

# Exercise 14:

## Foundations of Mathematical, WS24

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This is **exercise** 14 for Foundations of Mathematical, WS24. Generated on 2025-02-24 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.  $\mathbf{u} = \begin{bmatrix} -4 \\ -9 \\ -10 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -2 \\ -1 \\ 1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
2.  $\mathbf{u} = \begin{bmatrix} 7 \\ -8 \\ -6 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -1 \\ 3 \\ 1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
3.  $\mathbf{u} = \begin{bmatrix} -2 \\ 10 \\ 7 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -4 \\ 5 \\ 1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
4.  $\mathbf{u} = \begin{bmatrix} -8 \\ -3 \\ -4 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 8 \\ 7 \\ 8 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
5.  $\mathbf{u} = \begin{bmatrix} -7 \\ -9 \\ 1 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 6 \\ 7 \\ 7 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
6.  $\mathbf{u} = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -6 \\ 2 \\ -1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
7.  $\mathbf{u} = \begin{bmatrix} 8 \\ -9 \\ 5 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 8 \\ 8 \\ -3 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
8.  $\mathbf{u} = \begin{bmatrix} -5 \\ -2 \\ -9 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 9 \\ 8 \\ -2 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
9.  $\mathbf{u} = \begin{bmatrix} -7 \\ -9 \\ 7 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} -10 \\ -10 \\ 1 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .
10.  $\mathbf{u} = \begin{bmatrix} -2 \\ 3 \\ 8 \end{bmatrix}$  and  $\mathbf{v} = \begin{bmatrix} 2 \\ -8 \\ -3 \end{bmatrix}$   $\mathbf{u} + \mathbf{v}$ .

### 1.1.2. Subtraction

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

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

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

### 1.1.3. Scalar Multiplication

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

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

## 1.2. Matrix Arithmetic

### 1.2.1. Addition

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

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

and

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

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

and

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

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

and

$$B = \begin{bmatrix} -9 & 6 & -3 \\ 3 & -7 & 5 \\ -5 & -10 & 0 \end{bmatrix} \quad (6)$$

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

and

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

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

and

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

$$6. \quad A = \begin{bmatrix} -9 & -9 & 3 \\ 4 & -4 & 1 \\ -4 & -6 & 5 \end{bmatrix} \quad (11)$$

and

$$B = \begin{bmatrix} -9 & 9 & -9 \\ -8 & 3 & 4 \\ -10 & -6 & -6 \end{bmatrix} \quad (12)$$

7.

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

and

$$B = \begin{bmatrix} -5 & -1 & -7 \\ -4 & 2 & 4 \\ -3 & -4 & -1 \end{bmatrix} \quad (14)$$

8.

$$A = \begin{bmatrix} -9 & -5 & -3 \\ 8 & 7 & -4 \\ -7 & -1 & -4 \end{bmatrix} \quad (15)$$

and

$$B = \begin{bmatrix} -8 & -6 & -1 \\ -7 & -5 & -8 \\ 1 & 9 & -9 \end{bmatrix} \quad (16)$$

9.

$$A = \begin{bmatrix} 4 & 2 & -10 \\ -1 & -2 & -5 \\ 1 & -10 & 9 \end{bmatrix} \quad (17)$$

and

$$B = \begin{bmatrix} -7 & -8 & 9 \\ -10 & 5 & 2 \\ -6 & 0 & -7 \end{bmatrix} \quad (18)$$

10.

$$A = \begin{bmatrix} 9 & 3 & 2 \\ -10 & 2 & 0 \\ -9 & 4 & 6 \end{bmatrix} \quad (19)$$

and

$$B = \begin{bmatrix} -6 & -5 & 3 \\ -9 & -8 & 3 \\ 5 & -6 & 1 \end{bmatrix} \quad (20)$$

### 1.2.2. Subtraction

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

1.

$$A = \begin{bmatrix} 6 & 7 & -1 \\ 5 & -10 & 7 \\ 5 & -4 & -1 \end{bmatrix} \quad (21)$$

and

$$B = \begin{bmatrix} 9 & 0 & -8 \\ -10 & -1 & -9 \\ 7 & -7 & -8 \end{bmatrix} \quad (22)$$

2.

$$A = \begin{bmatrix} -4 & 4 & -10 \\ 7 & -8 & -7 \\ -8 & -7 & -7 \end{bmatrix} \quad (23)$$

and

$$B = \begin{bmatrix} -3 & 0 & 7 \\ -9 & 7 & -8 \\ 6 & 2 & 1 \end{bmatrix} \quad (24)$$

