Precalculus
Polynomial division and factorization of cubics with rational root

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Outline

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Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$x - 1 \quad \overline{\big)\, x^3 + 2x^2 \qquad + 1}$$

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$x - 1 \quad \overline{\big| \; x^3 + 2x^2 \qquad + 1}$$

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$\begin{array}{r|l} & \;\; ? \\ \cline{2-2} x - 1 & x^3 + 2x^2 \qquad + 1 \end{array}$$

Divide x^3 by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 \\
\cline{2-2}
x - 1 & x^3 + 2x^2 \quad\quad + 1
\end{array}
$$

Divide x^3 by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 \\
\cline{2-2}
x - 1 & x^3 + 2x^2 \qquad + 1 \\
 & ? \quad\ ? \\
\cline{2-2}
\end{array}
$$

Multiply x^2 by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & \color{red}{x^2} \\
\hline
\color{red}{x-1} & x^3 + 2x^2 \qquad + 1 \\
 & \color{red}{x^3 - x^2} \\
\hline
\end{array}
$$

Multiply x^2 by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 \\
\cline{2-2}
x - 1 & x^3 + 2x^2 \qquad + 1 \\
- & x^3 - x^2 \\
\cline{2-2}
 & \quad ? \qquad\qquad ?
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & \quad x^2 \\
x - 1 & \overline{\big) x^3 + 2x^2 \qquad + 1} \\
- & x^3 - x^2 \\
\hline
 & 3x^2 \qquad + 1
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 \quad \mathbf{?} \\
\cline{2-2}
x - 1 & x^3 + 2x^2 \qquad + 1 \\
- & x^3 - x^2 \\
\cline{2-2}
 & \qquad 3x^2 \qquad + 1
\end{array}
$$

Divide $3x^2$ by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 + 3x \\
\hline
x - 1 & x^3 + 2x^2 \qquad + 1 \\
- & x^3 - x^2 \\
\hline
 & \qquad 3x^2 \qquad + 1
\end{array}
$$

Divide $3x^2$ by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & \quad x^2 + 3x \\
x - 1 & \overline{\big)\, x^3 + 2x^2 \qquad + 1} \\
- & \quad x^3 - x^2 \\
\hline
 & \qquad 3x^2 \qquad + 1 \\
 & \qquad ? \qquad ? \\
\hline
\end{array}
$$

Multiply $3x$ by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & x^2 + 3x \\
\hline
x - 1 & x^3 + 2x^2 \qquad + 1 \\
- & x^3 - x^2 \\
\hline
 & \quad 3x^2 \qquad + 1 \\
 & \quad 3x^2 - 3x \\
\hline
\end{array}
$$

Multiply $3x$ by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|lllll}
 & x^2 & + 3x & & \\
\hline
x - 1 & x^3 & +2x^2 & & +1 \\
- & x^3 & - x^2 & & \\
\hline
 & & 3x^2 & & +1 \\
- & & 3x^2 & -3x & \\
\hline
 & & & ? & ?
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rr|llll}
 & & x^2 & + 3x & & \\
\cline{3-6}
x - 1 & & x^3 & +2x^2 & & +1 \\
- & & x^3 & - x^2 & & \\
\cline{3-6}
 & & & 3x^2 & & +1 \\
- & & & 3x^2 & -3x & \\
\cline{4-6}
 & & & & 3x & +1
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rrrrr}
 & x^2 & +\,3x & & \textbf{?} \\
\cline{2-5}
x - 1 & \multicolumn{1}{|r}{x^3 + 2x^2} & & & +1 \\
- & x^3 - x^2 & & & \\
\cline{2-5}
 & & 3x^2 & & +1 \\
- & & 3x^2 - 3x & & \\
\cline{3-5}
 & & & 3x & +1
\end{array}
$$

Divide $3x$ by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & x^2 + 3x + 3 \\
x - 1 & \big)\, x^3 + 2x^2 + 1 \\
- & \,x^3 - x^2 \\
\hline
 & \; 3x^2 + 1 \\
- & \; 3x^2 - 3x \\
\hline
 & \; 3x + 1
\end{array}
$$

Divide $3x$ by x.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & \quad x^2 + 3x \color{red}{+ 3} \\
\color{red}{x - 1} & \overline{)\,x^3 + 2x^2 \qquad + 1} \\
- & \;\; x^3 - x^2 \\
\hline
 & \qquad 3x^2 \qquad + 1 \\
- & \qquad 3x^2 - 3x \\
\hline
 & \qquad\qquad 3x + 1 \\
 & \qquad\qquad \color{red}{\textbf{?}} \quad \color{red}{\textbf{?}} \\
\hline
\end{array}
$$

Multiply $\color{red}{3}$ by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{r|l}
 & \phantom{x^3+{}} x^2 + 3x + 3 \\
\cline{2-2}
x - 1 & x^3 + 2x^2 \phantom{{}-3x} + 1 \\
- & x^3 - x^2 \\
\cline{2-2}
 & \phantom{x^3+{}} 3x^2 \phantom{{}-3x} + 1 \\
- & \phantom{x^3+{}} 3x^2 - 3x \\
\cline{2-2}
 & \phantom{x^3+2x^2-{}} 3x + 1 \\
 & \phantom{x^3+2x^2-{}} 3x - 3 \\
\cline{2-2}
\end{array}
$$

Multiply 3 by divisor.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & \; x^2 + 3x + 3 \\
x - 1 & \overline{)\, x^3 + 2x^2 + 1} \\
- & \; x^3 - x^2 \\
\hline
 & \; 3x^2 + 1 \\
- & \; 3x^2 - 3x \\
\hline
 & \; \color{red}{3x + 1} \\
\color{red}{-} & \; \color{red}{3x - 3} \\
\hline
 & \; \color{red}{\mathbf{?}}
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rrrrr}
 & & x^2 & +\,3x & +\,3 \\
\cline{2-5}
x-1 & \big) & x^3+2x^2 & & +1 \\
- & & x^3-\ x^2 & & \\
\cline{3-5}
 & & 3x^2 & & +1 \\
- & & 3x^2 & -3x & \\
\cline{3-5}
 & & & 3x & +1 \\
- & & & 3x & -3 \\
\cline{4-5}
 & & & & 4
\end{array}
$$

Subtract last two polynomials.

