

# Exercise 3:

## Foundations of Mathematical, WS24

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This is **exercise** 3 for Foundations of Mathematical, WS24. Generated on 2024-12-09 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.  $\mathbf{u} = \begin{bmatrix} 2 \\ 6 \\ -8 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -3 \\ -7 \\ 5 \end{bmatrix}$
2.  $\mathbf{u} = \begin{bmatrix} -3 \\ 9 \\ 0 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -1 \\ -4 \\ -8 \end{bmatrix}$
3.  $\mathbf{u} = \begin{bmatrix} 3 \\ 1 \\ -4 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -6 \\ -4 \\ -5 \end{bmatrix}$
4.  $\mathbf{u} = \begin{bmatrix} -4 \\ 8 \\ 8 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -6 \\ 9 \\ -8 \end{bmatrix}$
5.  $\mathbf{u} = \begin{bmatrix} 3 \\ 2 \\ 2 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -10 \\ 10 \\ -9 \end{bmatrix}$
6.  $\mathbf{u} = \begin{bmatrix} 9 \\ -10 \\ 10 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} 4 \\ -4 \\ 10 \end{bmatrix}$
7.  $\mathbf{u} = \begin{bmatrix} -5 \\ -5 \\ -4 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} 4 \\ -8 \\ -9 \end{bmatrix}$
8.  $\mathbf{u} = \begin{bmatrix} -6 \\ -10 \\ -5 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} 6 \\ 9 \\ 10 \end{bmatrix}$
9.  $\mathbf{u} = \begin{bmatrix} -9 \\ 2 \\ 5 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} 9 \\ -7 \\ -2 \end{bmatrix}$
10.  $\mathbf{u} = \begin{bmatrix} 8 \\ 6 \\ 1 \end{bmatrix}, \mathbf{v} = \begin{bmatrix} -7 \\ -3 \\ -10 \end{bmatrix}$

### 1.1.2. Subtraction

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

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

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

### 1.1.3. Scalar Multiplication

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

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

## 1.2. Matrix Arithmetic

### 1.2.1. Addition

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

1.  $A = \begin{bmatrix} -6 & 8 & -6 \\ 7 & -6 & 3 \\ -5 & -2 & 5 \end{bmatrix}$  and  $B = \begin{bmatrix} 1 & -10 & 3 \\ -8 & -3 & 4 \\ -7 & -1 & -5 \end{bmatrix}$

2.  $A = \begin{bmatrix} -7 & 9 & 2 \\ -10 & 5 & -1 \\ 1 & -1 & 4 \end{bmatrix}$  and  $B = \begin{bmatrix} -2 & 7 & 0 \\ -6 & 4 & -9 \\ -4 & -8 & -9 \end{bmatrix}$
3.  $A = \begin{bmatrix} -10 & 5 & -1 \\ 5 & -1 & 1 \\ -3 & -4 & -3 \end{bmatrix}$  and  $B = \begin{bmatrix} -3 & 8 & -10 \\ -9 & -10 & -2 \\ 5 & 7 & 3 \end{bmatrix}$
4.  $A = \begin{bmatrix} -7 & -2 & 2 \\ 0 & 7 & -5 \\ 3 & 0 & -6 \end{bmatrix}$  and  $B = \begin{bmatrix} -4 & -8 & -6 \\ -2 & -4 & 4 \\ 6 & -10 & -6 \end{bmatrix}$
5.  $A = \begin{bmatrix} 8 & 1 & 8 \\ -2 & -1 & -2 \\ -1 & 1 & -10 \end{bmatrix}$  and  $B = \begin{bmatrix} -7 & -6 & -5 \\ 3 & 8 & 5 \\ -2 & -4 & -5 \end{bmatrix}$
6.  $A = \begin{bmatrix} -4 & 9 & 8 \\ 1 & -7 & 0 \\ -5 & -4 & 4 \end{bmatrix}$  and  $B = \begin{bmatrix} 1 & 3 & -1 \\ 7 & -1 & -10 \\ -5 & 9 & 9 \end{bmatrix}$
7.  $A = \begin{bmatrix} -8 & 1 & -2 \\ -2 & -9 & -4 \\ -7 & 3 & -3 \end{bmatrix}$  and  $B = \begin{bmatrix} 3 & 1 & -3 \\ -2 & -3 & 3 \\ 3 & 2 & -3 \end{bmatrix}$
8.  $A = \begin{bmatrix} -6 & 3 & -7 \\ -8 & -10 & -4 \\ 0 & -1 & 6 \end{bmatrix}$  and  $B = \begin{bmatrix} -7 & 7 & 2 \\ -2 & -10 & -5 \\ -5 & -7 & -8 \end{bmatrix}$
9.  $A = \begin{bmatrix} 3 & -6 & -4 \\ -7 & 1 & -4 \\ 8 & 7 & -2 \end{bmatrix}$  and  $B = \begin{bmatrix} -1 & -5 & 2 \\ 0 & -9 & 1 \\ -1 & -9 & -9 \end{bmatrix}$
10.  $A = \begin{bmatrix} -3 & -6 & -3 \\ -9 & -10 & -7 \\ 7 & -6 & 4 \end{bmatrix}$  and  $B = \begin{bmatrix} -2 & -4 & -7 \\ -4 & -7 & -6 \\ 4 & 5 & -9 \end{bmatrix}$