3.

$$A = \begin{bmatrix} -8 & 1 & -10 \\ 8 & 9 & 2 \\ -3 & 1 & -6 \end{bmatrix} \quad (25)$$

and

$$B = \begin{bmatrix} 9 & -7 & 9 \\ 2 & 8 & 5 \\ 3 & 8 & 9 \end{bmatrix} \quad (26)$$

4.

$$A = \begin{bmatrix} -2 & 1 & -9 \\ 6 & -9 & 3 \\ -7 & -9 & -10 \end{bmatrix} \quad (27)$$

and

$$B = \begin{bmatrix} -5 & -7 & -3 \\ 9 & 8 & -9 \\ -1 & 9 & 4 \end{bmatrix} \quad (28)$$

5.

$$A = \begin{bmatrix} -4 & 9 & 5 \\ -1 & -8 & 5 \\ -8 & -8 & 2 \end{bmatrix} \quad (29)$$

and

$$B = \begin{bmatrix} 7 & -3 & -1 \\ -3 & 1 & -2 \\ 6 & -5 & 4 \end{bmatrix} \quad (30)$$

6.

$$A = \begin{bmatrix} -2 & -10 & -2 \\ -6 & 0 & -6 \\ 6 & 0 & 1 \end{bmatrix} \quad (31)$$

and

$$B = \begin{bmatrix} -6 & 3 & 5 \\ -8 & 4 & -10 \\ 1 & 4 & 1 \end{bmatrix} \quad (32)$$

7.

$$A = \begin{bmatrix} 5 & 5 & -4 \\ -6 & -1 & 5 \\ -3 & -1 & 6 \end{bmatrix} \quad (33)$$

and

$$B = \begin{bmatrix} 2 & 8 & 8 \\ -2 & -8 & 9 \\ -7 & -1 & -4 \end{bmatrix} \quad (34)$$

8.

$$A = \begin{bmatrix} -9 & 8 & -10 \\ -10 & -3 & 2 \\ -8 & -9 & -8 \end{bmatrix} \quad (35)$$

and

$$B = \begin{bmatrix} -4 & -9 & 6 \\ 3 & -2 & 9 \\ -3 & -2 & 5 \end{bmatrix} \quad (36)$$

9.

$$A = \begin{bmatrix} 9 & -9 & 1 \\ -8 & 0 & -4 \\ -6 & -4 & -4 \end{bmatrix} \quad (37)$$

and

$$B = \begin{bmatrix} -10 & 7 & -6 \\ -10 & 4 & -1 \\ 4 & 3 & -10 \end{bmatrix} \quad (38)$$

10.

$$A = \begin{bmatrix} 7 & 2 & -5 \\ 7 & -8 & -9 \\ 2 & 6 & -4 \end{bmatrix} \quad (39)$$

and

$$B = \begin{bmatrix} -6 & -8 & 1 \\ 6 & -8 & -6 \\ 9 & -6 & 9 \end{bmatrix} \quad (40)$$

### 1.2.3. Multiplication

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

1.

$$A = \begin{bmatrix} 4 & -5 & -7 \\ 9 & -5 & -4 \\ 0 & 4 & 0 \end{bmatrix} \quad (41)$$

and

$$B = \begin{bmatrix} 1 & 6 & 1 \\ 3 & 5 & -8 \\ -9 & 0 & -9 \end{bmatrix} \quad (42)$$

2.

$$A = \begin{bmatrix} 8 & -10 & -6 \\ -5 & 4 & 6 \\ 4 & 4 & 1 \end{bmatrix} \quad (43)$$

and

$$B = \begin{bmatrix} 0 & -9 & -1 \\ -9 & -1 & 6 \\ 4 & 0 & 5 \end{bmatrix} \quad (44)$$

3.

$$A = \begin{bmatrix} 2 & 5 & 9 \\ 4 & -5 & -8 \\ 3 & -5 & 3 \end{bmatrix} \quad (45)$$

and

$$B = \begin{bmatrix} 2 & -4 & 5 \\ 7 & 4 & 2 \\ 7 & 7 & 5 \end{bmatrix} \quad (46)$$

4.

$$A = \begin{bmatrix} -1 & -3 & 4 \\ 0 & 2 & 1 \\ -3 & 7 & 5 \end{bmatrix} \quad (47)$$

and

$$B = \begin{bmatrix} -5 & 1 & 3 \\ 4 & 5 & -8 \\ -3 & -3 & 8 \end{bmatrix} \quad (48)$$

5.

