

Precalculus

Polynomial division and factorization of cubics with rational root

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Outline

1 Polynomial division

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- 1 Polynomial division
- 2 Factoring cubics with rational root

Example (Polynomial long division)

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

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$$x - 1 \overline{) x^3 + 2x^2 + 1}$$

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Example (Polynomial long division)

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

$$\begin{array}{r}
 \text{?} \\
 x - 1 \overline{) x^3 + 2x^2 + 1}
 \end{array}$$

Divide x^3 by x .

Example (Polynomial long division)

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

$$x - 1 \overline{) \overset{x^2}{x^3 + 2x^2} + 1}$$

Divide x^3 by x .

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{? ?}
 \end{array}$$

Multiply x^2 by divisor.

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 + 1
 \end{array}$$

Multiply x^2 by divisor.

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{3x - 3} \\
 4
 \end{array}$$

Subtract last two polynomials.

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 \\
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Subtract last two polynomials.

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

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 x^2 \quad ? \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2
 \end{array}$$

Divide $3x^2$ by x .

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 + 3x \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 + 1
 \end{array}$$

Divide $3x^2$ by x .

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 + 3x \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 + 1 \\
 \underline{ \text{?} \text{?}}
 \end{array}$$

Multiply $3x$ by divisor.

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

$$\begin{array}{r}
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 \underline{x^3 - x^2} \\
 3x^2 + 1 \\
 \underline{3x^2 - 3x} \\
 4x + 1
 \end{array}$$

Multiply $3x$ by divisor.

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

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 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x \\
 \underline{3x - 3} \\
 4
 \end{array}$$

Subtract last two polynomials.

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

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 \end{array}$$

Subtract last two polynomials.

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 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
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 \end{array}$$

Divide $3x$ by x .

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 + 3x + 3 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 + 1 \\
 \underline{3x^2 - 3x} \\
 3x + 1
 \end{array}$$

Divide $3x$ by x .

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

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 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{ + 3} \\
 4
 \end{array}$$

Multiply 3 by divisor.

Example (Polynomial long division)

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

$$\begin{array}{r}
 x^2 + 3x + 3 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{3x - 3} \\
 4
 \end{array}$$

Multiply 3 by divisor.

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

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 x^2 + 3x + 3 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 + 1 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{3x - 3} \\
 ?
 \end{array}$$

Subtract last two polynomials.

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

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 \underline{ 3x^2 - 3x} \\
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 \end{array}$$

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 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{3x - 3} \\
 4
 \end{array}$$

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

$$(x^3 + 2x^2 + 1) = (x^2 + 3x + 3) \cdot (x - 1) + 4$$

Example (Polynomial long division)

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

$$\begin{array}{r}
 \text{Quotient: } x^2 + 3x + 3 \\
 x - 1 \overline{) x^3 + 2x^2 + 1} \\
 \underline{x^3 - x^2} \\
 3x^2 \\
 \underline{3x^2 - 3x} \\
 3x + 1 \\
 \underline{3x - 3} \\
 4
 \end{array}$$

Remainder: 4

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\begin{array}{r}
 3x^2 - 5x \\
 2x - 3 \overline{) 6x^3 - 19x^2 + 17x - 3} \\
 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3
 \end{array}$$

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

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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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 3x^2 - 5x \\
 2x - 3 \overline{) 6x^3 - 19x^2 + 17x - 3} \\
 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3 \\
 \quad ? \quad ?
 \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 $6x^3 - 19x^2 + 17x - 3 = 0$.

$$\begin{array}{r}
 3x^2 - 5x \\
 2x - 3 \overline{) 6x^3 - 19x^2 + 17x - 3} \\
 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3
 \end{array}$$

Multiply $-5x$ by divisor.

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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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 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3 \\
 \underline{2x - 3} \\
 0
 \end{array}$$

Subtract last two polynomials.

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Subtract last two polynomials.

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 3x^2 - 5x \quad ? \\
 2x - 3 \overline{) 6x^3 - 19x^2 + 17x - 3} \\
 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3
 \end{array}$$

Divide $2x$ by $2x$.

