 & -6 & 9 \end{bmatrix} \quad (41)$$

and

$$B = \begin{bmatrix} -10 & -7 & 1 \\ -10 & -5 & 8 \\ -2 & 7 & 5 \end{bmatrix} \quad (42)$$

$$2. \quad A = \begin{bmatrix} -6 & -3 & -1 \\ 3 & -10 & 2 \\ -1 & -8 & -6 \end{bmatrix} \quad (43)$$

and

$$B = \begin{bmatrix} -8 & 5 & -9 \\ -10 & 3 & -10 \\ -8 & 5 & -2 \end{bmatrix} \quad (44)$$

$$3. \quad A = \begin{bmatrix} -2 & 0 & -7 \\ 2 & 9 & 4 \\ -4 & -1 & 6 \end{bmatrix} \quad (45)$$

and

$$B = \begin{bmatrix} 7 & 7 & -7 \\ -6 & -10 & 9 \\ 3 & -4 & -6 \end{bmatrix} \quad (46)$$

$$4. \quad A = \begin{bmatrix} -7 & 5 & -10 \\ 0 & 6 & 8 \\ 8 & -2 & 5 \end{bmatrix} \quad (47)$$

and

$$B = \begin{bmatrix} -1 & 1 & 6 \\ -3 & 2 & 6 \\ 0 & -1 & -5 \end{bmatrix} \quad (48)$$

$$5. \quad A = \begin{bmatrix} -7 & 9 & 2 \\ 6 & 3 & -7 \\ -3 & -6 & -8 \end{bmatrix} \quad (49)$$

and

$$B = \begin{bmatrix} -7 & -9 & -4 \\ -1 & -8 & 1 \\ -6 & 2 & 4 \end{bmatrix} \quad (50)$$

$$6. \quad A = \begin{bmatrix} 9 & 0 & 7 \\ 3 & 0 & 8 \\ 7 & -3 & 2 \end{bmatrix} \quad (51)$$

and

$$B = \begin{bmatrix} 3 & -3 & 9 \\ 6 & 9 & 4 \\ -7 & -10 & -2 \end{bmatrix} \quad (52)$$

7.

$$A = \begin{bmatrix} 5 & -8 & -10 \\ -9 & -7 & 8 \\ 1 & -2 & -3 \end{bmatrix} \quad (53)$$

and

$$B = \begin{bmatrix} -2 & 3 & 9 \\ -8 & 3 & 9 \\ -3 & 7 & 4 \end{bmatrix} \quad (54)$$

8.

$$A = \begin{bmatrix} 0 & -9 & -2 \\ 0 & -5 & 0 \\ 8 & -3 & 8 \end{bmatrix} \quad (55)$$

and

$$B = \begin{bmatrix} 7 & -6 & -1 \\ 0 & -2 & -4 \\ -6 & 8 & -5 \end{bmatrix} \quad (56)$$

9.

$$A = \begin{bmatrix} -10 & -8 & -3 \\ -8 & 8 & 4 \\ -10 & 7 & -10 \end{bmatrix} \quad (57)$$

and

$$B = \begin{bmatrix} -1 & -2 & -1 \\ 8 & -2 & -4 \\ -8 & 0 & 4 \end{bmatrix} \quad (58)$$

10.

$$A = \begin{bmatrix} 6 & 1 & 8 \\ -5 & -10 & -8 \\ -8 & -4 & 8 \end{bmatrix} \quad (59)$$

and

$$B = \begin{bmatrix} 6 & 5 & -5 \\ 4 & -3 & 4 \\ -4 & -8 & -4 \end{bmatrix} \quad (60)$$

1.3. Matrix Properties

1.3.1. Properties

For each matrix A , find:

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

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

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

2.
$$A = \begin{bmatrix} 3 & 1 & -1 \\ 6 & 1 & -4 \\ -2 & 0 & 2 \end{bmatrix} \quad (62)$$

3.
$$A = \begin{bmatrix} 1 & 0 & -2 \\ -2 & 5 & 3 \\ 2 & -4 & -3 \end{bmatrix} \quad (63)$$

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

5.
$$A = \begin{bmatrix} 1 & 1 & -2 \\ -4 & -3 & 9 \\ 1 & 1 & -2 \end{bmatrix} \quad (65)$$