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

and

$$B = \begin{bmatrix} 8 & 4 & -9 \\ 0 & -3 & 3 \\ -10 & -1 & -4 \end{bmatrix} \quad (50)$$

6.

$$A = \begin{bmatrix} -5 & -4 & 3 \\ 9 & -9 & -6 \\ -5 & 1 & -5 \end{bmatrix} \quad (51)$$



and

$$B = \begin{bmatrix} -10 & 5 & -7 \\ 5 & 7 & 9 \\ -9 & 2 & -7 \end{bmatrix} \quad (52)$$

7.

$$A = \begin{bmatrix} -4 & 3 & 1 \\ -8 & -10 & 7 \\ -6 & 4 & -3 \end{bmatrix} \quad (53)$$

and

$$B = \begin{bmatrix} -9 & 3 & -1 \\ -2 & 7 & 9 \\ 0 & -1 & 1 \end{bmatrix} \quad (54)$$

8.

$$A = \begin{bmatrix} 7 & 9 & 7 \\ -10 & 0 & 8 \\ 0 & -7 & -2 \end{bmatrix} \quad (55)$$

and

$$B = \begin{bmatrix} 7 & -5 & 2 \\ -4 & 6 & -9 \\ -3 & 6 & 1 \end{bmatrix} \quad (56)$$

9.

$$A = \begin{bmatrix} -2 & 1 & -5 \\ 4 & -10 & -4 \\ -1 & -9 & 1 \end{bmatrix} \quad (57)$$

and

$$B = \begin{bmatrix} -2 & 7 & -5 \\ 3 & 0 & -2 \\ -7 & -8 & -5 \end{bmatrix} \quad (58)$$

10.

$$A = \begin{bmatrix} 2 & 0 & -9 \\ -4 & -10 & 5 \\ 9 & -10 & -8 \end{bmatrix} \quad (59)$$

and

$$B = \begin{bmatrix} 3 & -1 & -4 \\ -1 & 2 & 6 \\ 9 & 1 & -5 \end{bmatrix} \quad (60)$$

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

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

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

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

5. 
$$A = \begin{bmatrix} 1 & -5 & -14 \\ -1 & 4 & 11 \\ 0 & 2 & 5 \end{bmatrix} \quad (65)$$

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

7. 
$$A = \begin{bmatrix} 1 & 0 & 1 \\ -2 & -3 & -6 \\ -2 & -2 & -5 \end{bmatrix} \quad (67)$$

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

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

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

### 1.3.2. RREF

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

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

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

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

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

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

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

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

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

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

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

## 1.4. Calculus

### 1.4.1. Limit

Calculate the following limits

1. Calculate the limit of the following expression:

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

2. Calculate the limit of the following expression:

$$\lim_{x \rightarrow -1} 3 - 2x \quad (82)$$

3. Calculate the limit of the following expression:

$$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x \quad (83)$$

4. Calculate the limit of the following expression:

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

5. Calculate the limit of the following expression:

$$\lim_{x \rightarrow -3} -4x - 2 \quad (85)$$

6. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x + 1)}{x} \quad (86)$$

7. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 0} \frac{\log(x + 1)}{x} \quad (87)$$

8. Calculate the limit of the following expression:

$$\lim_{x \rightarrow 1} -4x^2 + x + 2 \quad (88)$$

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:

$$\lim_{x \rightarrow \infty} \left(1 + \frac{1}{x}\right)^x \quad (90)$$

### 1.4.2. Derivative

Calculate the derivatives of the following expressions

1. Calculate the derivative of the following expression:

$$x^2 e^x \quad (91)$$

2. Calculate the derivative of the following expression:

$$x^3 \log(x) \quad (92)$$

3. Calculate the derivative of the following expression:

$$x^3 \log(x) \quad (93)$$

4. Calculate the derivative of the following expression:

$$\log(x + 1) + \log(x^2 + 1) \quad (94)$$

5. Calculate the derivative of the following expression:

$$e^{2x} + e^{x^2} \quad (95)$$

6. Calculate the derivative of the following expression:

$$e^x \quad (96)$$

7. Calculate the derivative of the following expression:

$$e^{2x} + e^{x^2} \quad (97)$$

8. Calculate the derivative of the following expression:

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

9. Calculate the derivative of the following expression:

$$\log(x+1) + \log(x^2+1) \quad (99)$$

10. Calculate the derivative of the following expression:

$$x^2 \quad (100)$$

### 1.4.3. Integral

Calculate the indefinite and definite integrals of the following expressions

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

$$\int 2x^3 - 3x^2 - x - 5dx \quad (101)$$

2. Evaluate the improper integral:

$$\int_1^{\infty} e^{-x} dx \quad (102)$$

3. Evaluate the improper integral:

$$\int_1^{\infty} e^{-x} dx \quad (103)$$

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

$$\int \frac{3x+2}{x^2-4} dx \quad (104)$$

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

$$\int -3x^3 + 4x^2 - x + 3dx \quad (105)$$

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

$$\int \frac{1}{x^2 + 1} dx \quad (106)$$

7. Evaluate the improper integral:

$$\int_1^{\infty} \frac{1}{x^2} dx \quad (107)$$

8. Evaluate the improper integral:

$$\int_1^{\infty} e^{-x} dx \quad (108)$$

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

$$\int \frac{3x + 2}{x^2 - 4} dx \quad (109)$$

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

$$\int \frac{1}{x^2 + 1} dx \quad (110)$$

#### 1.4.4. Partial Derivative

Calculate the partial derivatives of the following expressions

1. the partial derivatives of the function:

$$f(x, y) = (x + y)e^{x^2 + y^2} \quad (111)$$

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

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

$$\frac{\partial f}{\partial x} \quad (112)$$

where  $f = f(u, v)$

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. the partial derivatives of the function:

$$f(x, y) = -\log(xy) + \log(x^3 + y^3) \quad (114)$$

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

5. Given the implicit function:

$$x^2 y + xy^2 - xy = 0 \quad (115)$$

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

6. the third order partial derivative of:

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

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

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

$$\frac{\partial f}{\partial x} \quad (117)$$

where  $f = f(u, v)$

8. the partial derivatives of the function:

$$f(x, y) = x^3 y^2 - 3x^2 y + 2xy^3 \quad (118)$$

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

9. Given the implicit function:

$$x^2 y + xy^2 - xy = 0 \quad (119)$$

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

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

$$\frac{\partial f}{\partial x} \quad (120)$$

where  $f = f(u, v)$

## 2. Solutions

### 2.1. Vector Arithmetic

#### 2.1.1. Addition

$$\begin{bmatrix} -6 \\ -10 \\ -9 \end{bmatrix} + \begin{bmatrix} 6 \\ -5 \\ -5 \end{bmatrix} = \begin{bmatrix} -6 \\ 15 \\ 8 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \\ 4 \end{bmatrix} = \begin{bmatrix} -1 \\ -2 \\ 8 \end{bmatrix}$$
$$\begin{bmatrix} -5 \\ 4 \\ 2 \end{bmatrix} + \begin{bmatrix} 16 \\ -1 \\ 2 \end{bmatrix} = \begin{bmatrix} 4 \\ 6 \\ -11 \end{bmatrix} + \begin{bmatrix} -17 \\ -19 \\ 8 \end{bmatrix} = \begin{bmatrix} 0 \\ -5 \\ 5 \end{bmatrix}$$

#### 2.1.2. Subtraction

$$\begin{bmatrix} 0 \\ 10 \\ 2 \end{bmatrix} - \begin{bmatrix} -4 \\ 4 \\ 6 \end{bmatrix} = \begin{bmatrix} 10 \\ 8 \\ 9 \end{bmatrix} - \begin{bmatrix} 2 \\ -4 \\ 6 \end{bmatrix} = \begin{bmatrix} -20 \\ 2 \\ 4 \end{bmatrix}$$
$$\begin{bmatrix} -6 \\ 6 \\ 7 \end{bmatrix} - \begin{bmatrix} 0 \\ -1 \\ 16 \end{bmatrix} = \begin{bmatrix} -2 \\ 9 \\ -2 \end{bmatrix} + \begin{bmatrix} 17 \\ 13 \\ 3 \end{bmatrix} = \begin{bmatrix} 3 \\ -9 \\ -14 \end{bmatrix}$$