### 1.2.2. Subtraction

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

1.  $A = \begin{bmatrix} -7 & -1 & 1 \\ -4 & -3 & -10 \\ 2 & -9 & 6 \end{bmatrix}$  and  $B = \begin{bmatrix} -1 & 8 & -1 \\ 5 & 6 & -6 \\ 8 & 2 & 2 \end{bmatrix}$
2.  $A = \begin{bmatrix} 8 & 6 & -7 \\ -6 & 2 & -1 \\ -6 & 7 & 2 \end{bmatrix}$  and  $B = \begin{bmatrix} 2 & 6 & 3 \\ 5 & 8 & -7 \\ -6 & -8 & -9 \end{bmatrix}$
3.  $A = \begin{bmatrix} -3 & -2 & 7 \\ -6 & 9 & 5 \\ 8 & 4 & 2 \end{bmatrix}$  and  $B = \begin{bmatrix} 5 & -4 & -4 \\ -7 & 2 & -10 \\ 2 & -2 & 7 \end{bmatrix}$
4.  $A = \begin{bmatrix} -8 & -3 & -10 \\ -2 & 2 & -5 \\ -10 & 7 & -4 \end{bmatrix}$  and  $B = \begin{bmatrix} -8 & -6 & 0 \\ -9 & 1 & -8 \\ -4 & -5 & -2 \end{bmatrix}$
5.  $A = \begin{bmatrix} -1 & 8 & -10 \\ -10 & -1 & -1 \\ 8 & 5 & -1 \end{bmatrix}$  and  $B = \begin{bmatrix} -10 & -8 & -3 \\ -6 & 3 & -3 \\ 0 & -2 & -5 \end{bmatrix}$
6.  $A = \begin{bmatrix} 0 & -8 & 9 \\ -8 & -3 & -8 \\ -4 & 9 & 2 \end{bmatrix}$  and  $B = \begin{bmatrix} 2 & -8 & -9 \\ 7 & -1 & 2 \\ -3 & 6 & 5 \end{bmatrix}$
7.  $A = \begin{bmatrix} 9 & -1 & 1 \\ -8 & 8 & -2 \\ 5 & -8 & -1 \end{bmatrix}$  and  $B = \begin{bmatrix} 6 & -3 & 1 \\ 4 & -8 & 1 \\ -8 & 5 & 1 \end{bmatrix}$
8.  $A = \begin{bmatrix} 4 & 1 & 3 \\ 4 & 6 & 5 \\ 0 & -7 & -5 \end{bmatrix}$  and  $B = \begin{bmatrix} 1 & -2 & -2 \\ 8 & 6 & -4 \\ -8 & 2 & -2 \end{bmatrix}$

$$\begin{aligned}
9. \quad A &= \begin{bmatrix} -5 & -5 & 9 \\ -2 & 6 & -6 \\ -7 & -10 & -7 \end{bmatrix} \text{ and } B = \begin{bmatrix} -4 & -6 & 6 \\ -2 & -8 & -9 \\ -1 & -3 & 8 \end{bmatrix} \\
10. \quad A &= \begin{bmatrix} 1 & -9 & -9 \\ -3 & 7 & -2 \\ 3 & 5 & 0 \end{bmatrix} \text{ and } B = \begin{bmatrix} -1 & -3 & 4 \\ 1 & -9 & -5 \\ 2 & 7 & -3 \end{bmatrix}
\end{aligned}$$