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rl}
 & \quad x^2 + 3x + 3 \\
x - 1 & \overline{\big) x^3 + 2x^2 \qquad + 1} \\
- & \quad x^3 - x^2 \\
 & \overline{\qquad 3x^2 \qquad + 1} \\
- & \qquad 3x^2 - 3x \\
 & \overline{\qquad\qquad 3x + 1} \\
- & \qquad\qquad 3x - 3 \\
 & \overline{\qquad\qquad\quad 4}
\end{array}
$$

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

Quotient: $x^2 + 3x + 3$

$$
\begin{array}{rl}
x - 1 & \overline{\big)\, x^3 + 2x^2 \qquad\quad + 1} \\
- & \; x^3 - \; x^2 \\
\hline
 & \qquad 3x^2 \qquad\quad + 1 \\
- & \qquad 3x^2 - 3x \\
\hline
 & \qquad\qquad\quad 3x + 1 \\
- & \qquad\qquad\quad 3x - 3 \\
\hline
 & \qquad\qquad\qquad\;\; 4
\end{array}
$$

$$
\begin{aligned}
\textbf{(Dividend)} &= \textbf{(Quotient)} \cdot \textbf{(Divisor)} + \textbf{(Remainder)} \\
(x^3 + 2x^2 + 1) &= (x^2 + 3x + 3) \cdot (x - 1) + 4
\end{aligned}
$$

Example (Polynomial long division)

Divide with quotient and remainder $x^3 + 2x^2 + 1$ by $x - 1$.

$$
\begin{array}{rr|llll}
\textbf{Quotient:} & & x^2 & +3x & +3 & \\
\hline
x-1 & & x^3+2x^2 & & +1 & \\
- & & x^3-x^2 & & & \\
\hline
 & & 3x^2 & & +1 & \\
- & & 3x^2-3x & & & \\
\hline
 & & & 3x+1 & & \\
- & & & 3x-3 & & \\
\hline
\textbf{Remainder:} & & & & 4 &
\end{array}
$$

$$
\begin{aligned}
\textbf{(Dividend)} &= \textbf{(Quotient)} \cdot \textbf{(Divisor)} + \textbf{(Remainder)} \\
(x^3 + 2x^2 + 1) &= (x^2 + 3x + 3) \cdot (x - 1) + 4
\end{aligned}
$$

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$2x - 3 \quad \overline{\big)\, 6x^3 - 19x^2 + 17x - 3}$$

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$2x - 3 \;\; \overline{\big)\, 6x^3 - 19x^2 + 17x - 3}$$

Example

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

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

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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

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

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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

Multiply $3x^2$ by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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

Multiply $3x^2$ by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r|l}
 & 3x^2 \\
\cline{2-2}
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\
\cline{2-2}
 & \quad -10x^2 + 17x - 3
\end{array}
$$

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & \quad 3x^2 \quad \textbf{?} \\
2x - 3 & \overline{\big)\, 6x^3 - 19x^2 + 17x - 3} \\
- & \;\; 6x^3 - 9x^2 \\
\hline
 & \qquad\; -10x^2 + 17x - 3
\end{array}
$$

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

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r|l}
 & \;3x^2 - 5x \\ \cline{2-2}
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\ \cline{2-2}
 & -10x^2 + 17x - 3
\end{array}
$$

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

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r l}
 & \ 3x^2 - 5x \\
2x - 3 & \overline{\big)\, 6x^3 - 19x^2 + 17x - 3} \\
- & \quad 6x^3 - 9x^2 \\
\hline
 & \qquad -10x^2 + 17x - 3 \\
 & \qquad\ \ \textbf{?} \qquad \textbf{?} \\
\hline
\end{array}
$$

Multiply $-5x$ by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r|l}
 & \quad\;\; 3x^2 - 5x \\
\cline{2-2}
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - \;\,9x^2 \\
\cline{2-2}
 & \qquad\;\, -10x^2 + 17x - 3 \\
 & \qquad\;\, -10x^2 + 15x \\
\cline{2-2}
\end{array}
$$

Multiply $-5x$ by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & 3x^2 - 5x \\
2x - 3 & \overline{\big)\, 6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \\
 & \overline{ -10x^2 + 17x - 3} \\
- & -10x^2 + 15x \\
 & \overline{ ? \quad ?}
\end{array}
$$

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & \; 3x^2 - 5x \\
2x - 3 & \overline{\big) 6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \\
\hline
 & {\color{red}-10x^2 + 17x - 3} \\
{\color{red}-} & {\color{red}-10x^2 + 15x} \\
\hline
 & {\color{red}2x - 3}
\end{array}
$$

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & \phantom{6x^3-{}}3x^2 - 5x \quad \mathbf{?} \\
2x - 3 & \big)\overline{6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \\
\hline
 & -10x^2 + 17x - 3 \\
- & -10x^2 + 15x \\
\hline
 & 2x - 3
\end{array}
$$

Divide $2x$ by $2x$.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r|l}
 & \;\;\;\;\;\;\;\; 3x^2 - 5x + 1 \\
\hline
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\
\hline
 & \;\;\;\;\;\; -10x^2 + 17x - 3 \\
- & \;\;\;\;\;\; -10x^2 + 15x \\
\hline
 & \; 2x - 3
\end{array}
$$

Divide $2x$ by $2x$.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & \quad 3x^2 - 5x + 1 \\
2x - 3 & \overline{\big)\, 6x^3 - 19x^2 + 17x - 3} \\
- & \quad 6x^3 - 9x^2 \\
\hline
 & \qquad -10x^2 + 17x - 3 \\
- & \qquad -10x^2 + 15x \\
\hline
 & \qquad\qquad 2x - 3 \\
 & \qquad\qquad ? \quad ? \\
\hline
\end{array}
$$