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

$$\begin{array}{r}
 3x^2 - 5x + 1 \\
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 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3
 \end{array}$$

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 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3 \\
 \underline{ ? ?}
 \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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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 2x - 3 \\
 \underline{2x - 3} \\
 0
 \end{array}$$

Multiply **1** by divisor.

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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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 \underline{6x^3 - 9x^2} \\
 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3 \\
 \underline{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 $6x^3 - 19x^2 + 17x - 3 = 0$.

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 2x - 3 \\
 \underline{2x - 3} \\
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 \end{array}$$

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$$\begin{array}{r}
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 \underline{-10x^2 + 15x} \\
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 \end{array}$$

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

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

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

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 \underline{-10x^2 + 15x} \\
 2x - 3 \\
 \underline{2x - 3} \\
 0
 \end{array}$$

Remainder: 0

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

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

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

$$\begin{array}{r}
 \text{Quotient:} \quad 3x^2 - 5x + 1 \\
 2x - 3 \overline{) 6x^3 - 19x^2 + 17x - 3} \\
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 -10x^2 + 17x - 3 \\
 \underline{-10x^2 + 15x} \\
 2x - 3 \\
 \underline{2x - 3} \\
 0
 \end{array}$$

Remainder: 0

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

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

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

No easy factorization of quadratic, so use formula:

$$x_1, x_2 = ?$$

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

$$\begin{aligned}(6x^3 - 19x^2 + 17x - 3) &= (3x^2 - 5x + 1) \cdot (2x - 3) \\ &= 3 \left(x - ? \right) \left(x - ? \right) (2x - 3)\end{aligned}$$

No easy factorization of quadratic, so use formula:

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

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

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

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

No easy factorization of quadratic, so use formula:

$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-5) \pm \sqrt{(-5)^2 - 4 \cdot 3 \cdot 1}}{2 \cdot 3}$$

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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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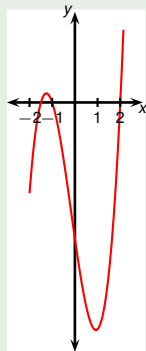


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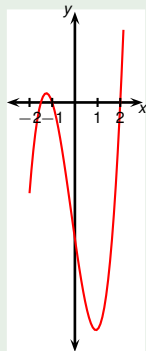


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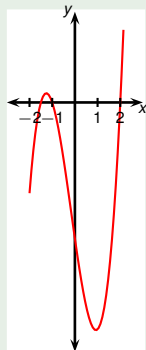
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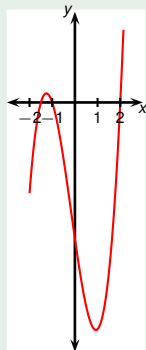
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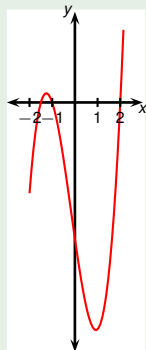
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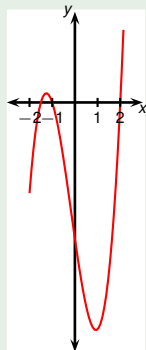
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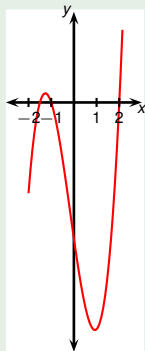
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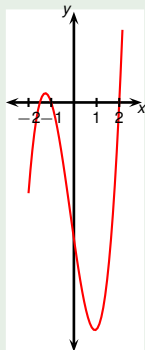
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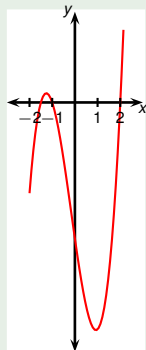
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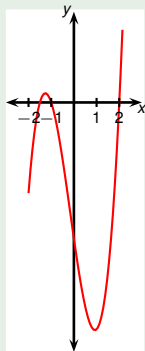
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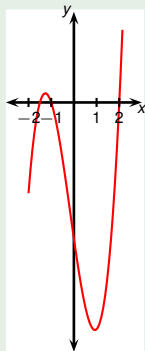
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 2x^3 + x^2 - 7x - 6 &= 0 \\
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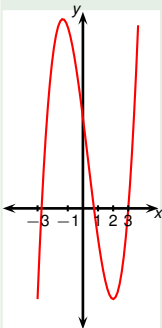
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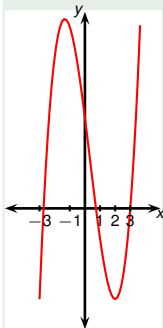


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The graph appears to intersect the x axis at:
?