#### 2.1.3. Scalar Multiplication

$$1: \begin{bmatrix} 20 \\ 8 \\ -10 \end{bmatrix} \quad 2: \begin{bmatrix} 18 \\ -63 \\ 63 \end{bmatrix} \quad 3: \begin{bmatrix} 21 \\ -7 \\ -42 \end{bmatrix} \quad 4: \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad 5: \begin{bmatrix} 0 \\ -7 \\ 10 \end{bmatrix}$$
$$6: \begin{bmatrix} -45 \\ 35 \\ 15 \end{bmatrix} \quad 7: \begin{bmatrix} -6 \\ -9 \\ -9 \end{bmatrix} \quad 8: \begin{bmatrix} 15 \\ 35 \\ 0 \end{bmatrix} \quad 9: \begin{bmatrix} 48 \\ -48 \\ -60 \end{bmatrix} \quad 10: \begin{bmatrix} 4 \\ -18 \\ -2 \end{bmatrix}$$

## 2.2. Matrix Arithmetic

#### 2.2.1. Addition

1:

$$\begin{bmatrix} 1 & -14 & -8 \\ -6 & 6 & -18 \\ 4 & -12 & 4 \end{bmatrix} \quad (121)$$

1:

$$\begin{bmatrix} 10 & 4 & -6 \\ 3 & 4 & 8 \\ 0 & 4 & -14 \end{bmatrix} \quad (122)$$

1:

$$\begin{bmatrix} -1 & 6 & -5 \\ 7 & -2 & 12 \\ -4 & -16 & 1 \end{bmatrix} \quad (123)$$

1:

$$\begin{bmatrix} -8 & -9 & -7 \\ -7 & 2 & -7 \\ -9 & -3 & -12 \end{bmatrix} \quad (124)$$



1:

$$\begin{bmatrix} 0 & -4 & -5 \\ -6 & -2 & 14 \\ 8 & 3 & -4 \end{bmatrix} \quad (125)$$

1:

$$\begin{bmatrix} -18 & 0 & -6 \\ -4 & -1 & 5 \\ -14 & -12 & -1 \end{bmatrix} \quad (126)$$

1:

$$\begin{bmatrix} 1 & -7 & -10 \\ -5 & -4 & -5 \\ -4 & -14 & -11 \end{bmatrix} \quad (127)$$

1:

$$\begin{bmatrix} -17 & -11 & -4 \\ 1 & 2 & -12 \\ -6 & 8 & -13 \end{bmatrix} \quad (128)$$

1:

$$\begin{bmatrix} -3 & -6 & -1 \\ -11 & 3 & -3 \\ -5 & -10 & 2 \end{bmatrix} \quad (129)$$

1:

$$\begin{bmatrix} 3 & -2 & 5 \\ -19 & -6 & 3 \\ -4 & -2 & 7 \end{bmatrix} \quad (130)$$

### 2.2.2. Subtraction

1:

$$\begin{bmatrix} -3 & 7 & 7 \\ 15 & -9 & 16 \\ -2 & 3 & 7 \end{bmatrix} \quad (131)$$

1:

$$\begin{bmatrix} -1 & 4 & -17 \\ 16 & -15 & 1 \\ -14 & -9 & -8 \end{bmatrix} \quad (132)$$

1:

$$\begin{bmatrix} -17 & 8 & -19 \\ 6 & 1 & -3 \\ -6 & -7 & -15 \end{bmatrix} \quad (133)$$

1:

$$\begin{bmatrix} 3 & 8 & -6 \\ -3 & -17 & 12 \\ -6 & -18 & -14 \end{bmatrix} \quad (134)$$

1:

$$\begin{bmatrix} -11 & 12 & 6 \\ 2 & -9 & 7 \\ -14 & -3 & -2 \end{bmatrix} \quad (135)$$

1:

$$\begin{bmatrix} 4 & -13 & -7 \\ 2 & -4 & 4 \\ 5 & -4 & 0 \end{bmatrix} \quad (136)$$

1:

$$\begin{bmatrix} 3 & -3 & -12 \\ -4 & 7 & -4 \\ 4 & 0 & 10 \end{bmatrix} \quad (137)$$

1:

$$\begin{bmatrix} -5 & 17 & -16 \\ -13 & -1 & -7 \\ -5 & -7 & -13 \end{bmatrix} \quad (138)$$

1:

$$\begin{bmatrix} 19 & -16 & 7 \\ 2 & -4 & -3 \\ -10 & -7 & 6 \end{bmatrix} \quad (139)$$

1:

$$\begin{bmatrix} 13 & 10 & -6 \\ 1 & 0 & -3 \\ -7 & 12 & -13 \end{bmatrix} \quad (140)$$