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

7.
$$A = \begin{bmatrix} 2 & 1 & -6 \\ -1 & 2 & 8 \\ 0 & -2 & -4 \end{bmatrix} \quad (67)$$

8.
$$A = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 5 & 2 \\ -3 & -7 & -2 \end{bmatrix} \quad (68)$$

9.
$$A = \begin{bmatrix} 3 & 4 & -1 \\ 2 & 3 & 0 \\ 4 & 5 & -1 \end{bmatrix} \quad (69)$$

10.
$$A = \begin{bmatrix} 7 & 5 & 10 \\ -3 & -2 & -4 \\ 0 & 0 & 0 \end{bmatrix} \quad (70)$$

1.3.2. RREF

Find the Reduced Row Echelon Form of the following matrix A

$$1. \quad A = \begin{bmatrix} 5 & 2 & 0 \\ -3 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (71)$$

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

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

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

$$5. \quad A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & -2 & 0 \end{bmatrix} \quad (75)$$

$$6. \quad A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 2 & 0 \end{bmatrix} \quad (76)$$

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

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

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

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

1.4. Calculus

1.4.1. Limit

Calculate the following limits

1. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (81)$$

2. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (82)$$

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:

$$\lim_{x \rightarrow 3} 3x^2 - x + 1 \quad (84)$$

5. Calculate the limit of the following expression:

$$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x \quad (85)$$

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:

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

8. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x+1)}{x} \quad (88)$$

9. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 1} \frac{x^2 - 1}{x - 1} \quad (89)$$

10. Calculate the limit of the following expression:

$$\lim_{x \rightarrow -3} 4x^2 - 4x - 3 \quad (90)$$

1.4.2. Derivative

Calculate the derivatives of the following expressions

1. Calculate the derivative of the following expression:

$$\log(x+1) + \log(x^2+1) \quad (91)$$

2. Calculate the derivative of the following expression:

$$\log(x+1) + \log(x^2+1) \quad (92)$$

3. Calculate the derivative of the following expression:

$$\frac{x^2}{x^2 + 1} \quad (93)$$

4. Calculate the derivative of the following expression:

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

5. Calculate the derivative of the following expression:

$$\log(x^2 + 3) \quad (95)$$

6. Calculate the derivative of the following expression:

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

7. Calculate the derivative of the following expression:

$$\log(x + 1) + \log(x^2 + 1) \quad (97)$$

8. Calculate the derivative of the following expression:

$$x^3 \log(x) \quad (98)$$

9. Calculate the derivative of the following expression:

$$e^{2x} + e^{x^2} \quad (99)$$

10. Calculate the derivative of the following expression:

$$x \log(x) \quad (100)$$

1.4.3. Integral

Calculate the indefinite and definite integrals of the following expressions

1. Evaluate the improper integral:

$$\int_1^{\infty} \frac{1}{\sqrt{x}} dx \quad (101)$$

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

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

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

$$\int 3x^3 - 3x^2 - 3 dx \quad (103)$$

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

$$\int x^3 \log(x) dx \quad (104)$$

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

$$\int \frac{1}{x^2 + 1} dx \quad (105)$$

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

$$\int \frac{1}{x \log(x)} dx \quad (106)$$

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

$$\int 4x^2 - 2x - 5 dx \quad (107)$$

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

$$\int \frac{1}{x^2 + 1} dx \quad (108)$$

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

$$\int x^2 e^x dx \quad (109)$$

10. the indefinite integral and evaluate from 1 to 2:

$$\int e^x \sin(x) dx \quad (110)$$

1.4.4. Partial Derivative

Calculate the partial derivatives of the following expressions

1. the mixed partial derivative of:

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

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

2. Given the implicit function:

$$x^2 y + xy^2 - xy = 0 \quad (112)$$

$$\frac{\partial y}{\partial x}$$

3. the mixed partial derivative of:

$$f(x, y) = x^3 y^2 + xy^4 \quad (113)$$

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

4. the mixed partial derivative of:

$$f(x, y) = x^3 y^2 + xy^4 \quad (114)$$

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

5. the partial derivatives of the function:

$$f(x, y) = x^3y^2 - 3x^2y + 2xy^3 \quad (115)$$

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

6. Given the implicit function:

$$x^2y + xy^2 - xy = 0 \quad (116)$$

$$\frac{\partial y}{\partial x}$$

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:

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

$$\text{where } f = f(u, v)$$

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

$$\frac{\partial f}{\partial x} \quad (119)$$

$$\text{where } f = f(u, v)$$

10. the partial derivatives of the function:

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

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

2. Solutions

2.1. Vector Arithmetic

2.1.1. Addition

$$\begin{bmatrix} 1 \\ -16 \\ -2 \end{bmatrix} + \begin{bmatrix} -7 \\ -1 \\ -17 \end{bmatrix} + \begin{bmatrix} -12 \\ -6 \\ 0 \end{bmatrix} + \begin{bmatrix} -3 \\ 4 \\ -10 \end{bmatrix} + \begin{bmatrix} -7 \\ -4 \\ 9 \end{bmatrix} \\ \begin{bmatrix} 0 \\ 1 \\ 5 \end{bmatrix} + \begin{bmatrix} -4 \\ 1 \\ -18 \end{bmatrix} + \begin{bmatrix} 3 \\ -5 \\ -1 \end{bmatrix} + \begin{bmatrix} -6 \\ 10 \\ -16 \end{bmatrix} + \begin{bmatrix} 2 \\ -7 \\ 0 \end{bmatrix}$$

2.1.2. Subtraction

$$\begin{bmatrix} -7 \\ -8 \\ -6 \end{bmatrix} - \begin{bmatrix} 8 \\ -3 \\ 4 \end{bmatrix} - \begin{bmatrix} 8 \\ -17 \\ -3 \end{bmatrix} - \begin{bmatrix} 9 \\ 11 \\ 6 \end{bmatrix} - \begin{bmatrix} 15 \\ 5 \\ 8 \end{bmatrix} \\ \begin{bmatrix} -16 \\ -6 \\ -1 \end{bmatrix} - \begin{bmatrix} 1 \\ -5 \\ -4 \end{bmatrix} - \begin{bmatrix} -6 \\ 3 \\ 1 \end{bmatrix} - \begin{bmatrix} 0 \\ -9 \\ 1 \end{bmatrix} - \begin{bmatrix} -4 \\ -10 \\ 1 \end{bmatrix}$$

2.1.3. Scalar Multiplication

$$\begin{array}{l} 1: \begin{bmatrix} -45 \\ 54 \\ -54 \end{bmatrix} \quad 2: \begin{bmatrix} -8 \\ 8 \\ 10 \end{bmatrix} \quad 3: \begin{bmatrix} -70 \\ 60 \\ -30 \end{bmatrix} \quad 4: \begin{bmatrix} 60 \\ -24 \\ -54 \end{bmatrix} \quad 5: \begin{bmatrix} 9 \\ 54 \\ 54 \end{bmatrix} \\ 6: \begin{bmatrix} -80 \\ -50 \\ 60 \end{bmatrix} \quad 7: \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad 8: \begin{bmatrix} 10 \\ 40 \\ 35 \end{bmatrix} \quad 9: \begin{bmatrix} 21 \\ -21 \\ -27 \end{bmatrix} \quad 10: \begin{bmatrix} 18 \\ -36 \\ 24 \end{bmatrix} \end{array}$$

2.2. Matrix Arithmetic

2.2.1. Addition

1:

$$\begin{bmatrix} -2 & 10 & 6 \\ 9 & -19 & -3 \\ 2 & 1 & 6 \end{bmatrix} \quad (121)$$

1:

$$\begin{bmatrix} -8 & -6 & 3 \\ 3 & 8 & -4 \\ -9 & 4 & 14 \end{bmatrix} \quad (122)$$

1:

$$\begin{bmatrix} -4 & 6 & -3 \\ -5 & -9 & -13 \\ 0 & 4 & -16 \end{bmatrix} \quad (123)$$

1:

$$\begin{bmatrix} -16 & 17 & 3 \\ 4 & -16 & -16 \\ -3 & 12 & 3 \end{bmatrix} \quad (124)$$

1:

$$\begin{bmatrix} 8 & -7 & 0 \\ 3 & 16 & -1 \\ 4 & -10 & 9 \end{bmatrix} \quad (125)$$

1:

$$\begin{bmatrix} -3 & -3 & -6 \\ -6 & -5 & -17 \\ 3 & 6 & -1 \end{bmatrix} \quad (126)$$

1:

$$\begin{bmatrix} 18 & 5 & 18 \\ -3 & -9 & -1 \\ 8 & -2 & 3 \end{bmatrix} \quad (127)$$