Multiply 1 by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{r|l}
 & 3x^2 - 5x + {\color{red}1} \\
\hline
{\color{red}2x - 3} & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\
\hline
 & -10x^2 + 17x - 3 \\
- & -10x^2 + 15x \\
\hline
 & 2x - 3 \\
 & {\color{red}2x - 3} \\
\hline
\end{array}
$$

Multiply 1 by divisor.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rrrrr}
 & 3x^2 & -5x & +1 & \\
\cline{2-5}
2x-3 & \big) \; 6x^3 & -19x^2 & +17x & -3 \\
- & 6x^3 & -9x^2 & & \\
\cline{2-5}
 & & -10x^2 & +17x & -3 \\
- & & -10x^2 & +15x & \\
\cline{3-5}
 & & & {\color{red}2x} & {\color{red}-3} \\
{\color{red}-} & & & {\color{red}2x} & {\color{red}-3} \\
\cline{4-5}
 & & & & {\color{red}\mathbf{?}}
\end{array}
$$

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & 3x^2 - 5x + 1 \\
2x - 3 & \overline{\big)\,6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \\
\hline
 & -10x^2 + 17x - 3 \\
- & -10x^2 + 15x \\
\hline
 & 2x - 3 \\
- & 2x - 3 \\
\hline
 & 0
\end{array}
$$

Subtract last two polynomials.

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$
\begin{array}{rl}
 & 3x^2 - 5x + 1 \\
2x - 3 & \overline{\big)\, 6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \\
\hline
 & - 10x^2 + 17x - 3 \\
- & - 10x^2 + 15x \\
\hline
 & 2x - 3 \\
- & 2x - 3 \\
\hline
 & 0
\end{array}
$$

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 $6x^3 - 19x^2 + 17x - 3 = 0$.

Quotient: $3x^2 - 5x + 1$

$$
\begin{array}{r|l}
 & 3x^2 - 5x + 1 \\
\cline{2-2}
2x - 3 & 6x^3 - 19x^2 + 17x - 3 \\
- & 6x^3 - 9x^2 \\
\cline{2-2}
 & -10x^2 + 17x - 3 \\
- & -10x^2 + 15x \\
\cline{2-2}
 & 2x - 3 \\
- & 2x - 3 \\
\cline{2-2}
 & 0
\end{array}
$$

(Dividend)=(**Quotient**) $\cdot$ **(Divisor)** + **(Remainder)**

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

Example

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\begin{array}{rr}
\textbf{Quotient:} & 3x^2 - 5x + 1 \\
2x - 3 & \overline{)6x^3 - 19x^2 + 17x - 3} \\
- & 6x^3 - 9x^2 \qquad\qquad \\ \hline
 & -10x^2 + 17x - 3 \\
- & -10x^2 + 15x \quad \\ \hline
 & 2x - 3 \\
- & 2x - 3 \\ \hline
\textbf{Remainder:} & 0
\end{array}
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$$\textbf{(Dividend)} = \textbf{(Quotient)} \cdot \textbf{(Divisor)} + \textbf{(Remainder)}$$

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No easy factorization of quadratic, so use formula:

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Example

Plot the left hand side of the equation with a graphing calculator. Solve the equation.

$$2x^3 + x^2 - 7x - 6 = 0$$

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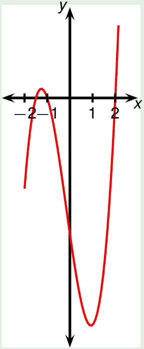

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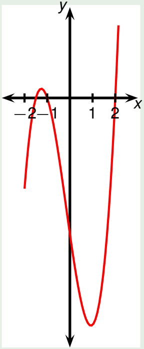

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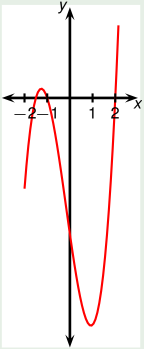

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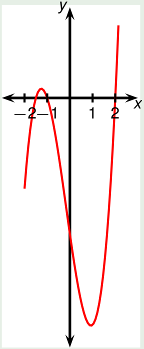

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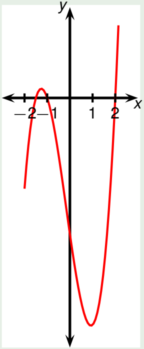

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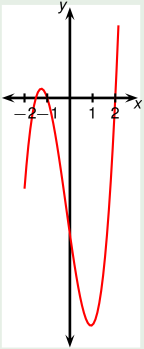

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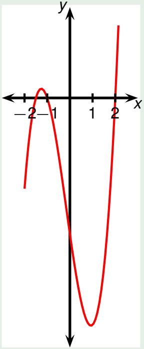

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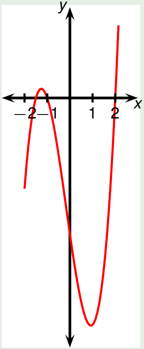

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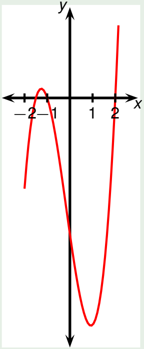

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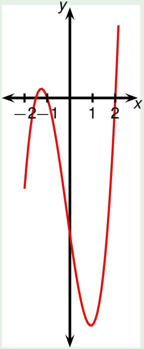

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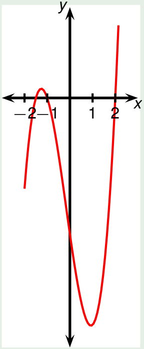

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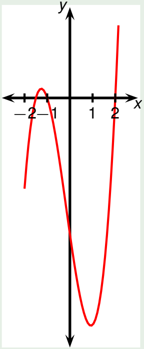

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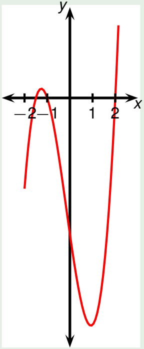
$$= (2x^2 + 5x + 3)(x - 2)$$

Check work to make sure we guessed the roots correctly.