### 2.2.3. Multiplication

1:

$$\begin{bmatrix} 52 & -1 & 107 \\ 30 & 29 & 85 \\ 12 & 20 & -32 \end{bmatrix} \quad (141)$$

1:

$$\begin{bmatrix} 66 & -62 & -98 \\ -12 & 41 & 59 \\ -32 & -40 & 25 \end{bmatrix} \quad (142)$$

1:

$$\begin{bmatrix} 102 & 75 & 65 \\ -83 & -92 & -30 \\ -8 & -11 & 20 \end{bmatrix} \quad (143)$$

1:

$$\begin{bmatrix} -19 & -28 & 53 \\ 5 & 7 & -8 \\ 28 & 17 & -25 \end{bmatrix} \quad (144)$$

1:

$$\begin{bmatrix} 162 & 39 & -39 \\ -14 & 12 & -82 \\ 110 & 36 & -26 \end{bmatrix} \quad (145)$$

1:

$$\begin{bmatrix} 3 & -47 & -22 \\ -81 & -30 & -102 \\ 100 & -28 & 79 \end{bmatrix} \quad (146)$$

1:

$$\begin{bmatrix} 30 & 8 & 32 \\ 92 & -101 & -75 \\ 46 & 13 & 39 \end{bmatrix} \quad (147)$$

1:

$$\begin{bmatrix} -8 & 61 & -60 \\ -94 & 98 & -12 \\ 34 & -54 & 61 \end{bmatrix} \quad (148)$$

1:

$$\begin{bmatrix} 42 & 26 & 33 \\ -10 & 60 & 20 \\ -32 & -15 & 18 \end{bmatrix} \quad (149)$$

1:

$$\begin{bmatrix} -75 & -11 & 37 \\ 43 & -11 & -69 \\ -35 & -37 & -56 \end{bmatrix} \quad (150)$$

## 2.3. Matrix Properties

### 2.3.1. Properties

#### Solution

#### Row Operations:

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

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

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

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

$$\text{Step 5: } r_2 := r_2 - (-1)r_3 \quad \begin{bmatrix} 1 & 0 & 0 & | & 2 & 1 & -3 \\ 0 & 1 & 0 & | & -1 & 0 & 1 \\ 0 & 0 & 1 & | & 0 & 0 & 1 \end{bmatrix}$$

#### Results:

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

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

c)  $\det(A) = 0$

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

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

#### Solution

#### Row Operations:

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

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

#### Results:

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

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

c)  $\det(A) = 0$

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

e)  $\ker(A) = \text{span} \left\{ \begin{bmatrix} 0 \\ 2 \\ 1 \end{bmatrix} \right\}$

### Solution

#### Row Operations:

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

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

Step 3:  $r_3 := r_3 - (3)r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & -1 & 1 & 5 & 0 \\ 0 & 1 & -1 & 0 & 1 & 0 \\ 0 & 0 & 1 & -1 & -3 & 1 \end{array} \right]$

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

Step 5:  $r_2 := r_2 - (-1)r_3$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 0 & 2 & 1 \\ 0 & 1 & 0 & -1 & -2 & 1 \\ 0 & 0 & 1 & -1 & -3 & 1 \end{array} \right]$

### Results:

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

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

c)  $\det(A) = 0$

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

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

### Solution

#### Row Operations:

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

Step 2:  $r_1 := r_1 - (-2)r_2$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 8 & 1 & 2 & 0 \\ 0 & 1 & 4 & 0 & 1 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 \end{array} \right]$

Step 3:  $r_1 := r_1 - (8)r_3$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 9 & 2 & -8 \\ 0 & 1 & 4 & 0 & 1 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 \end{array} \right]$

Step 4:  $r_2 := r_2 - (4)r_3$   $\left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 9 & 2 & -8 \\ 0 & 1 & 0 & 4 & 1 & -4 \\ 0 & 0 & 1 & -1 & 0 & 1 \end{array} \right]$

**Results:**

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

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

c)  $\det(A) = 0$

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

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

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

Step 1:  $r_2 := r_2 - (-1)r_1 \quad \begin{bmatrix} 1 & -5 & -14 & | & 1 & 0 & 0 \\ 0 & -1 & -3 & | & 1 & 1 & 0 \\ 0 & 2 & 5 & | & 0 & 0 & 1 \end{bmatrix}$

