Precalculus
Use polynomial division with remainder 0 to factor a polynomial

Todor Milev

2019

Example

Demonstrate that $6x^3 - 19x^2 + 17x - 3$ is divisible by $2x - 3$ using polynomial long division. Use your work to factor the cubic. Solve the equation $6x^3 - 19x^2 + 17x - 3 = 0$.

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$$\begin{array}{r} \color{red}{?} \\ \color{red}{2x} - 3 \quad \overline{\left| \color{red}{6x^3} - 19x^2 + 17x - 3 \right.} \end{array}$$

Divide $\color{red}{6x^3}$ by $\color{red}{2x}$.

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$$\begin{array}{r} 3x^2 \\ 2x - 3 \;\overline{)\; 6x^3 - 19x^2 + 17x - 3} \end{array}$$

Divide $6x^3$ by $2x$.

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$$\begin{array}{r} 3x^2 \\ 2x-3 \quad \overline{\big| 6x^3-19x^2+17x-3} \\ \underline{?\quad\quad ?} \end{array}$$

Multiply $3x^2$ by divisor.

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$$\begin{array}{r} 3x^2 \\ 2x-3 \quad \overline{\big| 6x^3-19x^2+17x-3} \\ \underline{6x^3-\ 9x^2} \end{array}$$

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$$
\begin{array}{r|l}
 & 3x^2 \\
\hline
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\
\hline
 & ? \quad ? \quad ?
\end{array}
$$

Subtract last two polynomials.

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$$\begin{array}{r} \quad 3x^2 \quad \textbf{?} \\ 2x - 3 \;\overline{)}\; 6x^3 - 19x^2 + 17x - 3 \\ \underline{6x^3 - 9x^2} \\ -10x^2 + 17x - 3 \end{array}$$

Divide $-10x^2$ by $2x$.

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$$
\begin{array}{r|l}
 & 3x^2 - 5x \\
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2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
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\hline
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\hline
 & \quad -10x^2 + 17x - 3 \\
 & \quad \;\; ? \qquad ? \\
\hline
\end{array}
$$

Multiply $-5x$ by divisor.

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 & -10x^2 + 15x \\
\hline
\end{array}
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 & & 2x - 3
\end{array}
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Divide $2x$ by $2x$.

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$$
\begin{array}{rr|l}
 & & 3x^2 - 5x + 1 \\
\hline
2x - 3 & & 6x^3 - 19x^2 + 17x - 3 \\
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 & & 2x - 3 \\
 & & ? \quad ? \\
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\end{array}
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Multiply 1 by divisor.

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\hline
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- & & 2x - 3 \\
\hline
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$$
\begin{array}{rl}
\textbf{Quotient:} & \quad 3x^2 - 5x + 1 \\
2x - 3 & \overline{\big| \; 6x^3 - 19x^2 + 17x - 3} \\
- & \quad 6x^3 - 9x^2 \\
\hline
 & \quad\quad -10x^2 + 17x - 3 \\
- & \quad\quad -10x^2 + 15x \\
\hline
 & \quad\quad\quad\quad 2x - 3 \\
- & \quad\quad\quad\quad 2x - 3 \\
\hline
 & \quad\quad\quad\quad\quad\quad 0
\end{array}
$$

$$\textbf{(Dividend)} = \textbf{(Quotient)} \cdot \textbf{(Divisor)} + \textbf{(Remainder)}$$

$$(6x^3 - 19x^2 + 17x - 3) = (3x^2 - 5x + 1) \cdot (2x - 3)$$

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$$= 3\left(x - \textbf{?}\right)\left(x - \textbf{?}\right)(2x - 3)$$

No easy factorization of quadratic, so use formula:

$x_1, x_2 =$ **?**

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$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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$$= 3\left(x - \left(\frac{5+\sqrt{13}}{6}\right)\right)\left(x - \left(\frac{5-\sqrt{13}}{6}\right)\right)(2x - 3)$$

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$$\begin{aligned} 6x^3 - 19x^2 + 17x - 3 &= 0 \\ 3\left(x - \left(\frac{5+\sqrt{13}}{6}\right)\right)\left(x - \left(\frac{5-\sqrt{13}}{6}\right)\right)(2x - 3) &= 0 \end{aligned}$$

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$$2x - 3 = 0 \quad \textbf{or} \quad x = \left(\frac{5+\sqrt{13}}{6}\right) \quad \textbf{or} \quad x = \left(\frac{5-\sqrt{13}}{6}\right)$$

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$2x - 3 = 0$ **or** $x = \left(\frac{5+\sqrt{13}}{6}\right)$ **or** $x = \left(\frac{5-\sqrt{13}}{6}\right)$

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$$2x - 3 = 0 \quad \textbf{or} \quad x = \left(\frac{5+\sqrt{13}}{6}\right) \quad \textbf{or} \quad x = \left(\frac{5-\sqrt{13}}{6}\right)$$

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Demonstrate that $6x^3 - 19x^2 + 17x - 3$ is divisible by $2x - 3$ using polynomial long division. Use your work to factor the cubic. Solve the equation $6x^3 - 19x^2 + 17x - 3 = 0$.

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$$= 3\left(x - \left(\frac{5+\sqrt{13}}{6}\right)\right)\left(x - \left(\frac{5-\sqrt{13}}{6}\right)\right)(2x - 3)$$

No easy factorization of quadratic, so use formula:

$x_1, x_2 = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{-(-5) \pm \sqrt{(-5)^2-4\cdot 3\cdot 1}}{2\cdot 3} = \frac{5 \pm \sqrt{13}}{6}$ We are ready to solve the equation.

$$6x^3 - 19x^2 + 17x - 3 = 0$$
$$3\left(x - \left(\frac{5+\sqrt{13}}{6}\right)\right)\left(x - \left(\frac{5-\sqrt{13}}{6}\right)\right)(2x - 3) = 0$$
$$2x - 3 = 0 \quad \textbf{or} \quad x = \left(\frac{5+\sqrt{13}}{6}\right) \quad \textbf{or} \quad x = \left(\frac{5-\sqrt{13}}{6}\right)$$
$$x = \frac{3}{2}$$

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