Example



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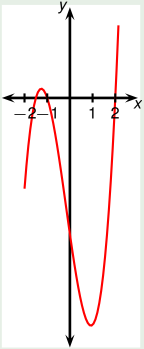

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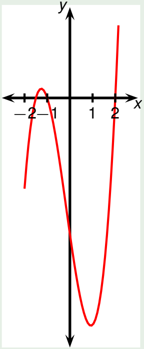

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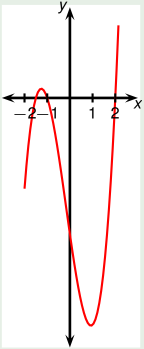

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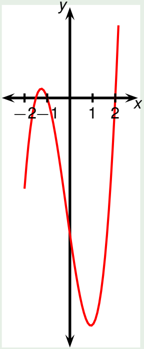

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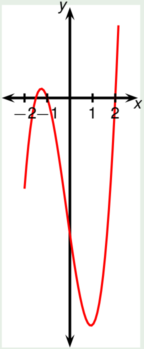

Plot the left hand side of the equation with a graphing calculator. Solve the equation.

$$\begin{array}{rcl} 2x^3 + x^2 - 7x - 6 &=& 0 \\ (2x+3)(x+1)(x-2) &=& 0 \\ x = -\frac{3}{2} \quad \textbf{or} \quad x = -1 \quad \textbf{or} \quad x = 2 \end{array}$$

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Example

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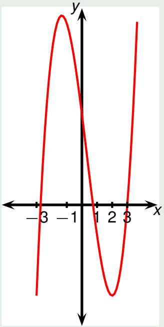

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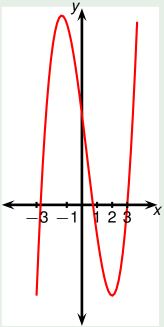

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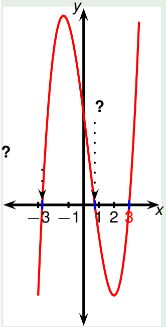

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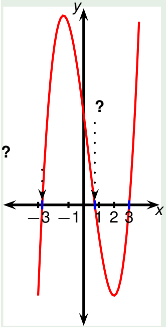
The graph appears to intersect the x axis at:

? , **?** , 3.

Example



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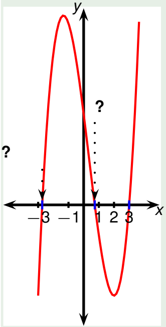

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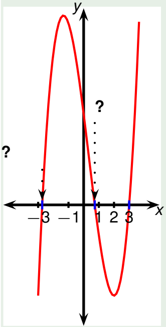

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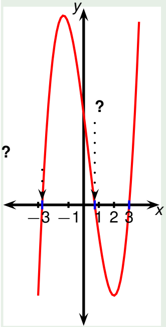

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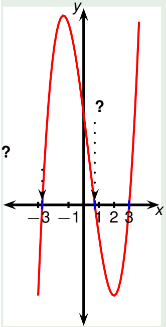
$$\begin{array}{r|l} & \color{red}{?} \\ \color{red}{x} - 3 & \color{red}{x^3} - x^2 - 8x + 6 \end{array}$$

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

Example



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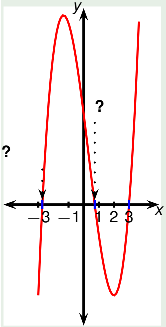
$$\begin{array}{r|l} & x^2 \\ \hline x-3 & x^3 - x^2 - 8x + 6 \end{array}$$

Divide x^3 by x.

Example



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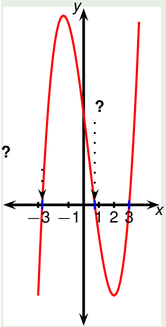
Multiply x^2 by divisor.

Example



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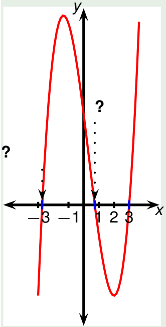
Example



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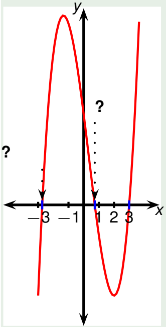
Subtract last two polynomials.

Example



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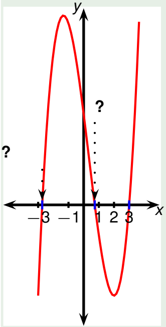

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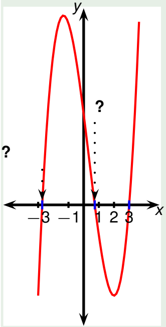
$$\begin{array}{r|l} & \quad x^2 \quad \color{red}{?} \\ \hline \color{red}{x} - 3 & x^3 - x^2 - 8x + 6 \\ & x^3 - 3x^2 \\ \hline & \qquad \color{red}{2x^2} - 8x + 6 \end{array}$$

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

Example



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The graph appears to intersect the x axis at:
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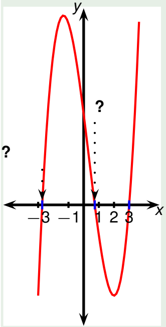
$$\begin{array}{r|l} & x^2 + 2x \\ \hline x - 3 & x^3 - x^2 - 8x + 6 \\ & x^3 - 3x^2 \\ \hline & 2x^2 - 8x + 6 \end{array}$$

Divide $2x^2$ by x.

Example



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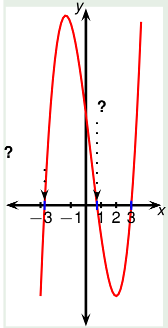
Multiply $\color{red}{2x}$ by divisor.

Example



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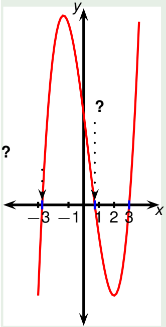

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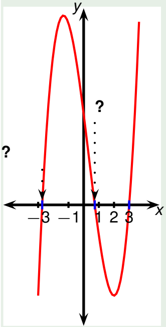
- & x^3 - 3x^2 \\
\hline
 & \quad 2x^2 - 8x + 6 \\
- & \quad 2x^2 - 6x \\
\hline
 & \qquad \mathbf{?} \quad \mathbf{?}
\end{array}$$

Subtract last two polynomials.