Step 2:  $r_2 := -1r_2 \quad \begin{bmatrix} 1 & -5 & -14 & | & 1 & 0 & 0 \\ 0 & 1 & 3 & | & -1 & -1 & 0 \\ 0 & 2 & 5 & | & 0 & 0 & 1 \end{bmatrix}$

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

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

Step 5:  $r_3 := -1r_3 \quad \begin{bmatrix} 1 & 0 & 1 & | & -4 & -5 & 0 \\ 0 & 1 & 3 & | & -1 & -1 & 0 \\ 0 & 0 & 1 & | & -2 & -2 & -1 \end{bmatrix}$

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

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

**Results:**

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

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

c)  $\det(A) = 0$

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

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

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

$$\begin{aligned} \text{Step 1: } r_1 &:= -1/3r_1 \begin{bmatrix} 1 & 5/3 & 1/3 & | & -1/3 & 0 & 0 \\ 0 & 1 & -1 & | & 0 & 1 & 0 \\ -2 & -3 & -1 & | & 0 & 0 & 1 \end{bmatrix} \\ \text{Step 2: } r_3 &:= r_3 - (-2)r_1 \begin{bmatrix} 1 & 5/3 & 1/3 & | & -1/3 & 0 & 0 \\ 0 & 1 & -1 & | & 0 & 1 & 0 \\ 0 & 1/3 & -1/3 & | & -2/3 & 0 & 1 \end{bmatrix} \\ \text{Step 3: } r_1 &:= r_1 - (5/3)r_2 \begin{bmatrix} 1 & 0 & 2 & | & -1/3 & -5/3 & 0 \\ 0 & 1 & -1 & | & 0 & 1 & 0 \\ 0 & 1/3 & -1/3 & | & -2/3 & 0 & 1 \end{bmatrix} \\ \text{Step 4: } r_3 &:= r_3 - (1/3)r_2 \begin{bmatrix} 1 & 0 & 2 & | & -1/3 & -5/3 & 0 \\ 0 & 1 & -1 & | & 0 & 1 & 0 \\ 0 & 0 & 0 & | & -2/3 & -1/3 & 1 \end{bmatrix} \end{aligned}$$

**Results:**

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

**Solution**

**Row Operations:**

$$\begin{aligned} \text{Step 1: } r_2 &:= r_2 - (-2)r_1 \begin{bmatrix} 1 & 0 & 1 & | & 1 & 0 & 0 \\ 0 & -3 & -4 & | & 2 & 1 & 0 \\ -2 & -2 & -5 & | & 0 & 0 & 1 \end{bmatrix} \\ \text{Step 2: } r_3 &:= r_3 - (-2)r_1 \begin{bmatrix} 1 & 0 & 1 & | & 1 & 0 & 0 \\ 0 & -3 & -4 & | & 2 & 1 & 0 \\ 0 & -2 & -3 & | & 2 & 0 & 1 \end{bmatrix} \\ \text{Step 3: } r_2 &:= -1/3r_2 \begin{bmatrix} 1 & 0 & 1 & | & 1 & 0 & 0 \\ 0 & 1 & 4/3 & | & -2/3 & -1/3 & 0 \\ 0 & -2 & -3 & | & 2 & 0 & 1 \end{bmatrix} \\ \text{Step 4: } r_3 &:= r_3 - (-2)r_2 \begin{bmatrix} 1 & 0 & 1 & | & 1 & 0 & 0 \\ 0 & 1 & 4/3 & | & -2/3 & -1/3 & 0 \\ 0 & 0 & -1/3 & | & 2/3 & -2/3 & 1 \end{bmatrix} \\ \text{Step 5: } r_3 &:= -3r_3 \begin{bmatrix} 1 & 0 & 1 & | & 1 & 0 & 0 \\ 0 & 1 & 4/3 & | & -2/3 & -1/3 & 0 \\ 0 & 0 & 1 & | & -2 & 2 & -3 \end{bmatrix} \\ \text{Step 6: } r_1 &:= r_1 - r_3 \begin{bmatrix} 1 & 0 & 0 & | & 3 & -2 & 3 \\ 0 & 1 & 4/3 & | & -2/3 & -1/3 & 0 \\ 0 & 0 & 1 & | & -2 & 2 & -3 \end{bmatrix} \\ \text{Step 7: } r_2 &:= r_2 - (4/3)r_3 \begin{bmatrix} 1 & 0 & 0 & | & 3 & -2 & 3 \\ 0 & 1 & 0 & | & 2 & -3 & 4 \\ 0 & 0 & 1 & | & -2 & 2 & -3 \end{bmatrix} \end{aligned}$$

