

2.3 EXERCISES

Unless otherwise specified, assume that all matrices in these exercises are $n \times n$. Determine which of the matrices in Exercises 1–10 are invertible. Use as few calculations as possible. Justify your answers.

1. $\begin{bmatrix} 5 & 7 \\ -3 & -6 \end{bmatrix}$

2. $\begin{bmatrix} -4 & 6 \\ 6 & -9 \end{bmatrix}$

3. $\begin{bmatrix} 5 & 0 & 0 \\ -3 & -7 & 0 \\ 8 & 5 & -1 \end{bmatrix}$

4. $\begin{bmatrix} -7 & 0 & 4 \\ 3 & 0 & -1 \\ 2 & 0 & 9 \end{bmatrix}$

5. $\begin{bmatrix} 0 & 3 & -5 \\ 1 & 0 & 2 \\ -4 & -9 & 7 \end{bmatrix}$

6. $\begin{bmatrix} 1 & -5 & -4 \\ 0 & 3 & 4 \\ -3 & 6 & 0 \end{bmatrix}$

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

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

9. [M] $\begin{bmatrix} 4 & 0 & -7 & -7 \\ -6 & 1 & 11 & 9 \\ 7 & -5 & 10 & 19 \\ -1 & 2 & 3 & -1 \end{bmatrix}$

10. [M] $\begin{bmatrix} 5 & 3 & 1 & 7 & 9 \\ 6 & 4 & 2 & 8 & -8 \\ 7 & 5 & 3 & 10 & 9 \\ 9 & 6 & 4 & -9 & -5 \\ 8 & 5 & 2 & 11 & 4 \end{bmatrix}$

In Exercises 11 and 12, the matrices are all $n \times n$. Each part of the exercises is an implication of the form “If ‘statement 1’, then ‘statement 2’.” Mark an implication as True if the truth of “statement 2” always follows whenever “statement 1” happens to be true. An implication is False if there is an instance in which “statement 2” is false but “statement 1” is true. Justify each answer.

11. ☒ a. If the equation $Ax = 0$ has only the trivial solution, then A is row equivalent to the $n \times n$ identity matrix.
- b. If the columns of A span \mathbb{R}^n , then the columns are linearly independent.
- c. If A is an $n \times n$ matrix, then the equation $Ax = b$ has at least one solution for each b in \mathbb{R}^n .
- d. If the equation $Ax = 0$ has a nontrivial solution, then A has fewer than n pivot positions.
- e. If A^T is not invertible, then A is not invertible.
12. ☒ a. If there is an $n \times n$ matrix D such that $AD = I$, then there is also an $n \times n$ matrix C such that $CA = I$.
- b. If the columns of A are linearly independent, then the columns of A span \mathbb{R}^n .
- c. If the equation $Ax = b$ has at least one solution for each b in \mathbb{R}^n , then the solution is unique for each b .

- d. If the linear transformation $(x) \mapsto Ax$ maps \mathbb{R}^n into \mathbb{R}^n , then A has n pivot positions.
- e. If there is a b in \mathbb{R}^n such that the equation $Ax = b$ is inconsistent, then the transformation $x \mapsto Ax$ is not one-to-one.

13. An $m \times n$ upper triangular matrix is one whose entries below the main diagonal are 0's (as in Exercise 8). When is a square upper triangular matrix invertible? Justify your answer.
14. An $m \times n$ lower triangular matrix is one whose entries above the main diagonal are 0's (as in Exercise 3). When is a square lower triangular matrix invertible? Justify your answer.
15. Can a square matrix with two identical columns be invertible? Why or why not?
16. Is it possible for a 5×5 matrix to be invertible when its columns do not span \mathbb{R}^5 ? Why or why not?
17. If A is invertible, then the columns of A^{-1} are linearly independent. Explain why.
18. If C is 6×6 and the equation $Cx = v$ is consistent for every v in \mathbb{R}^6 , is it possible that for some v , the equation $Cx = v$ has more than one solution? Why or why not?
19. If the columns of a 7×7 matrix D are linearly independent, what can you say about solutions of $Dx = b$? Why?
20. If $n \times n$ matrices E and F have the property that $EF = I$, then E and F commute. Explain why.
21. If the equation $Gx = y$ has more than one solution for some y in \mathbb{R}^n , can the columns of G span \mathbb{R}^n ? Why or why not?
22. If the equation $Hx = c$ is inconsistent for some c in \mathbb{R}^n , what can you say about the equation $Hx = 0$? Why?
23. If an $n \times n$ matrix K cannot be row reduced to I_n , what can you say about the columns of K ? Why?
24. If L is $n \times n$ and the equation $Lx = 0$ has the trivial solution, do the columns of L span \mathbb{R}^n ? Why?
25. Verify the boxed statement preceding Example 1.
26. Explain why the columns of A^T span \mathbb{R}^n whenever the columns of A are linearly independent.
27. Show that if AB is invertible, so is A . You cannot use Theorem 6(b), because you cannot assume that A and B are invertible. [Hint: There is a matrix W such that $ABW = I$. Why?]
28. Show that if AB is invertible, so is B .
29. If A is an $n \times n$ matrix and the equation $Ax = b$ has more than one solution for some b , then the transformation $x \mapsto Ax$ is not one-to-one. What else can you say about this transformation? Justify your answer.

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