Example



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$$\begin{array}{r|l} & \phantom{x^3-{}} x^2 + 2x \\ \hline x - 3 & x^3 - x^2 - 8x + 6 \\ - & x^3 - 3x^2 \\ \hline & \phantom{x^3-{}} 2x^2 - 8x + 6 \\ - & \phantom{x^3-{}} 2x^2 - 6x \\ \hline & \phantom{x^3 - 2x^2 {}} -2x + 6 \end{array}$$

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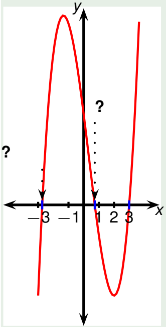

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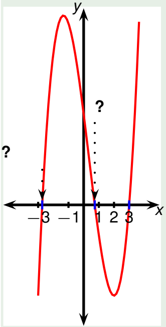
Divide $\color{red}{-2x}$ by $\color{red}{x}$.

Example



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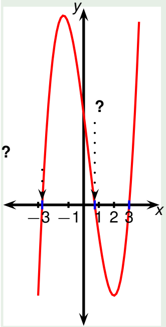
x - 3 & \overline{\big) x^3 - x^2 - 8x + 6} \\
- & x^3 - 3x^2 \\
 & \overline{\quad 2x^2 - 8x + 6} \\
- & \quad 2x^2 - 6x \\
 & \overline{\quad\quad -2x + 6}
\end{array}$$

Divide $-2x$ by x.

Example



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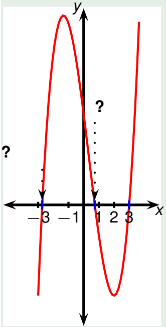
 & 2x^2 - 8x + 6 \\
- & \underline{2x^2 - 6x} \\
 & -2x + 6 \\
 & \underline{\mathbf{?} \quad \mathbf{?}}
\end{array}$$

Multiply -2 by divisor.

Example



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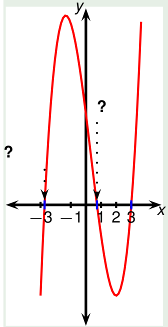
Example



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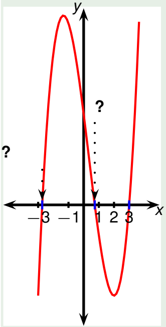
Subtract last two polynomials.

Example



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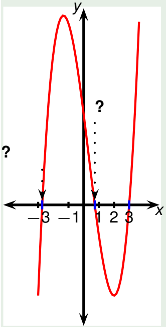
$$\begin{array}{r r l}
 & & x^2 + 2x - 2 \\
x - 3 & & \overline{\big) x^3 - x^2 - 8x + 6} \\
- & & x^3 - 3x^2 \\ \hline
 & & 2x^2 - 8x + 6 \\
- & & 2x^2 - 6x \\ \hline
 & & -2x + 6 \\
- & & -2x + 6 \\ \hline
 & & 0
\end{array}$$

Subtract last two polynomials.

Example



Plot the left hand side of the equation with a graphing calculator. Solve the equation.

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The graph appears to intersect the x axis at:
? , **?** , 3. What are the two roots besides 3?

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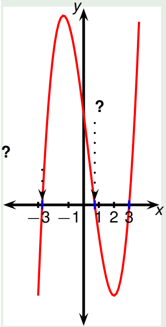
Example



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$$\begin{aligned} x^3 - x^2 - 8x + 6 &= 0 \\ (x-3)({\color{red}x^2 + 2x - 2}) + 0 &= 0 \end{aligned}$$

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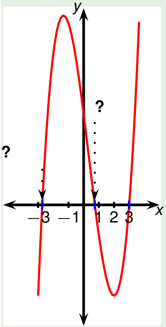
$$\begin{array}{rl} \textbf{\color{red}Quotient:} & {\color{red}x^2 + 2x - 2} \\ x-3 & \overline{\big) x^3 - x^2 - 8x + 6} \\ - & \underline{x^3 - 3x^2} \\ & \quad 2x^2 - 8x + 6 \\ - & \quad \underline{2x^2 - 6x} \\ & \qquad -2x + 6 \\ - & \qquad \underline{-2x + 6} \\ & \qquad\qquad {\color{orange}0} \end{array}$$

Example



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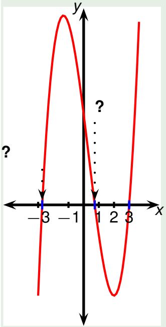
Example



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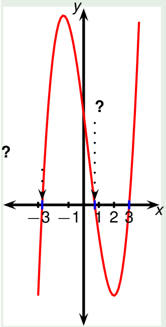

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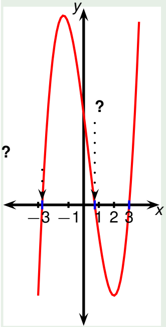

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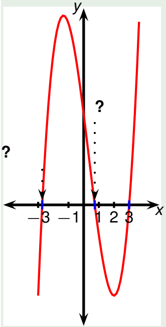

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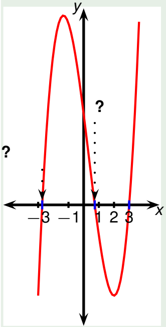

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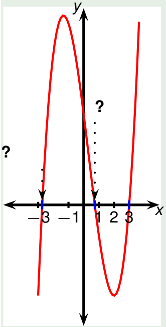

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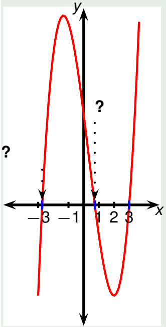

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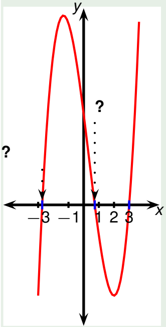
Example



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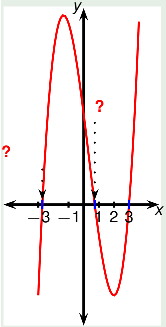
Example



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The graph appears to intersect the x axis at:

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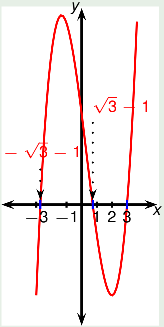

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The graph appears to intersect the x axis at: $-\sqrt{3}-1, \sqrt{3}-1, 3$. What are the two roots besides 3?

