

Reduced Row Echelon Form Practice

ALLEGHENY COLLEGE

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MATH 320

Linear Algebra

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Problem Set 1 Due Wednesday February 1

1. Find all solutions to the following system of equations.

$$\begin{aligned}x_2 + x_3 &= 4 \\x_1 - x_2 + 2x_3 &= 1 \\2x_1 + 2x_2 - x_3 &= 6\end{aligned}$$

2. Find all solutions to the following system of equations.

$$\begin{aligned}x_1 + x_2 &= 9 \\x_1 - x_2 &= 7 \\3x_1 + x_2 &= 6\end{aligned}$$

3. Find all solutions to the following system of equations.

$$\begin{aligned}x_1 + x_2 + x_3 - x_4 &= 1 \\-x_1 + x_2 - x_3 + x_4 &= 3 \\-2x_1 + x_2 - x_3 &= 2\end{aligned}$$

4. A positive three-digit number has two properties. The tens-digit and the ones-digit add up to 5. If the number is written with the digits in the reverse order, and then subtracted from the original number, the result is 792. Use a system of equations to find all of the three-digit numbers with these properties.
5. Three students enter a game with varying amounts of money. The game is played for three rounds. At the end of each round, there are two winners and one loser, moreover the loser gives each of the winners an amount equal to what the winner currently possesses. At the end of the three rounds, each player has lost exactly one round and each player now has \$24. How much money did each student enter the game with?

Reduced row echelon form practice is an essential topic in linear algebra that focuses on manipulating matrices to a specific form that simplifies the process of solving systems of linear equations. Understanding how to perform these transformations is crucial for students and professionals alike, as it lays the groundwork for more advanced topics such as vector spaces and linear transformations. In this article, we will explore the concepts behind reduced row echelon form, the steps necessary to achieve this form, and provide practice problems for mastery.

Understanding Reduced Row Echelon Form

To grasp the essence of reduced row echelon form (RREF), it's important to first understand what echelon form is. A matrix is in echelon form if it satisfies the following conditions:

1. All nonzero rows are above any rows of all zeros.
2. The leading entry of each nonzero row (also called a pivot) is 1.
3. The leading entry of each nonzero row is the only nonzero entry in its column.

Reduced row echelon form takes it a step further by requiring:

1. Each leading 1 is the only nonzero entry in its column.
2. The leading 1 in each row is to the right of the leading 1 in the previous row.

Achieving RREF is particularly useful for solving linear systems, as it allows for straightforward interpretation of the solutions.

Steps to Achieve Reduced Row Echelon Form

Transforming a matrix into its reduced row echelon form involves a series of row operations. These operations include:

- Row swapping: Exchanging two rows.
- Row multiplication: Multiplying all entries of a row by a nonzero scalar.
- Row addition: Adding or subtracting a multiple of one row from another row.

The following steps outline the process to achieve RREF:

Step 1: Identify the Pivot Position

Start with the leftmost column and identify the first nonzero entry. This entry will become your pivot. If the pivot is not 1, you may need to multiply the entire row by the reciprocal of the pivot value.

Step 2: Create Zeros Below the Pivot

Use row addition to create zeros below the pivot. For every row beneath the pivot row, subtract an appropriate multiple of the pivot row from it.

Step 3: Move to the Next Column

Once all entries below the pivot are zeros, move to the next column to the right and repeat steps 1 and 2, working from the top down.

Step 4: Create Zeros Above the Pivot

After achieving a row echelon form, work from the bottom up to create zeros above each leading one. This step ensures that each pivot is the only nonzero entry in its column.

Step 5: Normalize the Leading Entries

Lastly, ensure that each leading entry is 1. If it is not, divide the entire row by the leading entry.

Following these steps will allow you to systematically convert a matrix into its reduced row echelon form.

Practice Problems

To reinforce the concepts discussed, let's work through some practice problems. For each problem, perform the necessary row operations to convert the given matrix into reduced row echelon form.