### 1.2.3. Multiplication

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

$$\begin{aligned}
1. \quad A &= \begin{bmatrix} 9 & 4 & -4 \\ 3 & -8 & -8 \\ -3 & -4 & -2 \end{bmatrix} \text{ and } B = \begin{bmatrix} -1 & -10 & 2 \\ -2 & -8 & 2 \\ -5 & 5 & 9 \end{bmatrix} \\
2. \quad A &= \begin{bmatrix} -1 & -1 & -7 \\ 8 & -7 & 1 \\ 1 & 2 & -10 \end{bmatrix} \text{ and } B = \begin{bmatrix} -5 & 6 & 6 \\ -3 & -4 & 7 \\ -8 & 7 & 6 \end{bmatrix} \\
3. \quad A &= \begin{bmatrix} -8 & -2 & -1 \\ -1 & -6 & -1 \\ 9 & 8 & 2 \end{bmatrix} \text{ and } B = \begin{bmatrix} -2 & -4 & -5 \\ 4 & -6 & -4 \\ 2 & 0 & 6 \end{bmatrix} \\
4. \quad A &= \begin{bmatrix} -7 & 6 & 7 \\ -10 & -2 & -10 \\ -10 & 5 & 6 \end{bmatrix} \text{ and } B = \begin{bmatrix} -7 & -3 & -10 \\ 5 & 1 & 5 \\ -9 & -1 & -7 \end{bmatrix} \\
5. \quad A &= \begin{bmatrix} 5 & 5 & -9 \\ 9 & 8 & -9 \\ -10 & 6 & -7 \end{bmatrix} \text{ and } B = \begin{bmatrix} 0 & -7 & 8 \\ 8 & -10 & 9 \\ 3 & -3 & -5 \end{bmatrix} \\
6. \quad A &= \begin{bmatrix} -2 & 4 & 5 \\ -3 & -3 & -10 \\ -2 & 9 & 9 \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 & 1 & -6 \\ -5 & 0 & -10 \\ -1 & -7 & -9 \end{bmatrix} \\
7. \quad A &= \begin{bmatrix} 4 & 1 & -5 \\ -2 & 4 & -6 \\ -2 & 5 & -9 \end{bmatrix} \text{ and } B = \begin{bmatrix} -4 & -4 & -8 \\ 7 & 5 & 3 \\ -3 & 9 & -1 \end{bmatrix} \\
8. \quad A &= \begin{bmatrix} 2 & 1 & -4 \\ -6 & 0 & -7 \\ -1 & -6 & 9 \end{bmatrix} \text{ and } B = \begin{bmatrix} 8 & 3 & 4 \\ 1 & -2 & 8 \\ 9 & -8 & -8 \end{bmatrix} \\
9. \quad A &= \begin{bmatrix} 8 & -9 & 9 \\ -6 & 3 & 9 \\ -7 & 1 & 9 \end{bmatrix} \text{ and } B = \begin{bmatrix} -6 & 5 & -10 \\ 7 & 6 & 6 \\ -2 & -6 & -4 \end{bmatrix} \\
10. \quad A &= \begin{bmatrix} 4 & -9 & -7 \\ -3 & -9 & -7 \\ 0 & 9 & -3 \end{bmatrix} \text{ and } B = \begin{bmatrix} 3 & 4 & 1 \\ -3 & -6 & -3 \\ 0 & -5 & -5 \end{bmatrix}
\end{aligned}$$

## 1.3. Matrix Properties

### 1.3.1. Properties

For each matrix  $A$ , find:

- $\text{rank}(A)$
- $\text{nullity}(A)$
- $\det(A)$
- $A^{-1}$  (if exists)
- basis of  $\ker(A)$

