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Example:

$$\text{Given } A = \begin{pmatrix} 1 & 2 & -1 \\ 2 & 0 & 1 \end{pmatrix} \text{and } B = \begin{pmatrix} 3 & 1 \\ 0 & -1 \\ -2 & 3 \end{pmatrix}$$

Find $C = A \times B$

Solution:

Step 1 : Multiply the elements in the first row of A with the corresponding elements in the first column of B. Add the products to get the element C_{11}

$$\begin{array}{rccl} \text{row 1} \longrightarrow & \begin{pmatrix} 1 & 2 & -1 \\ 2 & 0 & 1 \end{pmatrix} & \begin{pmatrix} 3 & 1 \\ 0 & -1 \\ -2 & 3 \end{pmatrix} & = \begin{pmatrix} (1\times 3)+(2\times 0)+(-1\times -2) & \\ & \end{pmatrix} = \begin{pmatrix} 5 & \\ & \end{pmatrix} \\ & & \uparrow & \\ & & \text{column 1} & \end{array}$$

Showing Step 1 in detail:

$$\begin{pmatrix} 1 & 2 & -1 \\ 2 & 0 & 1 \end{pmatrix}\begin{pmatrix} 3 & 1 \\ 0 & -1 \\ -2 & 3 \end{pmatrix} = \begin{pmatrix} (1\times 3)+(2\times 0)+(-1\times -2) & \\ & \end{pmatrix} = \begin{pmatrix} 5 & \\ & \end{pmatrix}$$

Step 2: Multiply the elements in the first row of A with the corresponding elements in the second column of B. Add the products to get the element C_{12}

$$\begin{array}{l} \text{row 1} \longrightarrow \\ \\ \end{array}\begin{pmatrix} 1 & 2 & -1 \\ 2 & 0 & 1 \end{pmatrix}\begin{array}{c}\begin{pmatrix} 3 & 1 \\ 0 & -1 \\ -2 & 3 \end{pmatrix} \\ \quad\ \uparrow \\ \qquad\text{column 2}\end{array} = \begin{pmatrix} 5 & \overbrace{(1\times 1)+(2\times -1)+(-1\times 3)} \\ & \end{pmatrix} = \begin{pmatrix} 5 & -4 \\ & \end{pmatrix}$$

Step 3: Multiply the elements in the second row of A with the corresponding elements in the first column of B. Add the products to get the element C_{21}

$$\begin{array}{l} \\ \text{row 2} \longrightarrow \end{array}\begin{pmatrix} 1 & 2 & -1 \\ 2 & 0 & 1 \end{pmatrix}\begin{array}{c}\begin{pmatrix} 3 & 1 \\ 0 & -1 \\ -2 & 3 \end{pmatrix} \\ \uparrow\qquad \\ \text{column 1}\qquad\end{array} = \begin{pmatrix} 5 & -4 \\ \underbrace{(2\times 3)+(0)+(1\times -2)} & \end{pmatrix} = \begin{pmatrix} 5 & -4 \\ 4 & \end{pmatrix}$$

Step 4: Multiply the elements in the second row of A with the corresponding elements in the second column of B. Add the products to get the element C_{22}

$$\begin{array}{r} \\ \text{row 2} \longrightarrow \end{array}\begin{pmatrix}1 & 2 & -1\\ 2 & 0 & 1\end{pmatrix}\begin{array}{c}\begin{pmatrix}3 & 1\\ 0 & -1\\ -2 & 3\end{pmatrix}\\ \begin{array}{cc} & \uparrow \\ & \text{column 2}\end{array}\end{array} = \begin{pmatrix}5 & -4\\ 4 & (2\times 1)+(0\times -1)+(1\times 3)\end{pmatrix} = \begin{pmatrix}5 & -4\\ 4 & 5\end{pmatrix}$$

$$\text{So, } C = \begin{pmatrix}5 & -4\\ 4 & 5\end{pmatrix}$$

Matrices that can or cannot be Multiplied

Not all matrices can be multiplied together.

$$\text{Let } A = \begin{pmatrix}3 & 2 & 1\\ 2 & 0 & -1\end{pmatrix} \text{ and } B = \begin{pmatrix}-1 & 0\\ 3 & 2\end{pmatrix}$$

For example, the product of A and B is not defined.

$$\begin{pmatrix}3 & 2 & 1\\ 2 & 0 & -1\end{pmatrix}\begin{pmatrix}-1 & 0\\ 3 & 2\end{pmatrix}$$

We **cannot** multiply A and B because there are 3 elements in the row to be multiplied with 2 elements in the column

This means that we can only multiply two matrices if the number of columns in the first matrix is equal to the number of rows in the second matrix.

An easy method to determine whether two matrices can be multiplied together would be to check the order of the matrices.

- [redacted]