Final answer:

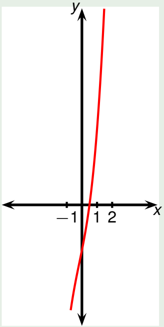
$x = 3$ **or** $x = -1 - \sqrt{3}$ **or** $x = -1 + \sqrt{3}$.

Example

Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

$$2x^3 + x^2 + 5x - 3 \quad = \quad 0$$

Example



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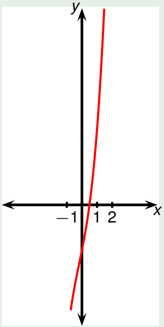

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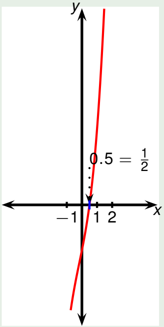

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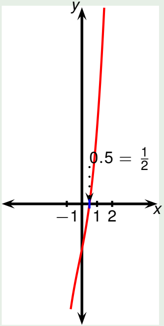
We see only one root, $x = 0.5 = \frac{1}{2}$.

Example



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We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)?

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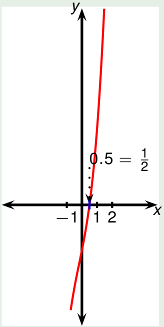

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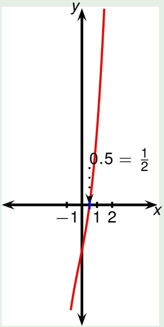

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$$x - \frac{1}{2} \quad \overline{\big) 2x^3 + x^2 + 5x - 3}$$

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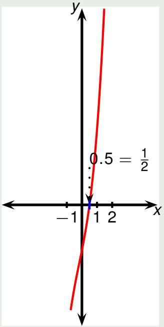

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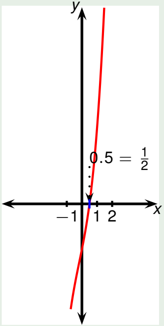

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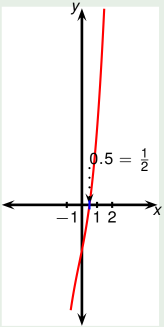

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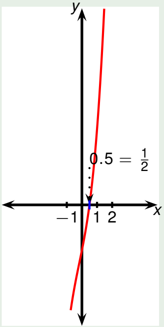
Divide $2x^3$ by x.

Example



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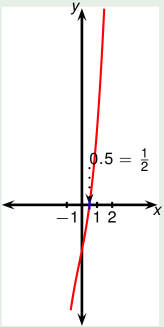

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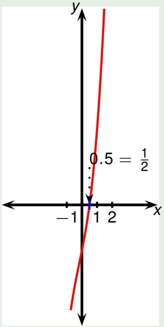
$$\begin{array}{r|l} & \color{red}{2x^2} \\ \cline{2-2} \color{red}{x - \frac{1}{2}} & 2x^3 + x^2 + 5x - 3 \\ & \color{red}{\textbf{?} \quad \textbf{?}} \\ \cline{2-2} \end{array}$$

Multiply $\color{red}{2x^2}$ by divisor.

Example



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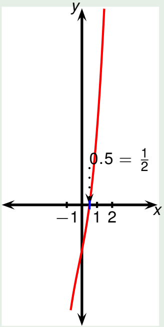

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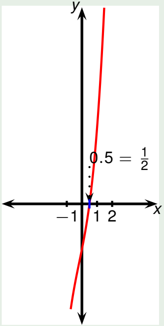
Subtract last two polynomials.

Example



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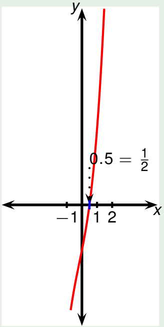

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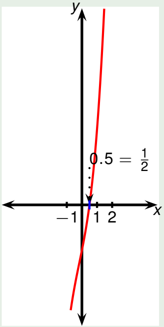
Divide $\color{red}{2x^2}$ by $\color{red}{x}$.

Example



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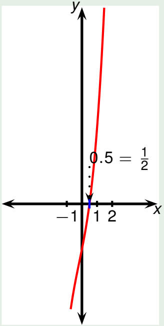
Example



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- & \;\; 2x^3 - x^2 \\ \cline{2-2}
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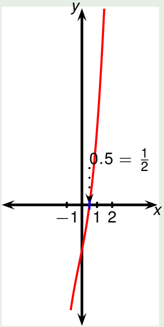
 & \qquad\quad \;\; ? \qquad ? \\ \cline{2-2}
\end{array}$$

Multiply $2x$ by divisor.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

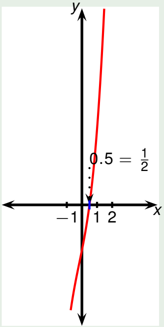
$$2x^3 + x^2 + 5x - 3 = 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{r|l} & 2x^2 + 2x \\ \hline x - \frac{1}{2} & 2x^3 + x^2 + 5x - 3 \\ - & 2x^3 - x^2 \\ \hline & \qquad 2x^2 + 5x - 3 \\ & \qquad 2x^2 - x \\ \hline \end{array}$$

Multiply $2x$ by divisor.

Example



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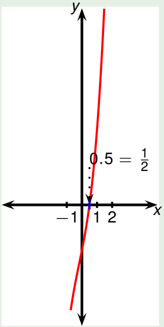
$$
\begin{array}{r|l}
 & 2x^2 + 2x \\
\cline{2-2}
x - \frac{1}{2} & 2x^3 + x^2 + 5x - 3 \\
- & 2x^3 - x^2 \\
\cline{2-2}
 & \qquad 2x^2 + 5x - 3 \\
- & \qquad 2x^2 - x \\
\cline{2-2}
 & \qquad\qquad \mathbf{?} \quad \mathbf{?}
\end{array}
$$

Subtract last two polynomials.