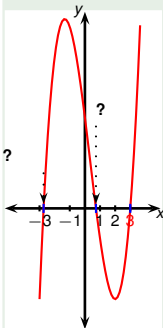


Example

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

$$x^3 - x^2 - 8x + 6 = 0$$

The graph appears to intersect the x axis at:
 ? , ? , 3.

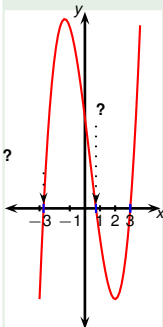


Example

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

$$x^3 - x^2 - 8x + 6 = 0$$

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



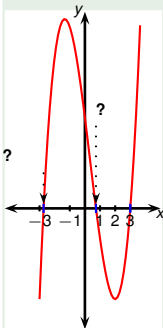
$$x - 3 \quad \overline{x^3 - x^2 - 8x + 6}$$

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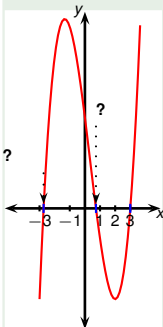
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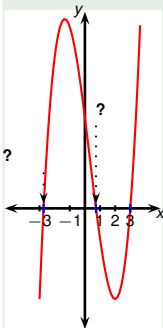
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$$x - 3 \overline{) \overset{?}{x^3} - x^2 - 8x + 6}$$

Divide x^3 by x .

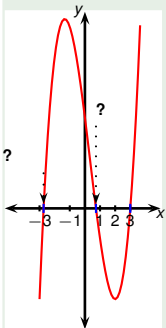
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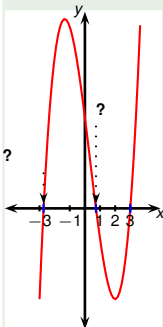
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$$\begin{array}{r}
 x - 3 \overline{) \begin{array}{c} x^3 - x^2 - 8x + 6 \\ x^2 \\ - 8x + 6 \\ \\ \end{array} } \\
 \hline
 \end{array}$$

Multiply x^2 by divisor.

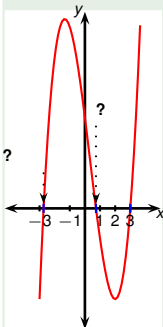
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The graph appears to intersect the x axis at:

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$$\begin{array}{r}
 x^2 \\
 x - 3 \overline{) x^3 - x^2 - 8x + 6} \\
 \underline{x^3 - 3x^2} \\
 2x^2 - 8x + 6
 \end{array}$$

Multiply x^2 by divisor.

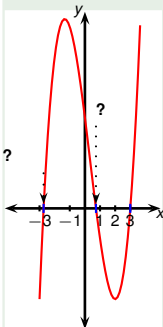
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 2x + 6 \\
 \underline{2x + 6} \\
 0
 \end{array}$$

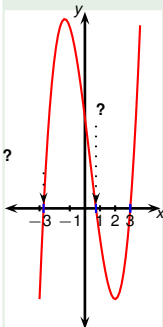
Subtract last two polynomials.

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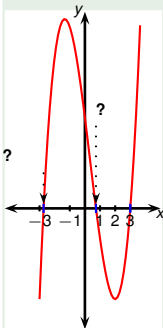
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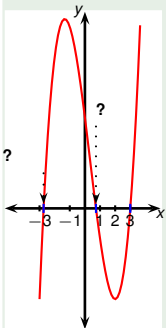
Divide $2x^2$ by x .