Problem 1

Given the matrix:

```
\[
\begin{pmatrix}
2 & 4 & 1 \\
1 & 2 & 3 \\
3 & 6 & 2
\end{pmatrix}
\]
```

Solution Steps:

1. Select the pivot in the first column: The first pivot is in the first row. Divide the first row by 2 to obtain a leading 1:

```
\[
\begin{pmatrix}
1 & 2 & 0.5 \\
1 & 2 & 3 \\
3 & 6 & 2
\end{pmatrix}
\]
```

2. Eliminate below the pivot: Subtract the first row from the second row, and subtract 3 times the first row from the third row:

```
\[
```

```

\begin{pmatrix}
1 & 2 & 0.5 \\
0 & 0 & 2.5 \\
0 & 0 & -1.5
\end{pmatrix}

```

3. Next pivot: The second pivot is in the last row. Divide the last row by -1.5 to get a leading 1:

```

\begin{pmatrix}
1 & 2 & 0.5 \\
0 & 0 & 2.5 \\
0 & 0 & 1
\end{pmatrix}

```

4. Eliminate above the pivot: Subtract 2.5 times the last row from the second row:

```

\begin{pmatrix}
1 & 2 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{pmatrix}

```

5. Normalize the second pivot: Divide the second row by 2 to get:

```

\begin{pmatrix}
1 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{pmatrix}

```

The RREF of the matrix is:

```

\begin{pmatrix}
1 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{pmatrix}

```

Problem 2

Given the matrix:

```

\begin{pmatrix}

```

```

1 & 3 & 1 \\
2 & 6 & 2 \\
3 & 9 & 3
\end{pmatrix}
\]
```

Solution Steps:

1. Pivot in the first column: The first row is already suitable.
2. Eliminate below the pivot: Subtract 2 times the first row from the second row and subtract 3 times the first row from the third row:

```

\begin{pmatrix}
1 & 3 & 1 \\
0 & 0 & 0 \\
0 & 0 & 0
\end{pmatrix}
\]
```

3. Normalize leading entries: The first row is already normalized.

The RREF is:

```

\begin{pmatrix}
1 & 3 & 1 \\
0 & 0 & 0 \\
0 & 0 & 0
\end{pmatrix}
\]
```

Conclusion

Practicing the transformation of matrices into reduced row echelon form is a valuable skill in linear algebra. By mastering the row operations and understanding the process, students can efficiently solve systems of equations, analyze linear independence, and explore the dimensions of vector spaces. The practice problems provided illustrate the systematic approach necessary to achieve RREF, thereby enhancing comprehension and retention of this critical mathematical concept. As you continue to work through various matrices, remember to focus on each step and verify your results to build a solid foundation in linear algebra.

Frequently Asked Questions

What is reduced row echelon form (RREF)?

Reduced row echelon form is a matrix format where each leading entry in a row is 1, each leading 1 is the only non-zero entry in its column, and the leading 1s move to the right as you go down the rows.

How do you convert a matrix to reduced row echelon form?

To convert a matrix to RREF, you use a series of row operations: swapping rows, multiplying a row by a non-zero scalar, and adding or subtracting multiples of rows from each other until the matrix satisfies the RREF conditions.

What are the benefits of using reduced row echelon form?

RREF simplifies the process of solving systems of linear equations, determining the rank of a matrix, and finding inverse matrices when applicable.

Can all matrices be converted to reduced row echelon form?

Yes, all matrices can be converted to RREF, although the resulting form may have fewer rows than the original matrix if some rows are linearly dependent.

What are the key properties of a matrix in reduced row echelon form?

Key properties include that each leading 1 is the only non-zero entry in its column, leading 1s are arranged in a staircase pattern from top-left to bottom-right, and any rows of all zeros are at the bottom of the matrix.

How can I practice converting matrices to RREF?

You can practice by taking various matrices and applying row operations systematically, or by using online tools or software that provide RREF calculators for verification.

What is the relationship between RREF and solving linear equations?

RREF provides a clear and systematic way to solve linear equations by transforming the coefficient matrix into a form that directly reveals the solutions or indicates if no solutions exist.

Are there specific algorithms or methods for finding RREF?

Yes, the Gauss-Jordan elimination method is commonly used to find RREF, which involves performing row operations until the matrix reaches the desired form.

How does RREF help in understanding the solutions of a system of equations?

RREF helps by clearly indicating the number of free variables and leading variables, thus allowing you to easily determine if the system has a unique solution, infinitely many solutions, or no solution at all.

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