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

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

### 1.3.2. RREF

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

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

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

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

## 2. Solutions

### 2.1. Vector Arithmetic

#### 2.1.1. Addition

$$\begin{bmatrix} -1 \\ -1 \\ -3 \end{bmatrix} \begin{bmatrix} -4 \\ 5 \\ -8 \end{bmatrix} \begin{bmatrix} -3 \\ -3 \\ -9 \end{bmatrix} \begin{bmatrix} -10 \\ 17 \\ 0 \end{bmatrix} \begin{bmatrix} -7 \\ 12 \\ -7 \end{bmatrix}$$
$$\begin{bmatrix} 13 \\ -14 \\ 20 \end{bmatrix} \begin{bmatrix} -1 \\ -13 \\ -13 \end{bmatrix} \begin{bmatrix} 0 \\ -1 \\ 5 \end{bmatrix} \begin{bmatrix} 0 \\ -5 \\ 3 \end{bmatrix} \begin{bmatrix} 1 \\ 3 \\ -9 \end{bmatrix}$$

#### 2.1.2. Subtraction

$$\begin{bmatrix} -17 \\ -6 \\ 5 \end{bmatrix} \begin{bmatrix} -2 \\ 8 \\ -13 \end{bmatrix} \begin{bmatrix} 11 \\ 10 \\ -16 \end{bmatrix} \begin{bmatrix} 4 \\ 12 \\ -9 \end{bmatrix} \begin{bmatrix} 0 \\ -12 \\ 7 \end{bmatrix}$$
$$\begin{bmatrix} -12 \\ 5 \\ 13 \end{bmatrix} \begin{bmatrix} -4 \\ 12 \\ 9 \end{bmatrix} \begin{bmatrix} -3 \\ 1 \\ -12 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ -8 \end{bmatrix} \begin{bmatrix} 15 \\ 3 \\ 12 \end{bmatrix}$$

#### 2.1.3. Scalar Multiplication

$$1: \begin{bmatrix} 20 \\ 50 \\ 50 \end{bmatrix} \quad 2: \begin{bmatrix} -42 \\ 0 \\ 56 \end{bmatrix} \quad 3: \begin{bmatrix} -20 \\ 8 \\ -14 \end{bmatrix} \quad 4: \begin{bmatrix} 20 \\ 28 \\ -20 \end{bmatrix} \quad 5: \begin{bmatrix} 49 \\ 70 \\ -42 \end{bmatrix}$$
$$6: \begin{bmatrix} -21 \\ 0 \\ 7 \end{bmatrix} \quad 7: \begin{bmatrix} 8 \\ -8 \\ 56 \end{bmatrix} \quad 8: \begin{bmatrix} 42 \\ -21 \\ 0 \end{bmatrix} \quad 9: \begin{bmatrix} -2 \\ 14 \\ -2 \end{bmatrix} \quad 10: \begin{bmatrix} -36 \\ 90 \\ 9 \end{bmatrix}$$

## 2.2. Matrix Arithmetic

#### 2.2.1. Addition

$$1: \begin{bmatrix} -5 & -2 & -3 \\ -1 & -9 & 7 \\ -12 & -3 & 0 \end{bmatrix} \quad 2: \begin{bmatrix} -9 & 16 & 2 \\ -16 & 9 & -10 \\ -3 & -9 & -5 \end{bmatrix} \quad 3: \begin{bmatrix} -13 & 13 & -11 \\ -4 & -11 & -1 \\ 2 & 3 & 0 \end{bmatrix} \quad 4: \begin{bmatrix} -11 & -10 & -4 \\ -2 & 3 & -1 \\ 9 & -10 & -12 \end{bmatrix} \quad 5: \begin{bmatrix} 1 & -5 & 3 \\ 1 & 7 & 3 \\ -3 & -3 & -15 \end{bmatrix}$$
$$6: \begin{bmatrix} -3 & 12 & 7 \\ 8 & -8 & -10 \\ -10 & 5 & 13 \end{bmatrix} \quad 7: \begin{bmatrix} -5 & 2 & -5 \\ -4 & -12 & -1 \\ -4 & 5 & -6 \end{bmatrix} \quad 8: \begin{bmatrix} -13 & 10 & -5 \\ -10 & -20 & -9 \\ -5 & -8 & -2 \end{bmatrix} \quad 9: \begin{bmatrix} 2 & -11 & -2 \\ -7 & -8 & -3 \\ 7 & -2 & -11 \end{bmatrix} \quad 10: \begin{bmatrix} -5 & -10 & -10 \\ -13 & -17 & -13 \\ 11 & -1 & -5 \end{bmatrix}$$