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 x^2 + 2x \\
 \overline{x^3 - x^2 - 8x + 6} \\
 x^3 - 3x^2 \\
 \hline
 2x^2 - 8x + 6
 \end{array}$$

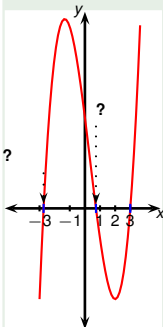
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 \underline{ } \\

 \end{array}$$

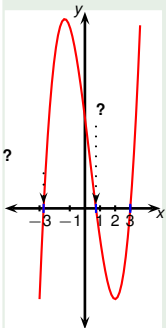
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 \hline
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 \hline
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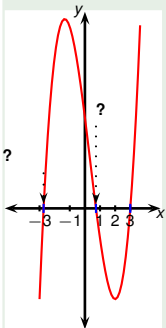
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 \hline
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 2x^2 - 6x \\
 \hline
 2x + 6 \\
 2x + 6 \\
 \hline
 0
 \end{array}$$

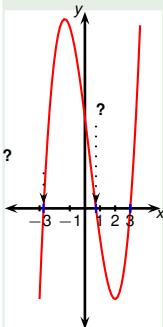
Subtract last two polynomials.

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 \hline
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Subtract last two polynomials.

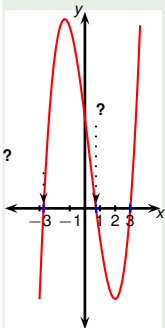
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 x^2 + 2x \quad ? \\
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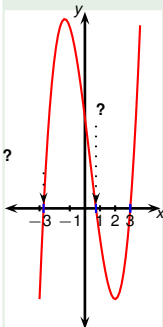
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 x^2 + 2x - 2 \\
 x - 3 \overline{) x^3 - x^2 - 8x + 6} \\
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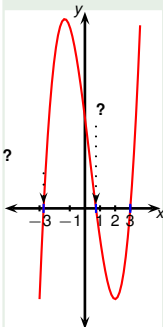
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 -2x + 6 \\
 \underline{2x - 6} \\
 12
 \end{array}$$

Multiply -2 by divisor.

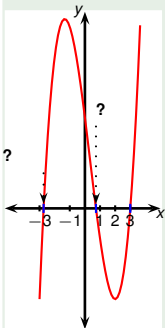
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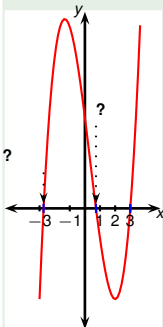
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 ?
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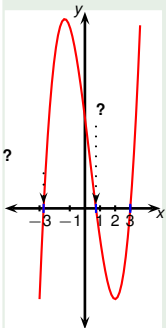
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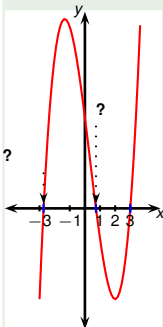
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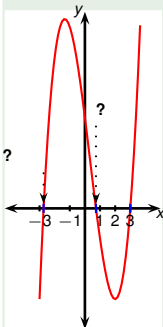
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Plot the left hand side of the equation with a graphing calculator. Solve the equation.

$$x^3 - x^2 - 8x + 6 = 0$$

$$(x - 3)(x^2 + 2x - 2) + 0 = 0$$

The graph appears to intersect the x axis at:
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Quotient: $x^2 + 2x - 2$

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

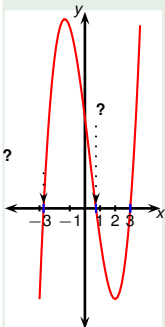
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Quotient:	$x^2 + 2x - 2$
$x - 3$	$\begin{array}{r} \overline{) x^3 - x^2 - 8x + 6} \\ x^3 - 3x^2 \\ \hline 2x^2 - 8x + 6 \\ - 2x^2 + 6x \\ \hline - 2x + 6 \\ - 2x + 6 \\ \hline 0 \end{array}$
	Remainder: 0

