synthetic division

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Synthetic division is simply a shorthand for long division, when one of the factors is linear. So when an equation such as

$$y = 2x^2 + 10x + 12$$

is given and a factor of $x + 3$ is known, we can do the following:

$$
\begin{array}{c|ccc}
 & 2 & 10 & 12 \\
\hline
 & & &
\end{array}
$$

First, we can use -3 since -3 is a solution if $x + 3 = 0$.

$$
\begin{array}{c|ccc}
-3 & 2 & 10 & 12 \\
\hline
 & & &
\end{array}
$$

Carry down the first coefficient:

$$
\begin{array}{c|ccc}
-3 & 2 & 10 & 12 \\
\hline
 & 2 & &
\end{array}
$$

Multiply 2 by -3:

$$
\begin{array}{c|ccc}
-3 & 2 & 10 & 12 \\
 & & -6 & \\
\hline
 & 2 & &
\end{array}
$$

Add up 10 and -6:

$$
\begin{array}{c|ccc}
-3 & 2 & 10 & 12 \\
 & & -6 & \\
\hline
 & 2 & 4 &
\end{array}
$$

Multiply 4 by -3:

$$
\begin{array}{c|ccc}
-3 & 2 & 10 & 12 \\
 & & -6 & -12 \\
\hline
 & 2 & 4 & 0
\end{array}
$$

This means that, by factoring the equation by $x + 3$, we will get another factor as $2x + 4$.

Synthetic is simply an variation of the long division — a version that's manipulated and simplified to shorten the calculations.