1:

$$\begin{bmatrix} -2 & -11 & -1 \\ 15 & 16 & -11 \\ 8 & -2 & 1 \end{bmatrix} \quad (128)$$

1:

$$\begin{bmatrix} -13 & -2 & 0 \\ 6 & -4 & 0 \\ 3 & 14 & -2 \end{bmatrix} \quad (129)$$

1:

$$\begin{bmatrix} -1 & 5 & -2 \\ -9 & -1 & -9 \\ 7 & 10 & 5 \end{bmatrix} \quad (130)$$

2.2.2. Subtraction

1:

$$\begin{bmatrix} -6 & -9 & -7 \\ 2 & 9 & 2 \\ -6 & -1 & 7 \end{bmatrix} \quad (131)$$

1:

$$\begin{bmatrix} -11 & -1 & 5 \\ -4 & -7 & -2 \\ 15 & 2 & -10 \end{bmatrix} \quad (132)$$

1:

$$\begin{bmatrix} 3 & 2 & -8 \\ 1 & 9 & -9 \\ 15 & -10 & -11 \end{bmatrix} \quad (133)$$

1:

$$\begin{bmatrix} -1 & -3 & -12 \\ 10 & 8 & -7 \\ 1 & -1 & 2 \end{bmatrix} \quad (134)$$

1:

$$\begin{bmatrix} 2 & -11 & 4 \\ 19 & -1 & -7 \\ 9 & 10 & -2 \end{bmatrix} \quad (135)$$

1:

$$\begin{bmatrix} 6 & 0 & -2 \\ 9 & 1 & 3 \\ 0 & 8 & 16 \end{bmatrix} \quad (136)$$

1:

$$\begin{bmatrix} -2 & 3 & 0 \\ 13 & -1 & 10 \\ -1 & -8 & 1 \end{bmatrix} \quad (137)$$

1:

$$\begin{bmatrix} 4 & -11 & -15 \\ -10 & -6 & -9 \\ 6 & -15 & -5 \end{bmatrix} \quad (138)$$

1:

$$\begin{bmatrix} 10 & -14 & 9 \\ -9 & 8 & -3 \\ 7 & 14 & -1 \end{bmatrix} \quad (139)$$

1:

$$\begin{bmatrix} 6 & 5 & -3 \\ 10 & 4 & -3 \\ -10 & 9 & 6 \end{bmatrix} \quad (140)$$

2.2.3. Multiplication

1:

$$\begin{bmatrix} 22 & -19 & 25 \\ 138 & 127 & -55 \\ 52 & 100 & -4 \end{bmatrix} \quad (141)$$

1:

$$\begin{bmatrix} 86 & -44 & 86 \\ 60 & -5 & 69 \\ 136 & -59 & 101 \end{bmatrix} \quad (142)$$

1:

$$\begin{bmatrix} -35 & 14 & 56 \\ -28 & -92 & 43 \\ -4 & -42 & -17 \end{bmatrix} \quad (143)$$

1:

$$\begin{bmatrix} -8 & 13 & 38 \\ -18 & 4 & -4 \\ -2 & -1 & 11 \end{bmatrix} \quad (144)$$

1:

$$\begin{bmatrix} 28 & -5 & 45 \\ -3 & -92 & -49 \\ 75 & 59 & -26 \end{bmatrix} \quad (145)$$

1:

$$\begin{bmatrix} -22 & -97 & 67 \\ -47 & -89 & 11 \\ -11 & -68 & 47 \end{bmatrix} \quad (146)$$

1:

$$\begin{bmatrix} 84 & -79 & -67 \\ 50 & 8 & -112 \\ 23 & -24 & -21 \end{bmatrix} \quad (147)$$

1:

$$\begin{bmatrix} 12 & 2 & 46 \\ 0 & 10 & 20 \\ 8 & 22 & -36 \end{bmatrix} \quad (148)$$

1:

$$\begin{bmatrix} -30 & 36 & 30 \\ 40 & 0 & -8 \\ 146 & 6 & -58 \end{bmatrix} \quad (149)$$

1:

$$\begin{bmatrix} 8 & -37 & -58 \\ -38 & 69 & 17 \\ -96 & -92 & -8 \end{bmatrix} \quad (150)$$

2.3. Matrix Properties

2.3.1. Properties

Solution

Row Operations:

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

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:

$$\text{Step 1: } r_1 := 1/3r_1 \quad \begin{bmatrix} 1 & 1/3 & -1/3 & | & 1/3 & 0 & 0 \\ 6 & 1 & -4 & | & 0 & 1 & 0 \\ -2 & 0 & 2 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 2: } r_2 := r_2 - (6)r_1 \quad \begin{bmatrix} 1 & 1/3 & -1/3 & | & 1/3 & 0 & 0 \\ 0 & -1 & -2 & | & -2 & 1 & 0 \\ -2 & 0 & 2 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 3: } r_3 := r_3 - (-2)r_1 \quad \begin{bmatrix} 1 & 1/3 & -1/3 & | & 1/3 & 0 & 0 \\ 0 & -1 & -2 & | & -2 & 1 & 0 \\ 0 & 2/3 & 4/3 & | & 2/3 & 0 & 1 \end{bmatrix}$$

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

$$\text{Step 5: } r_1 := r_1 - (1/3)r_2 \quad \begin{bmatrix} 1 & 0 & -1 & | & -1/3 & 1/3 & 0 \\ 0 & 1 & 2 & | & 2 & -1 & 0 \\ 0 & 2/3 & 4/3 & | & 2/3 & 0 & 1 \end{bmatrix}$$

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

Results:

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

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

c) $\det(A) = 0$

d) A^{-1} does not exist

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

Solution

Row Operations:

Step 1: $r_2 := r_2 - (-2)r_1$ $\begin{bmatrix} 1 & 0 & -2 & | & 1 & 0 & 0 \\ 0 & 5 & -1 & | & 2 & 1 & 0 \\ 2 & -4 & -3 & | & 0 & 0 & 1 \end{bmatrix}$

Step 2: $r_3 := r_3 - (2)r_1$ $\begin{bmatrix} 1 & 0 & -2 & | & 1 & 0 & 0 \\ 0 & 5 & -1 & | & 2 & 1 & 0 \\ 0 & -4 & 1 & | & -2 & 0 & 1 \end{bmatrix}$

Step 3: $r_2 := 1/5r_2$ $\begin{bmatrix} 1 & 0 & -2 & | & 1 & 0 & 0 \\ 0 & 1 & -1/5 & | & 2/5 & 1/5 & 0 \\ 0 & -4 & 1 & | & -2 & 0 & 1 \end{bmatrix}$

Step 4: $r_3 := r_3 - (-4)r_2$ $\begin{bmatrix} 1 & 0 & -2 & | & 1 & 0 & 0 \\ 0 & 1 & -1/5 & | & 2/5 & 1/5 & 0 \\ 0 & 0 & 1/5 & | & -2/5 & 4/5 & 1 \end{bmatrix}$

Step 5: $r_3 := 5r_3$ $\begin{bmatrix} 1 & 0 & -2 & | & 1 & 0 & 0 \\ 0 & 1 & -1/5 & | & 2/5 & 1/5 & 0 \\ 0 & 0 & 1 & | & -2 & 4 & 5 \end{bmatrix}$

Step 6: $r_1 := r_1 - (-2)r_3$ $\begin{bmatrix} 1 & 0 & 0 & | & -3 & 8 & 10 \\ 0 & 1 & -1/5 & | & 2/5 & 1/5 & 0 \\ 0 & 0 & 1 & | & -2 & 4 & 5 \end{bmatrix}$

Step 7: $r_2 := r_2 - (-1/5)r_3$ $\begin{bmatrix} 1 & 0 & 0 & | & -3 & 8 & 10 \\ 0 & 1 & 0 & | & 0 & 1 & 1 \\ 0 & 0 & 1 & | & -2 & 4 & 5 \end{bmatrix}$

Results:

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

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

c) $\det(A) = 0$

d) $A^{-1} = \begin{bmatrix} 1 & -2 & -2 \\ 2 & -3 & -4 \\ -2 & 4 & 5 \end{bmatrix}$

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

Solution

Row Operations:

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

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

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

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

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

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

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

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

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

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

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

$$\text{Step 4: } r_1 := r_1 - (-1)r_3 \begin{bmatrix} 1 & 0 & 0 & | & 2 & 0 & 1 \\ 0 & 1 & 1 & | & 0 & 1 & 0 \\ 0 & 0 & 1 & | & 1 & 1 & 1 \end{bmatrix}$$

$$\text{Step 5: } r_2 := r_2 - r_3 \begin{bmatrix} 1 & 0 & 0 & | & 2 & 0 & 1 \\ 0 & 1 & 0 & | & -1 & 0 & -1 \\ 0 & 0 & 1 & | & 1 & 1 & 1 \end{bmatrix}$$

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

$$\text{Step 1: } r_1 := 1/2r_1 \begin{bmatrix} 1 & 1/2 & -3 & | & 1/2 & 0 & 0 \\ -1 & 2 & 8 & | & 0 & 1 & 0 \\ 0 & -2 & -4 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 2: } r_2 := r_2 - (-1)r_1 \begin{bmatrix} 1 & 1/2 & -3 & | & 1/2 & 0 & 0 \\ 0 & 5/2 & 5 & | & 1/2 & 1 & 0 \\ 0 & -2 & -4 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 3: } r_2 := 2/5r_2 \begin{bmatrix} 1 & 1/2 & -3 & | & 1/2 & 0 & 0 \\ 0 & 1 & 2 & | & 1/5 & 2/5 & 0 \\ 0 & -2 & -4 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 4: } r_1 := r_1 - (1/2)r_2 \begin{bmatrix} 1 & 0 & -4 & | & 2/5 & -1/5 & 0 \\ 0 & 1 & 2 & | & 1/5 & 2/5 & 0 \\ 0 & -2 & -4 & | & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Step 5: } r_3 := r_3 - (-2)r_2 \begin{bmatrix} 1 & 0 & -4 & | & 2/5 & -1/5 & 0 \\ 0 & 1 & 2 & | & 1/5 & 2/5 & 0 \\ 0 & 0 & 0 & | & 2/5 & 4/5 & 1 \end{bmatrix}$$

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

$$\text{Step 1: } r_2 := r_2 - (2)r_1 \quad \left[\begin{array}{ccc|ccc} 1 & 2 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & -2 & 1 & 0 \\ -3 & -7 & -2 & 0 & 0 & 1 \end{array} \right]$$

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

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

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

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

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

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

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

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

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

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

$$\text{Step 6: } r_3 := r_3 - (-1/3)r_2 \quad \left[\begin{array}{ccc|ccc} 1 & 0 & -3 & 3 & -4 & 0 \\ 0 & 1 & 2 & -2 & 3 & 0 \\ 0 & 0 & 1 & -2 & 1 & 1 \end{array} \right]$$

$$\text{Step 7: } r_1 := r_1 - (-3)r_3 \quad \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & -3 & -1 & 3 \\ 0 & 1 & 2 & -2 & 3 & 0 \\ 0 & 0 & 1 & -2 & 1 & 1 \end{array} \right]$$

$$\text{Step 8: } r_2 := r_2 - (2)r_3 \quad \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & -3 & -1 & 3 \\ 0 & 1 & 0 & 2 & 1 & -2 \\ 0 & 0 & 1 & -2 & 1 & 1 \end{array} \right]$$

Results:

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

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

c) $\det(A) = 0$

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

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

Solution

Row Operations:

$$\text{Step 1: } r_1 := 1/7r_1 \quad \left[\begin{array}{ccc|ccc} 1 & 5/7 & 10/7 & 1/7 & 0 & 0 \\ -3 & -2 & -4 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 2: } r_2 := r_2 - (-3)r_1 \quad \left[\begin{array}{ccc|ccc} 1 & 5/7 & 10/7 & 1/7 & 0 & 0 \\ 0 & 1/7 & 2/7 & 3/7 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 3: } r_2 := 7r_2 \quad \left[\begin{array}{ccc|ccc} 1 & 5/7 & 10/7 & 1/7 & 0 & 0 \\ 0 & 1 & 2 & 3 & 7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$

$$\text{Step 4: } r_1 := r_1 - (5/7)r_2 \quad \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & -2 & -5 & 0 \\ 0 & 1 & 2 & 3 & 7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right]$$

Results:

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

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

c) $\det(A) = 0$

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

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

2.3.2. RREF

Solution

Elementary Row Operations:

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

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

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

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

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

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

Result:

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

Solution**Elementary Row Operations:**

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

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

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

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

Result:

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

Solution**Elementary Row Operations:**

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

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

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

Result:

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

Solution

Elementary Row Operations:

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

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

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

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

Result:

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

2.4. Calculus

2.4.1. Limit

The limit is:

$$1 \tag{151}$$

The limit is:

$$1 \tag{152}$$

The limit is:

$$1 \tag{153}$$

The limit is:

$$25 \tag{154}$$

The limit is:

$$e \quad (155)$$

The limit is:

$$2 \quad (156)$$

The limit is:

$$2 \quad (157)$$

The limit is:

$$1 \quad (158)$$

The limit is:

$$2 \quad (159)$$

The limit is:

$$45 \quad (160)$$

2.4.2. Derivative

The derivative is:

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

The derivative is:

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

The derivative is:

$$-\frac{2x^3}{(x^2 + 1)^2} + \frac{2x}{x^2 + 1} \quad (163)$$

The derivative is:

$$2x \log(x) + x \quad (164)$$

The derivative is:

$$\frac{2x}{x^2 + 3} \quad (165)$$

The derivative is:

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

The derivative is:

$$\frac{2x}{x^2 + 1} + \frac{1}{x + 1} \quad (167)$$

The derivative is:

$$3x^2 \log(x) + x^2 \quad (168)$$

The derivative is:

$$2xe^{x^2} + 2e^{2x} \quad (169)$$

The derivative is:

$$\log(x) + 1 \quad (170)$$

2.4.3. Integral

The improper integral converges to:

$$\infty \quad (171)$$

The indefinite integral is:

$$\text{Si}(x) \quad (172)$$

Definite integral from 2 to 4:

$$-\text{Si}(2) + \text{Si}(4) \quad (173)$$

The indefinite integral is:

$$\frac{3x^4}{4} - x^3 - 3x \quad (174)$$

Definite integral from 5 to 5:

$$0 \quad (175)$$

The indefinite integral is:

$$\frac{x^4 \log(x)}{4} - \frac{x^4}{16} \quad (176)$$

Definite integral from 4 to 5:

$$-64 \log(4) - \frac{369}{16} + \frac{625 \log(5)}{4} \quad (177)$$

The indefinite integral is:

$$\text{atan}(x) \quad (178)$$

Definite integral from 2 to 3:

$$-\text{atan}(2) + \text{atan}(3) \quad (179)$$

The indefinite integral is:

$$\log(\log(x)) \quad (180)$$

Definite integral from 4 to 5:

$$-\log(\log(4)) + \log(\log(5)) \quad (181)$$

The indefinite integral is:

$$\frac{4x^3}{3} - x^2 - 5x \quad (182)$$

Definite integral from 3 to 4:

$$\frac{112}{3} \quad (183)$$

The indefinite integral is:

$$\operatorname{atan}(x) \quad (184)$$

Definite integral from 2 to 4:

$$-\operatorname{atan}(2) + \operatorname{atan}(4) \quad (185)$$

The indefinite integral is:

$$(x^2 - 2x + 2)e^x \quad (186)$$

Definite integral from 1 to 3:

$$-e + 5e^3 \quad (187)$$

The indefinite integral is:

$$\frac{e^x \sin(x)}{2} - \frac{e^x \cos(x)}{2} \quad (188)$$

Definite integral from 1 to 2:

$$-\frac{e \sin(1)}{2} + \frac{e \cos(1)}{2} - \frac{e^2 \cos(2)}{2} + \frac{e^2 \sin(2)}{2} \quad (189)$$

2.4.4. Partial Derivative

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

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

$$\frac{\partial^2 f}{\partial x \partial y} = 2y(3x^2 + 2y^2) \quad (192)$$

$$\frac{\partial^2 f}{\partial x \partial y} = 2y(3x^2 + 2y^2) \quad (193)$$

$$\frac{\partial f}{\partial x} = 3x^2y^2 - 6xy + 2y^3 \quad (194)$$

$$\frac{\partial f}{\partial y} = 2x^3y - 3x^2 + 6xy^2 \quad (195)$$

$$\frac{\partial y}{\partial x} = \frac{-2xy - y^2 + y}{x^2 + 2xy - x} \quad (196)$$

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

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (198)$$

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (199)$$

$$\frac{\partial f}{\partial x} = 3x^2y^2 - 6xy + 2y^3 \quad (200)$$

$$\frac{\partial f}{\partial y} = 2x^3y - 3x^2 + 6xy^2 \quad (201)$$