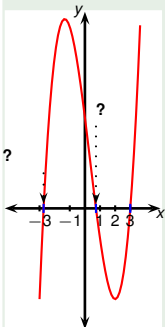
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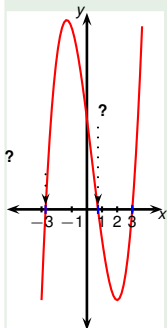
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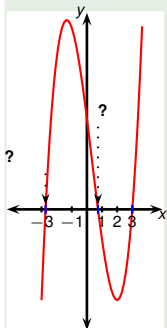
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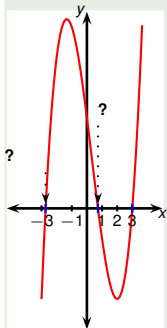
$$x^3 - x^2 - 8x + 6 = 0$$

$$(x - 3)(x^2 + 2x - 2) = 0$$

$$x - 3 = 0 \quad \text{or} \quad x = \frac{-2 \pm \sqrt{(2)^2 - 4 \cdot 1 \cdot (-2)}}{2 \cdot 1}$$

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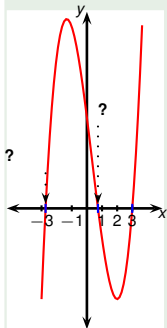
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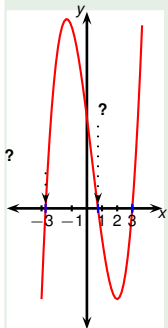
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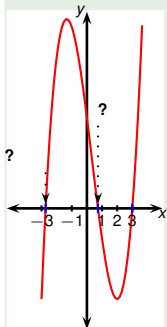
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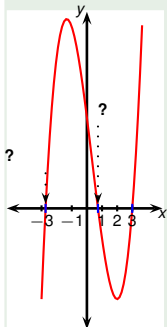
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$$x = 3 \quad x = \frac{-2 \pm \sqrt{12}}{2}$$

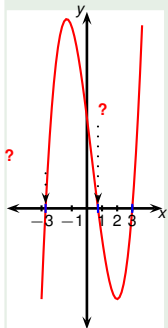
$$x = \frac{-2 \pm 2\sqrt{3}}{2}$$

The graph appears to intersect the x axis at:

?, ?, 3. What are the two roots besides 3?

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$$x^3 - x^2 - 8x + 6 = 0$$

$$(x - 3)(x^2 + 2x - 2) = 0$$

$$x - 3 = 0 \quad \text{or} \quad x = \frac{-2 \pm \sqrt{(2)^2 - 4 \cdot 1 \cdot (-2)}}{2 \cdot 1}$$

$$x = 3 \quad x = \frac{-2 \pm \sqrt{12}}{2}$$

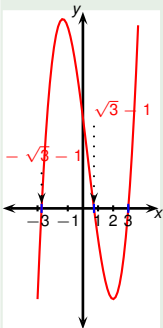
$$x = \frac{-2 \pm 2\sqrt{3}}{2} = -1 \pm \sqrt{3}.$$

The graph appears to intersect the x axis at:

?, **?**, 3. What are the two roots besides 3?

Example

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



$$x^3 - x^2 - 8x + 6 = 0$$

$$(x - 3)(x^2 + 2x - 2) = 0$$

$$x - 3 = 0 \quad \text{or} \quad x = \frac{-2 \pm \sqrt{(2)^2 - 4 \cdot 1 \cdot (-2)}}{2 \cdot 1}$$

$$x = 3$$

$$x = \frac{-2 \pm \sqrt{12}}{2}$$

$$x = \frac{-2 \pm 2\sqrt{3}}{2} = -1 \pm \sqrt{3}.$$

The graph appears to intersect the x axis at:

$-1 - \sqrt{3}$, $-1 + \sqrt{3}$, 3. What are the two roots besides 3?

Final answer:

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

Example

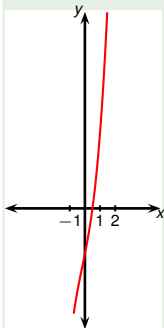
Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

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

Example

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

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

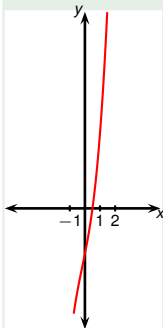


Example

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, $x = ?$.

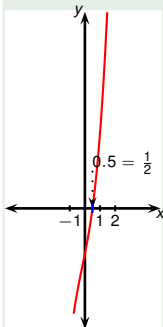


Example

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, $x = 0.5 = \frac{1}{2}$.

