Matrix Algebra

Objectives

1. Find the sum and difference of two or more matrices.
2. Multiply a matrix by a scalar.
3. Multiply matrices together.

What is a Matrix?

Matrix

A **matrix** is a rectangular array of numbers.

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Matrix Dimensions

The **dimensions** of a matrix (*pl: matrices*) are listed as

$$\text{Number of rows } (r) \times \text{Number of columns } (c)$$

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We use upper-case letters to refer to entire matrices.

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Example of some matrices:

3×2 matrix	2×2 matrix	1×4 matrix:
$A = \begin{bmatrix} 5 & -3 \\ 2 & 1 \\ 0 & 4.5 \end{bmatrix}$	$B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$	$C = \begin{bmatrix} 8 & 6 & 7 & 5 \end{bmatrix}$

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We use lower-case letters to refer to individual elements of a matrix.

For instance, the element in row 3 column 1 of matrix A is denoted

$$a_{3,1}$$

Adding and Subtracting Matrices

We can add and subtract matrices **that are of the same dimension** by adding or subtracting corresponding elements.

Example 1

For the matrices

$$A = \begin{bmatrix} 5 & -8 & 4 \\ 2 & 0 & -1 \end{bmatrix} \quad B = \begin{bmatrix} -4 & 6 & 12 \\ 7 & 2 & -9 \end{bmatrix} \quad \text{and} \quad C = \begin{bmatrix} 10 & 9 \\ -5 & 7 \end{bmatrix}$$

find each of the following, if possible.

(a) $A + B$

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

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(b) $A - B$

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$$A_{2\times 3} \quad C_{2\times 2}$$

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Matrix addition is **not possible**.

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What is a Scalar?

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To multiply a matrix by a scalar, multiply each element of the matrix by the scalar.

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find each of the following.

(a) $5A$

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

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$$2A = \begin{bmatrix} 10 & -16 & 8 \\ 4 & 0 & -2 \end{bmatrix} \quad 3B = \begin{bmatrix} -12 & 18 & 36 \\ 21 & 6 & -27 \end{bmatrix}$$

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$$2A - 3B = \begin{bmatrix} 22 & -34 & -28 \\ -17 & -6 & 25 \end{bmatrix}$$

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Matrix Multiplication

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When multiplying matrices, we **DO NOT** multiply corresponding elements (like when we add and subtract corresponding elements with adding and subtracting matrices).

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- We can only multiply matrices if the number of columns in the first matrix equals the number of rows in the second.

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That being said:

- We can only multiply matrices if the number of columns in the first matrix equals the number of rows in the second.
- Our final result will be a matrix with dimensions equal to the number of rows in the first matrix $\times$ the number of columns in the second.

Matrix Multiplication

So to multiply

$$D = \begin{bmatrix} 4 & -1 & -7 \\ 2 & 0 & 6 \end{bmatrix} \quad \text{and} \quad E = \begin{bmatrix} 1 & 9 \\ 3 & -2 \\ 4 & 0 \end{bmatrix}$$

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Note that the dimensions of D are $\mathbf{2} \times \mathbf{3}$ and the dimensions of E are $\mathbf{3} \times \mathbf{2}$.

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Since the number of rows in D ($\mathbf{3}$) equals the number of columns in E ($\mathbf{3}$), we can multiply the matrices.

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The product will be a matrix with $\mathbf{2}$ rows and $\mathbf{2}$ columns.

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$$\begin{bmatrix} 4 & -1 & -7 \\ 2 & 0 & 6 \end{bmatrix} \cdot \begin{bmatrix} 1 & 9 \\ 3 & -2 \\ 4 & 0 \end{bmatrix}$$

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$$\begin{bmatrix} 4(1) + (-1)(3) + (-7)(4) & \\ & \end{bmatrix}$$

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$$\begin{bmatrix} -27 & 38 \\ & \end{bmatrix}$$

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$$\begin{bmatrix} -27 & 38 \\ 26 & 18 \end{bmatrix}$$

Matrix Multiplication

Note: Always remember to check that the number of columns in the first matrix equals the number of rows in the second. If this is not the case, you can not multiply the matrices together.

Example 3

For the matrices below, find the products.

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

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

(a) AB

$$\begin{bmatrix} 4(7) + 8(1) + (-9)(0) & 4(4) + 8(-5) + (-9)(6) \\ 2(7) + 0(1) + 3(0) & 2(4) + 0(-5) + 3(6) \end{bmatrix}$$

$$\begin{bmatrix} 36 & -78 \\ 14 & \end{bmatrix}$$

Example 3

For the matrices below, find the products.

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

(a) AB

$$\begin{bmatrix} 4(7) + 8(1) + (-9)(0) & 4(4) + 8(-5) + (-9)(6) \\ 2(7) + 0(1) + 3(0) & 2(4) + 0(-5) + 3(6) \end{bmatrix}$$

$$\begin{bmatrix} 36 & -78 \\ 14 & 26 \end{bmatrix}$$

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

(b) BA

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

(b) BA

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

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

(b) BA

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

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

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & & \\ & & \\ & & \end{bmatrix}$$

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

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & & \\ & & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & \\ & \\ & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & \\ & & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & \\ & \\ & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & \\ & & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & \\ & & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 \\ & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ & & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ 12 & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & 0(8)+6(0) & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ 12 & & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & 0(8)+6(0) & \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ 12 & 0 & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & 0(8)+6(0) & 0(-9)+6(3) \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ 12 & 0 & \end{bmatrix}$$

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

(b) BA

$$\begin{bmatrix} 7(4)+4(2) & 7(8)+4(0) & 7(-9)+4(3) \\ 1(4)+(-5)(2) & 1(8)+(-5)(0) & 1(-9)+(-5)(3) \\ 0(4)+6(2) & 0(8)+6(0) & 0(-9)+6(3) \end{bmatrix}$$

$$\begin{bmatrix} 36 & 56 & -51 \\ -6 & 8 & -24 \\ 12 & 0 & 18 \end{bmatrix}$$

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

(c) AC

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

(c) AC

Not possible

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

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

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & \\ & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & \\ & \end{bmatrix}$$

$$\begin{bmatrix} 16 & \\ & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ & \end{bmatrix}$$

$$\begin{bmatrix} 16 & \\ & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ & \end{bmatrix}$$

$$\begin{bmatrix} 16 & -35 \\ & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ 4(6) + 1(4) & \end{bmatrix}$$

$$\begin{bmatrix} 16 & -35 \\ & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ 4(6) + 1(4) & \end{bmatrix}$$

$$\begin{bmatrix} 16 & -35 \\ 28 & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ 4(6) + 1(4) & 4(-5) + 1(1) \end{bmatrix}$$

$$\begin{bmatrix} 16 & -35 \\ 28 & \end{bmatrix}$$

Example 3 $C = \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$

(d) C^2

$$\begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix} \cdot \begin{bmatrix} 6 & -5 \\ 4 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 6(6) + (-5)(4) & 6(-5) + (-5)(1) \\ 4(6) + 1(4) & 4(-5) + 1(1) \end{bmatrix}$$

$$\begin{bmatrix} 16 & -35 \\ 28 & -19 \end{bmatrix}$$