Example



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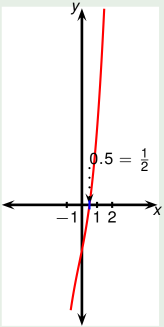
$$2x^3 + x^2 + 5x - 3 = 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$
\begin{array}{rl}
 & 2x^2 + 2x \\
x - \frac{1}{2} & \overline{\left) 2x^3 + x^2 + 5x - 3 \right.} \\
- & 2x^3 - x^2 \\
\hline
 & \quad 2x^2 + 5x - 3 \\
- & \quad 2x^2 - x \\
\hline
 & \qquad 6x - 3
\end{array}
$$

Subtract last two polynomials.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

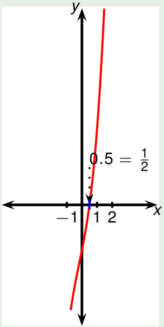
$$2x^3 + x^2 + 5x - 3 = 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rrrrrr}
 & & 2x^2 & +2x & & \textbf{?} \\ \cline{2-6}
x - \frac{1}{2} & \multicolumn{1}{|r}{2x^3} & + x^2 & +5x & -3 & \\
- & 2x^3 & - x^2 & & & \\ \cline{2-6}
 & & 2x^2 & +5x & -3 & \\
- & & 2x^2 & - x & & \\ \cline{3-6}
 & & & 6x & -3 &
\end{array}$$

Divide $6x$ by x.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

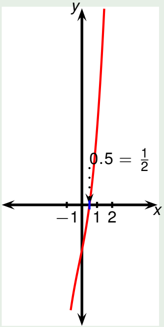
$$2x^3 + x^2 + 5x - 3 \quad = \quad 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$
\begin{array}{rl}
 & \phantom{2x^3+{}} 2x^2 + 2x + 6 \\
x - \frac{1}{2} & \overline{\big)\, 2x^3 + x^2 + 5x - 3} \\
- & \underline{2x^3 - x^2} \\
 & \phantom{2x^3-{}} 2x^2 + 5x - 3 \\
- & \phantom{2x^3-{}} \underline{2x^2 - x} \\
 & \phantom{2x^3-2x^2-{}} 6x - 3
\end{array}
$$

Divide $6x$ by x.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

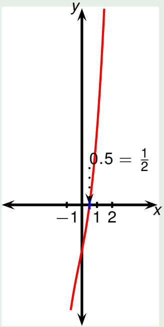
$$2x^3 + x^2 + 5x - 3 \quad = \quad 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rr}
 & 2x^2 + 2x {\color{red} + 6} \\
{\color{red} x - \frac{1}{2}} & \overline{\big) 2x^3 + x^2 + 5x - 3} \\
- & 2x^3 - x^2 \qquad\qquad \\
\hline
 & 2x^2 + 5x - 3 \\
- & 2x^2 - x \qquad \\
\hline
 & 6x - 3 \\
 & {\color{red} ? \quad ?} \\
\hline
\end{array}$$

Multiply ${\color{red}6}$ by divisor.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

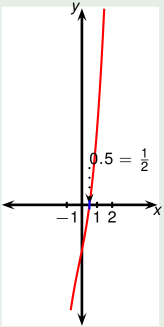
$$2x^3 + x^2 + 5x - 3 = 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rl}
 & 2x^2 + 2x + 6 \\
x - \frac{1}{2} & \overline{\big) 2x^3 + x^2 + 5x - 3} \\
- & 2x^3 - x^2 \\
\hline
 & 2x^2 + 5x - 3 \\
- & 2x^2 - x \\
\hline
 & 6x - 3 \\
 & 6x - 3 \\
\hline
\end{array}$$

Multiply 6 by divisor.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

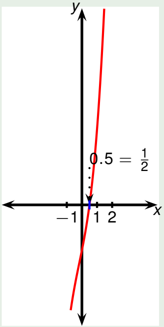
$$2x^3 + x^2 + 5x - 3 \quad = \quad 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rrl}
 & & 2x^2 + 2x + 6 \\ \cline{3-3}
x - \frac{1}{2} & & \multicolumn{1}{|l}{2x^3 + x^2 + 5x - 3} \\
- & & 2x^3 - x^2 \\ \cline{3-3}
 & & \quad\quad 2x^2 + 5x - 3 \\
- & & \quad\quad 2x^2 - x \\ \cline{3-3}
 & & \quad\quad\quad\quad 6x - 3 \\
- & & \quad\quad\quad\quad 6x - 3 \\ \cline{3-3}
 & & \quad\quad\quad\quad\quad ?
\end{array}$$

Subtract last two polynomials.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

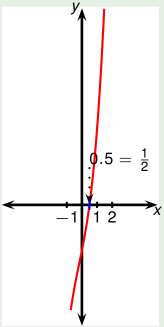
$$2x^3 + x^2 + 5x - 3 \quad = \quad 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rrl}
 & & 2x^2 + 2x + 6 \\ \cline{3-3}
x - \frac{1}{2} & & \multicolumn{1}{|l}{2x^3 + x^2 + 5x - 3} \\
- & & 2x^3 - x^2 \\ \cline{3-3}
 & & \qquad 2x^2 + 5x - 3 \\
- & & \qquad 2x^2 - x \\ \cline{3-3}
 & & \qquad\qquad 6x - 3 \\
- & & \qquad\qquad 6x - 3 \\ \cline{3-3}
 & & \qquad\qquad\quad 0
\end{array}$$

Subtract last two polynomials.