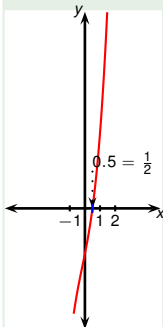


Example

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)?



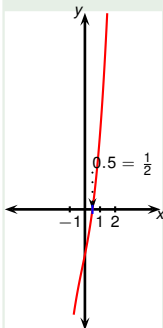
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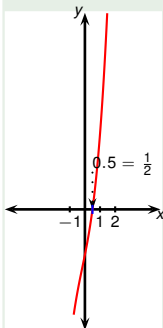
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$$2x^3 + x^2 + 5x - 3 = 0$$

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

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



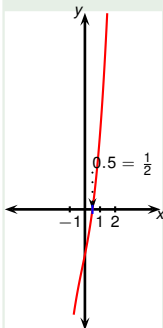
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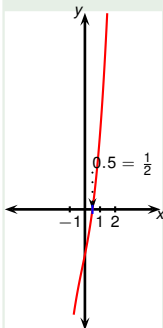
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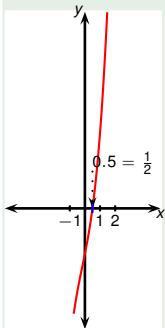


Example

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

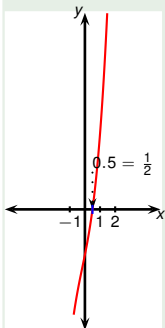
Divide $2x^3$ by x .

Example

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

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

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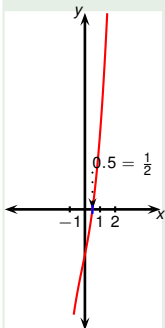
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We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:



$$x - \frac{1}{2} \overline{) \begin{array}{l} 2x^3 + x^2 + 5x - 3 \\ 2x^2 \\ \hline ? \\ ? \end{array}}$$

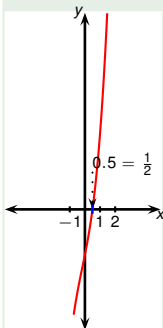
Multiply $2x^2$ by divisor.

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:



$$\begin{array}{r}
 2x^2 \\
 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3
 \end{array}$$

Multiply $2x^2$ by divisor.

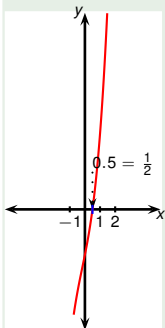
2019

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:



$$\begin{array}{r}
 x - \frac{1}{2} \quad \overline{2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3
 \end{array}$$

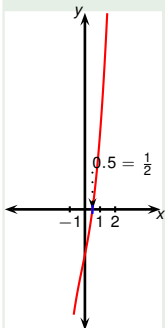
Subtract last two polynomials.

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:



$$\begin{array}{r}
 2x^2 \quad ? \\
 \hline
 x - \frac{1}{2} \quad \left| \begin{array}{l} 2x^3 + x^2 + 5x - 3 \\ 2x^3 - x^2 \end{array} \right. \\
 \hline
 2x^2 + 5x - 3
 \end{array}$$

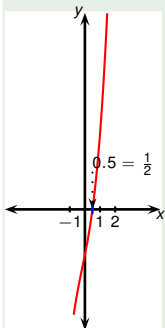
Divide $2x^2$ by x .

Example

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

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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)? Factor:



$$\begin{array}{r}
 2x^2 + 2x \\
 \hline
 x - \frac{1}{2} \quad \overline{2x^3 + x^2 + 5x - 3} \\
 \quad \quad \quad \underline{2x^3 - x^2} \\
 \quad \quad \quad \quad \quad 2x^2 + 5x - 3
 \end{array}$$

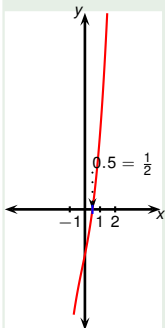
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 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{ ? ?}
 \end{array}$$

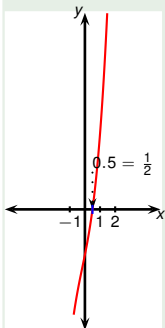
Multiply $2x$ by divisor.