**Results:**

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

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

c)  $\det(A) = 0$

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

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

### Solution

#### Row Operations:

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

#### Results:

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

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

c)  $\det(A) = 0$

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

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

### Solution

#### Row Operations:

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

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

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

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

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

#### Results:

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

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



c)  $\det(A) = 0$

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

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

### Solution

#### Row Operations:

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

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

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

### Results:

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

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

c)  $\det(A) = 0$

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

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

### 2.3.2. RREF

#### Solution

#### Elementary Row Operations:

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

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

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

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

### Result:

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

### Solution

#### Elementary Row Operations:

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

(3)  $r_1 := r_1 - r_2$

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

(1)  $r_1 := r_1 - r_2$

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

## 2.4. Calculus

### 2.4.1. Limit

The limit is:

$$1 \tag{151}$$

The limit is:

$$5 \tag{152}$$

The limit is:

$$e \tag{153}$$

The limit is:

$$2 \tag{154}$$

The limit is:

$$10 \tag{155}$$

The limit is:

$$1 \tag{156}$$

The limit is:

$$1 \tag{157}$$

The limit is:

$$-1 \tag{158}$$

The limit is:

$$1 \tag{159}$$

The limit is:

$$e \quad (160)$$

### 2.4.2. Derivative

The derivative is:

$$x^2 e^x + 2x e^x \quad (161)$$

The derivative is:

$$3x^2 \log(x) + x^2 \quad (162)$$

The derivative is:

$$3x^2 \log(x) + x^2 \quad (163)$$

The derivative is:

$$\frac{2x}{x^2 + 1} + \frac{1}{x + 1} \quad (164)$$

The derivative is:

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

The derivative is:

$$e^x \quad (166)$$

The derivative is:

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

The derivative is:

$$2x e^{x^2+1} \quad (168)$$

The derivative is:

$$\frac{2x}{x^2 + 1} + \frac{1}{x + 1} \quad (169)$$

The derivative is:

$$2x \quad (170)$$

### 2.4.3. Integral

The indefinite integral is:

$$\frac{x^4}{2} - x^3 - \frac{x^2}{2} - 5x \quad (171)$$

Definite integral from 2 to 5:

$$162 \quad (172)$$

The improper integral converges to:

$$e^{-1} \quad (173)$$

The improper integral converges to:

$$e^{-1} \quad (174)$$

The indefinite integral is:

$$2 \log(x - 2) + \log(x + 2) \quad (175)$$

Definite integral from 2 to 5:

$$\infty \quad (176)$$

The indefinite integral is:

$$-\frac{3x^4}{4} + \frac{4x^3}{3} - \frac{x^2}{2} + 3x \quad (177)$$

Definite integral from 1 to 5:

$$-\frac{908}{3} \quad (178)$$

The indefinite integral is:

$$\operatorname{atan}(x) \quad (179)$$

Definite integral from 3 to 5:

$$-\operatorname{atan}(3) + \operatorname{atan}(5) \quad (180)$$

The improper integral converges to:

$$1 \quad (181)$$

The improper integral converges to:

$$e^{-1} \quad (182)$$

The indefinite integral is:

$$2 \log(x - 2) + \log(x + 2) \quad (183)$$

Definite integral from 2 to 3:

$$\infty \quad (184)$$

The indefinite integral is:

$$\operatorname{atan}(x) \quad (185)$$

Definite integral from 2 to 3:

$$- \operatorname{atan}(2) + \operatorname{atan}(3) \quad (186)$$

#### 2.4.4. Partial Derivative

$$\frac{\partial f}{\partial x} = 2x(x+y)e^{x^2+y^2} + e^{x^2+y^2} \quad (187)$$

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

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (189)$$

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

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

$$\frac{\partial f}{\partial x} = \frac{3x^2}{x^3 + y^3} - \frac{1}{x} \quad (192)$$

$$\frac{\partial f}{\partial y} = \frac{3y^2}{x^3 + y^3} - \frac{1}{y} \quad (193)$$

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

$$\frac{\partial^3 f}{\partial y^3} = 6x^2(x^2 + 12y) \quad (195)$$

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

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

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

$$\frac{\partial y}{\partial x} = \frac{-2xy - y^2 + y}{x^2 + 2xy - x} \quad (199)$$

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial f}{\partial v} \frac{\partial v}{\partial x} \quad (200)$$