#### 2.2.2. Subtraction

$$1: \begin{bmatrix} -6 & -9 & 2 \\ -9 & -9 & -4 \\ -6 & -11 & 4 \end{bmatrix} \quad 2: \begin{bmatrix} 6 & 0 & -10 \\ -11 & -6 & 6 \\ 0 & 15 & 11 \end{bmatrix} \quad 3: \begin{bmatrix} -8 & 2 & 11 \\ 1 & 7 & 15 \\ 6 & 6 & -5 \end{bmatrix} \quad 4: \begin{bmatrix} 0 & 3 & -10 \\ 7 & 1 & 3 \\ -6 & 12 & -2 \end{bmatrix} \quad 5: \begin{bmatrix} 9 & 16 & -7 \\ -4 & -4 & 2 \\ 8 & 7 & 4 \end{bmatrix}$$
$$6: \begin{bmatrix} -2 & 0 & 18 \\ -15 & -2 & -10 \\ -1 & 3 & -3 \end{bmatrix} \quad 7: \begin{bmatrix} 3 & 2 & 0 \\ -12 & 16 & -3 \\ 13 & -13 & -2 \end{bmatrix} \quad 8: \begin{bmatrix} 3 & 3 & 5 \\ -4 & 0 & 9 \\ 8 & -9 & -3 \end{bmatrix} \quad 9: \begin{bmatrix} -1 & 1 & 3 \\ 0 & 14 & 3 \\ -6 & -7 & -15 \end{bmatrix} \quad 10: \begin{bmatrix} 2 & -6 & -13 \\ -4 & 16 & 3 \\ 1 & -2 & 3 \end{bmatrix}$$

#### 2.2.3. Multiplication

$$1: \begin{bmatrix} 3 & -142 & -10 \\ 53 & -6 & -82 \\ 21 & 52 & -32 \end{bmatrix} \quad 2: \begin{bmatrix} 64 & -51 & -55 \\ -27 & 83 & 5 \\ 69 & -72 & -40 \end{bmatrix} \quad 3: \begin{bmatrix} 6 & 44 & 42 \\ -24 & 40 & 23 \\ 18 & -84 & -65 \end{bmatrix} \quad 4: \begin{bmatrix} 16 & 20 & 51 \\ 150 & 38 & 160 \\ 41 & 29 & 83 \end{bmatrix} \quad 5: \begin{bmatrix} 13 & -58 & 130 \\ 37 & -116 & 189 \\ 27 & 31 & 9 \end{bmatrix}$$
$$6: \begin{bmatrix} -31 & -37 & -73 \\ 16 & 67 & 138 \\ -60 & -65 & -159 \end{bmatrix} \quad 7: \begin{bmatrix} 6 & -56 & -24 \\ 54 & -26 & 34 \\ 70 & -48 & 40 \end{bmatrix} \quad 8: \begin{bmatrix} -19 & 36 & 48 \\ -111 & 38 & 32 \\ 67 & -63 & -124 \end{bmatrix} \quad 9: \begin{bmatrix} -129 & -68 & -170 \\ 39 & -66 & 42 \\ 31 & -83 & 40 \end{bmatrix} \quad 10: \begin{bmatrix} 39 & 105 & 66 \\ 18 & 77 & 59 \\ -27 & -39 & -12 \end{bmatrix}$$

## 2.3. Matrix Properties



### 2.3.1. Properties

#### Solution

##### Row Operations:

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

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

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

$$\text{Step 4: } r_3 := r_3 - (-1)r_2 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & -3 & 5 & -2 & 0 \\ 0 & 1 & 1 & -2 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 \end{array} \right]$$