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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)? Factor:



$$\begin{array}{r}
 x - \frac{1}{2} \quad \overline{2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3
 \end{array}$$

Multiply $2x$ by divisor.

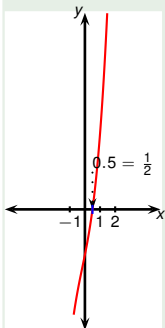
2019

Example

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

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

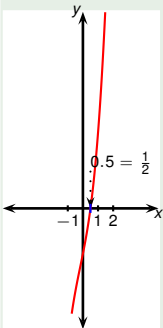
We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct? Is there another root (far away from 0)? Factor:



$$\begin{array}{r}
 x - \frac{1}{2} \quad \overline{2x^3 + x^2 + 5x - 3} \\
 \underline{\phantom{x - \frac{1}{2}} 2x^3 - x^2} \\
 \phantom{x - \frac{1}{2}} 2x^2 + 5x - 3 \\
 \phantom{x - \frac{1}{2}} \underline{\phantom{x - \frac{1}{2}} 2x^2 - x} \\
 \phantom{x - \frac{1}{2}} 6x - 3
 \end{array}$$

Subtract last two polynomials.

Example



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

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

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 2x^2 + 2x \quad ? \\
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 x - \frac{1}{2} \quad \left| \begin{array}{l} 2x^3 + x^2 + 5x - 3 \\ 2x^3 - x^2 \end{array} \right. \\
 \hline
 \phantom{x - \frac{1}{2}} 2x^2 + 5x - 3 \\
 \phantom{x - \frac{1}{2}} - \\
 \phantom{x - \frac{1}{2}} 2x^2 - x \\
 \phantom{x - \frac{1}{2}} \hline
 \phantom{x - \frac{1}{2}} 6x - 3
 \end{array}$$

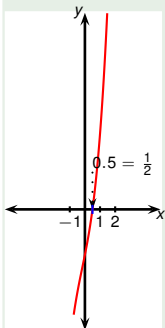
Divide $6x$ by x .

Example

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

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

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



$$\begin{array}{r}
 2x^2 + 2x + 6 \\
 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3
 \end{array}$$

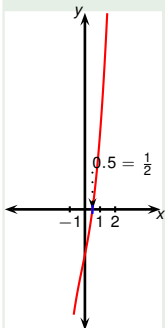
Divide $6x$ by x .

Example

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

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

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 x - \frac{1}{2} \quad \overline{2x^3 + x^2 + 5x - 3} \\
 \underline{\phantom{x - \frac{1}{2}} 2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{\phantom{x - \frac{1}{2}} 2x^2 - x} \\
 6x - 3 \\
 \underline{\phantom{x - \frac{1}{2}} - 3} \\
 \phantom{x - \frac{1}{2}} 0
 \end{array}$$

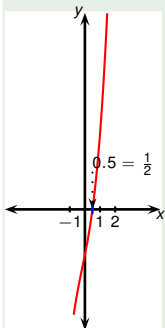
Multiply 6 by divisor.

Example

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

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

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



$$\begin{array}{r}
 2x^2 + 2x + 6 \\
 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 0
 \end{array}$$

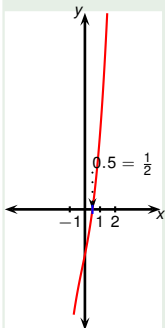
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Example

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 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 ?
 \end{array}$$

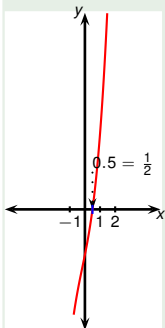
Subtract last two polynomials.