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

$$2x^3 + x^2 + 5x - 3 = 0$$

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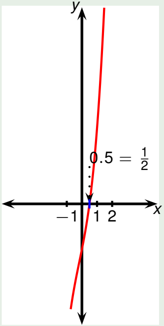
 & 2x^2 + 2x + 6 \\
x - \frac{1}{2} & \overline{)\,2x^3 + x^2 + 5x - 3} \\
- & 2x^3 - x^2 \\
\hline
 & \qquad 2x^2 + 5x - 3 \\
- & \qquad 2x^2 - x \\
\hline
 & \qquad\qquad 6x - 3 \\
- & \qquad\qquad 6x - 3 \\
\hline
 & \qquad\qquad\quad 0
\end{array}$$

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

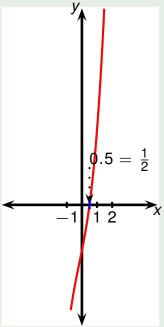
$$\begin{aligned} 2x^3 + x^2 + 5x - 3 &= 0 \\ \left(x - \tfrac{1}{2}\right)\left(2x^2 + 2x + 6\right) + 0 &= 0 \end{aligned}$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

Quotient: $2x^2 + 2x + 6$

$$\begin{array}{rr} x - \frac{1}{2} & \overline{\big)\, 2x^3 + x^2 + 5x - 3} \\ - & 2x^3 - x^2 \\ \hline & 2x^2 + 5x - 3 \\ - & 2x^2 - x \\ \hline & 6x - 3 \\ - & 6x - 3 \\ \hline & 0 \end{array}$$

Example



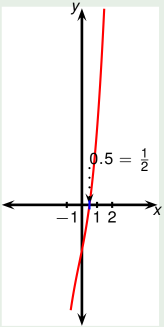
Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

$$\begin{aligned} 2x^3 + x^2 + 5x - 3 &= 0 \\ \left(x - \frac{1}{2}\right)\left(2x^2 + 2x + 6\right) {\color{red} + 0} &= 0 \end{aligned}$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:

$$\begin{array}{rr} \textbf{Quotient:} & 2x^2 + 2x + 6 \\ x - \frac{1}{2} & \overline{\big) 2x^3 + x^2 + 5x - 3} \\ - & 2x^3 - x^2 \\ \hline & 2x^2 + 5x - 3 \\ - & 2x^2 - x \\ \hline & 6x - 3 \\ - & 6x - 3 \\ \hline {\color{orange}\textbf{Remainder:}} & {\color{orange}0} \end{array}$$

Example



Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

$$\begin{aligned} 2x^3 + x^2 + 5x - 3 &= 0 \\ \left(x - \tfrac{1}{2}\right)\left(2x^2 + 2x + 6\right) &= 0 \end{aligned}$$

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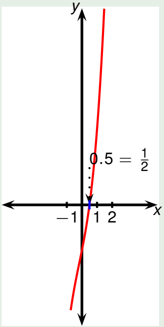
$$\begin{array}{rr} \textbf{Quotient:} & 2x^2 + 2x + 6 \\ x - \frac{1}{2} & \overline{\left)\, 2x^3 + x^2 + 5x - 3\right.} \\ - & 2x^3 - x^2 \qquad\qquad \\ \hline & 2x^2 + 5x - 3 \\ - & 2x^2 - x \qquad \\ \hline & 6x - 3 \\ - & 6x - 3 \\ \hline \textbf{Remainder:} & 0 \end{array}$$

Example



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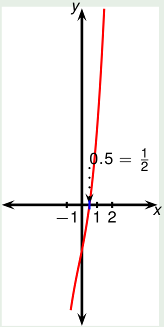
$x - \frac{1}{2} = 0$ **or** $x =$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)?

Example



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$$x - \frac{1}{2} = 0 \quad \textbf{or} \quad x =$$

$$x = \frac{1}{2}$$

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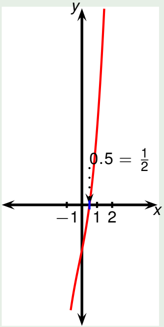
Example



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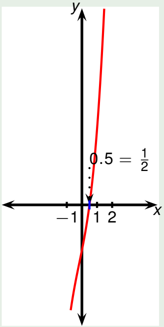
$$\begin{aligned} 2x^3 + x^2 + 5x - 3 &= 0 \\ \left(x - \tfrac{1}{2}\right)\left(2x^2 + 2x + 6\right) &= 0 \end{aligned}$$

$$x - \tfrac{1}{2} = 0 \quad \textbf{or} \quad x = \frac{-2 \pm \sqrt{2^2 - 4 \cdot 2 \cdot 6}}{2 \cdot 2}$$

$$x = \tfrac{1}{2}$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)?

Example



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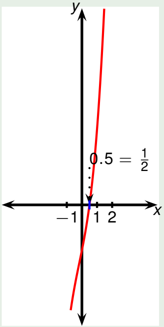
Example



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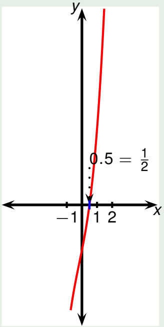
Example



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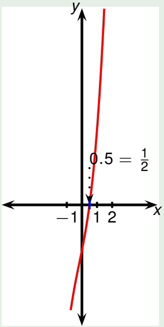
$$\begin{aligned} 2x^3 + x^2 + 5x - 3 &= 0 \\ \left(x - \frac{1}{2}\right)\left(2x^2 + 2x + 6\right) &= 0 \end{aligned}$$

$$\begin{aligned} x - \frac{1}{2} &= 0 & \textbf{or} \quad x &= \frac{-2 \pm \sqrt{2^2 - 4 \cdot 2 \cdot 6}}{2 \cdot 2} \\ x &= \frac{1}{2} & x &= \frac{-2 \pm \sqrt{-44}}{2 \cdot 2} \end{aligned}$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)?

Example



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$$x - \frac{1}{2} = 0 \quad \textbf{or} \quad x = \frac{-2 \pm \sqrt{2^2 - 4 \cdot 2 \cdot 6}}{2 \cdot 2}$$

$$x = \frac{1}{2} \qquad\qquad x = \frac{-2 \pm \sqrt{-44}}{2 \cdot 2}$$

no real solution

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)?