MATH103 Mathematics for Business and Economics – I

Linear Equations, Fractional Equations and Radical Equations, Absolute Value Equality

Linear Equations

Equations

An equation is a statement that two expressions are equal.' They are separated by the equality sign, "=."

EXAMPLE 1 Examples of Equations



Equivalent Equations

1. Adding (subtracting) the same polynomial³ to (from) both sides of an equation, where the polynomial is in the same variable as that occurring in the equation.

For example, if -5x = 5 - 6x, then adding 6x to both sides gives the equivalent equation -5x + 6x = 5 - 6x + 6x, or x = 5.

2. Multiplying (dividing) both sides of an equation by the same nonzero constant.

For example, if 10x = 5, then dividing both sides by 10 gives the equivalent equation $\frac{10x}{10} = \frac{5}{10}$, or $x = \frac{1}{2}$.

- 4. Multiplying both sides of an equation by an expression involving the variable;
- 5. Dividing both sides of an equation by an expression involving the variable;

LINEAR EQUATIONS

A **linear equation in one variable**, such as *x*, is an equation that can be written in the *standard form*

$$ax + b = 0,$$

where *a* and *b* are real numbers with $a \neq 0$.

FINDING THE SOLUTION: Procedure for solving linear equations in one variable

- **Step 1 Eliminate Fractions.** Multiply both sides of the equation by the least common denominator (LCD) of all the fractions.
- **Step 2 Simplify.** Simplify both sides of the equation by removing parentheses and other grouping symbols (if any) and combining like terms.

FINDING THE SOLUTION: Procedure for solving linear equations in one variable

Step 3 Isolate the Variable Term. Add

appropriate expressions to both sides, so that when both sides are simplified, the terms containing the variable are on one side and all constant terms are on the other side.

Step 4 Combine Terms. Combine terms containing the variable to obtain one term that contains the variable as a factor.

FINDING THE SOLUTION: Procedure for solving linear equations in one variable

Step 5 Isolate the Variable. Divide both sides by the coefficient of the variable to obtain the solution.

Step 6 Check the Solution. Substitute the solution into the original equation.

EXAMPLE 1 Solving a Linear Equation

Solve:
$$6x - [3x - 2(x - 2)] = 11.$$

Solution Step 2 6x - [3x - 2(x - 2)] = 116x - [3x - 2x + 4] = 11

6x - 3x + 2x - 4 = 11 5x - 4 = 11

 Step 3
 5x - 4 + 4 = 11 + 4

 Step 4
 5x = 15

EXAMPLE 1 Solving a Linear Equation

Solve:
$$6x - [3x - 2(x - 2)] = 11.$$

Solution continued

Step 5
$$\frac{5x}{5} = \frac{15}{5}$$
$$x = 3$$

Step 6 Check:
$$6(3) - [3(3) - 2((3) - 2)] = 11$$

 $18 - [9 - 2] = 11$
 $18 - 7 = 11$

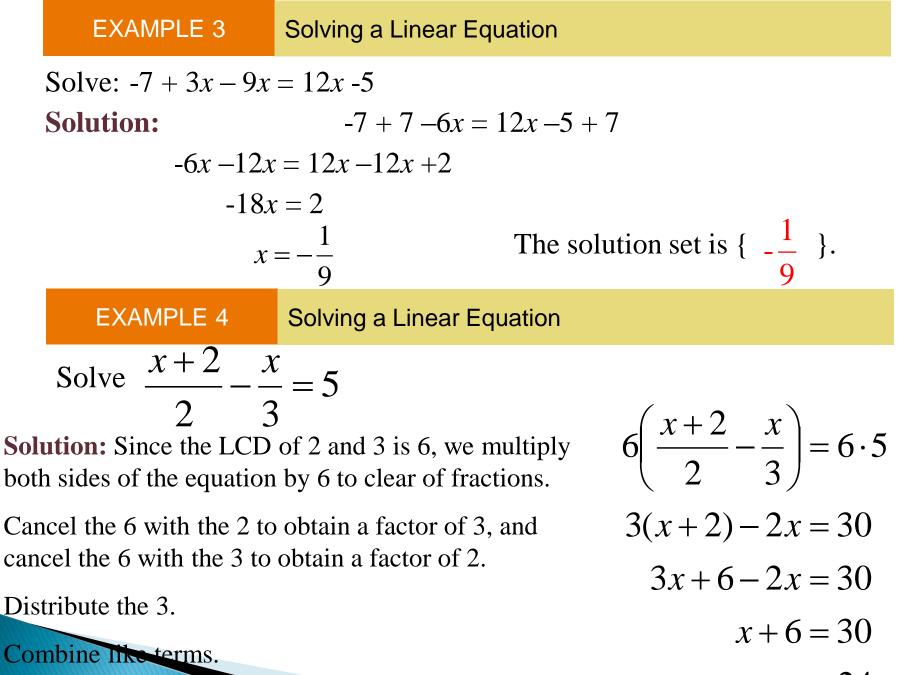
The solution set is $\{3\}$.

EXAMPLE 2 Solving a Linear Equation Solve: 1-5y+2(y+7)=2y+5(3-y). Solution 1-5y+2(y+7)=2y+5(3-y)Step 2 1 - 5y + 2y + 14 = 2y + 15 - 5y15 - 3v = 15 - 3v15 - 3v + 3v = 15 - 3v + 3vStep 3 15 = 150 = 0

Solve: 1-5y+2(y+7)=2y+5(3-y).

Solution continued

0 = 0 is equivalent to the original equation. The equation 0 = 0 is always true and its solution set is the set of real numbers. So the solution set to the original equation is the set of real numbers. The original equation is an identity.