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:



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 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 0
 \end{array}$$

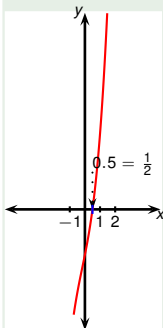
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Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

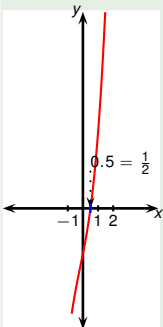
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 \underline{\phantom{x - \frac{1}{2}} 2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{\phantom{x - \frac{1}{2}} 2x^2 - x} \\
 6x - 3 \\
 \underline{\phantom{x - \frac{1}{2}} 6x - 3} \\
 0
 \end{array}$$

Example



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

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

$$(x - \frac{1}{2}) (2x^2 + 2x + 6) + 0 = 0$$

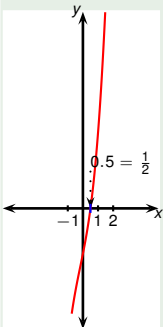
We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct?

Is there another root (far away from 0)? Factor:

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

$$\begin{array}{r}
 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 0
 \end{array}$$

Example



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

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

$$(x - \frac{1}{2})(2x^2 + 2x + 6) + 0 = 0$$

We see only one root, $x = 0.5 = \frac{1}{2}$. Is our guess correct?

Is there another root (far away from 0)? Factor:

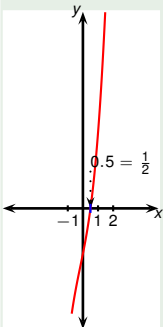
Quotient: $2x^2 + 2x + 6$

$$\begin{array}{r}
 x - \frac{1}{2} \overline{) 2x^3 + x^2 + 5x - 3} \\
 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 0
 \end{array}$$

Remainder:

0

Example



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

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

$$(x - \frac{1}{2})(2x^2 + 2x + 6) = 0$$

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

$$\begin{array}{r}
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 \underline{2x^3 - x^2} \\
 2x^2 + 5x - 3 \\
 \underline{2x^2 - x} \\
 6x - 3 \\
 \underline{6x - 3} \\
 0
 \end{array}$$

Remainder:

0

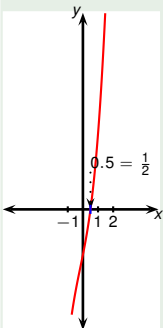
Example

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

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

$$(x - \frac{1}{2})(2x^2 + 2x + 6) = 0$$

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



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

Example

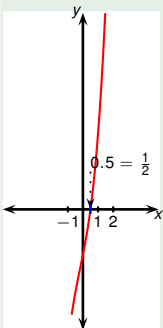
Plot the left hand side of the equation with a graphing calculator. Find all real solutions of the equation.

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

$$(x - \frac{1}{2})(2x^2 + 2x + 6) = 0$$

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

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



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

Example

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

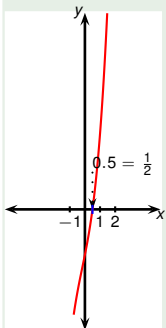
$$2x^3 + x^2 + 5x - 3 = 0$$

$$(x - \frac{1}{2}) (2x^2 + 2x + 6) = 0$$

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

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

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



Example

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

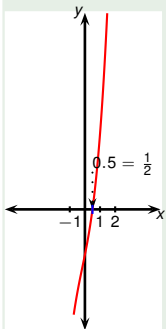
$$2x^3 + x^2 + 5x - 3 = 0$$

$$(x - \frac{1}{2})(2x^2 + 2x + 6) = 0$$

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

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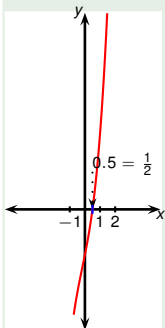
$$2x^3 + x^2 + 5x - 3 = 0$$

$$\left(x - \frac{1}{2}\right) (2x^2 + 2x + 6) = 0$$

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

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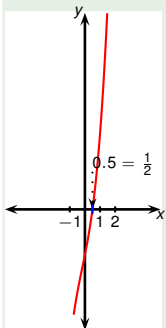
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$$x - \frac{1}{2} = 0 \quad \text{or} \quad x = \frac{-2 \pm \sqrt{2^2 - 4 \cdot 2 \cdot 6}}{2 \cdot 2}$$

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

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



Example

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

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

$$(x - \frac{1}{2})(2x^2 + 2x + 6) = 0$$

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

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

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)?