##### 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:

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

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

##### 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:**

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

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

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

**Results:**

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

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

c)  $\det(A) = 0$

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

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

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

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

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

**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:**

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

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

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

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

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

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

### Results:

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

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

c)  $\det(A) = 0$

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

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

### Solution

#### Row Operations:

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

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

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

### 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:**

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

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

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

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

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

**Results:**

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

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

c)  $\det(A) = 0$

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

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

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

$$\text{Step 1: } r_3 := r_3 - (-1)r_1 \quad \begin{bmatrix} 1 & -2 & 1 & | & 1 & 0 & 0 \\ 0 & -7 & -9 & | & 0 & 1 & 0 \\ 0 & 4 & 5 & | & 1 & 0 & 1 \end{bmatrix}$$

$$\text{Step 2: } r_2 := -1/7r_2 \quad \begin{bmatrix} 1 & -2 & 1 & | & 1 & 0 & 0 \\ 0 & 1 & 9/7 & | & 0 & -1/7 & 0 \\ 0 & 4 & 5 & | & 1 & 0 & 1 \end{bmatrix}$$

$$\text{Step 3: } r_1 := r_1 - (-2)r_2 \quad \begin{bmatrix} 1 & 0 & 25/7 & | & 1 & -2/7 & 0 \\ 0 & 1 & 9/7 & | & 0 & -1/7 & 0 \\ 0 & 4 & 5 & | & 1 & 0 & 1 \end{bmatrix}$$

$$\text{Step 4: } r_3 := r_3 - (4)r_2 \quad \begin{bmatrix} 1 & 0 & 25/7 & | & 1 & -2/7 & 0 \\ 0 & 1 & 9/7 & | & 0 & -1/7 & 0 \\ 0 & 0 & -1/7 & | & 1 & 4/7 & 1 \end{bmatrix}$$

$$\text{Step 5: } r_3 := -7r_3 \quad \begin{bmatrix} 1 & 0 & 25/7 & | & 1 & -2/7 & 0 \\ 0 & 1 & 9/7 & | & 0 & -1/7 & 0 \\ 0 & 0 & 1 & | & -7 & -4 & -7 \end{bmatrix}$$

$$\text{Step 6: } r_1 := r_1 - (25/7)r_3 \quad \begin{bmatrix} 1 & 0 & 0 & | & 26 & 14 & 25 \\ 0 & 1 & 9/7 & | & 0 & -1/7 & 0 \\ 0 & 0 & 1 & | & -7 & -4 & -7 \end{bmatrix}$$

$$\text{Step 7: } r_2 := r_2 - (9/7)r_3 \quad \left[ \begin{array}{ccc|ccc} 1 & 0 & 0 & 26 & 14 & 25 \\ 0 & 1 & 0 & 9 & 5 & 9 \\ 0 & 0 & 1 & -7 & -4 & -7 \end{array} \right]$$

**Results:**

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

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

c)  $\det(A) = 0$

d)  $A^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 2 \\ -7 & -4 & -7 \end{bmatrix}$

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

**Solution**

**Row Operations:**

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

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

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

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

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

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

**Results:**

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

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

c)  $\det(A) = 0$

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

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

**Solution**

**Row Operations:**

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

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

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

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

**Results:**

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

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

c)  $\det(A) = 0$

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

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

### 2.3.2. RREF

**Solution**

**Elementary Row Operations:**

(1)  $r_3 := r_3 - r_2$

$$\left[ \begin{array}{ccc} 1 & -1 & 0 \\ 0 & 1 & 0 \\ -1 & 1 & 1 \end{array} \right]$$

(2)  $r_3 := r_3 - r_1$

$$\left[ \begin{array}{ccc} 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{array} \right]$$

(3)  $r_1 := r_1 - r_2$

$$\left[ \begin{array}{ccc} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{array} \right]$$

**Result:**

$$\left[ \begin{array}{ccc} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{array} \right]$$

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

$$(3) \ r_3 := r_3 + (-1)r_1$$



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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

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

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

**Result:**

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

**Solution**

**Elementary Row Operations:**

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

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

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

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

$$(3) \ r_2 := r_2 + (-2)r_3$$

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

**Result:**

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