The solution set is $\{24\}$

x = 24

Solve: 6 - (4 + x) = 8x - 2(3x + 5)Solution: Step 1: Does not apply Step 2: 6 - 4 - x = 8x - 6x - 10 -x + 2 = 2x - 10Step 3: -x + (-2x) + 2 + (-2) = 2x + (-2x) - 10 + (-2) -3x = -12Step 4: $(-\frac{1}{3})(-3)x = (-\frac{1}{3})(-12)$

x = 4Step 5: 6 - (4 + 4) = 8(4) - 2(3(4) + 5)6 - 8 = 32 - 34-2 = -2

The solution set is {4}.

EXAMPLE 6

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

 $\frac{x+1}{2} + \frac{x+3}{4} = \frac{1}{2}$ Solve: Solution: $4(\frac{x+1}{2} + \frac{x+3}{4}) = 4(\frac{1}{2})$ Step 1: $4(\frac{x+1}{2}) + 4(\frac{x+3}{4}) = 4(\frac{1}{2})$ Step 2: 2(x+1) + (x+3) = 22x + 2 + x + 3 = 23x + 5 = 2Step 3: 3x + 5 + (-5) = 2 + (-5)3x = -3Step 4: $(\frac{1}{3})$ $3x = (\frac{1}{3})(-3)$ x = -1Step 5: The solution set is $\{-1\}$. $\frac{-1}{4} = \frac{1}{2}$ -1+1 -1+3Check

Solve 5x - 6 = 3x.

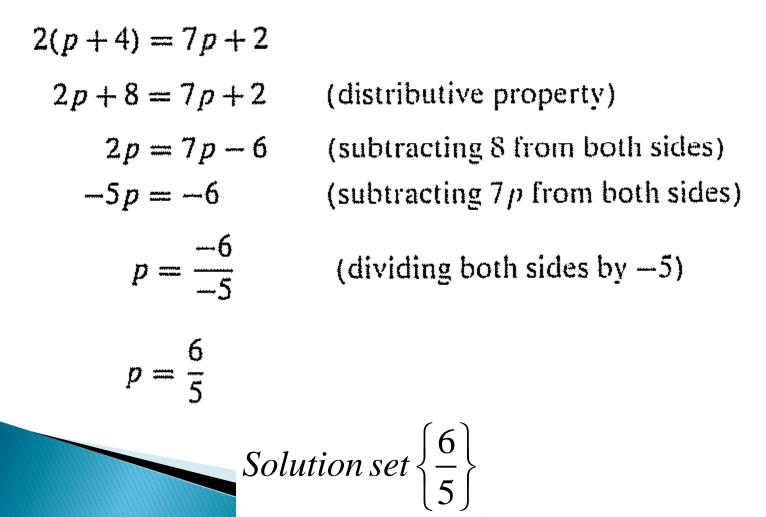
Solution: We begin by getting the terms involving x on one side and the constant on the other. Then we solve for x by the appropriate mathematical operation. We have

5x - 6 = 3x

(adding -3x to both sides) 5x - 6 + (-3x) = 3x + (-3x)2x - 6 = 0(simplifying, that is, Operation 3) 2x - 6 + 6 = 0 + 6(adding 6 to both sides) 2x = 6(simplifying) 2*x* 6 (dividing both sides by 2) $\overline{2} = \overline{2}$ x = 3the solution set is [3].

Solve 2(p + 4) = 7p + 2.

Solution: First, we remove parentheses. Then we collect similar terms and solve. We have



EXAMPLE 8 Solving a Linear Equation

Solve
$$\frac{7x+3}{2} - \frac{9x-8}{4} = 6$$

Solution: We first clear the equation of fractions by multiplying both sides by the least common denominator (LCD),⁴ which is 4. Then we use various algebraic operations to obtain a solution. Thus,

$$4\left(\frac{7x+3}{2} - \frac{9x-8}{4}\right) = 4(6)$$

$$4 \cdot \frac{7x+3}{2} - 4 \cdot \frac{9x-8}{4} = 2^{4}$$

$$2(7x+3) - (9x-8) = 24$$

$$14x+6-9x+8 = 24$$

$$5x + 14 = 24$$

$$5x = 10$$

$$x = 2$$

Solution set {2}

(distributive property)

(simplifying)

(distributive property)

(simplifying)

(subtracting 14 from both sides) (dividing both sides by 5)

Fractional Equations

A fractional equation is an equation in which an unknown is in a denominator. We illustrate that solving such a nonlinear equation may lead to a linear equation.

EXAMPLE 8 Solving a Fractional Equation Solve $\frac{5}{x-4} = \frac{6}{x-3}$.

Multiplying both sides by the LCD, (x - 4)(x - 3), we have

$$(x-4)(x-3)\left(\frac{5}{x-4}\right) = (x-4)(x-3)\left(\frac{6}{x-3}\right)$$

5(x-3) = 6(x-4) (linear equation)
5x-15 = 6x - 24
9 = x
Solution set {9}

EXAMPLE 9 Solving Fractional Equations

a. Solve
$$\frac{3x+4}{x+2} - \frac{3x-5}{x-4} = \frac{12}{x^2 - 2x - 8}$$

Solution: Observing the denominators and noting that

$$x^2 - 2x - 8 = (x + 2)(x - 4)$$

we conclude that the LCD is (x + 2)(x - 4). Multiplying both sides by the LCD, we have

$$(x+2)(x-4)\left(\frac{3x+4}{x+2} - \frac{3x-5}{x-4}\right) = (x+2)(x-4) \cdot \frac{12}{(x+2)(x-4)}$$
$$(x-4)(3x+4) - (x+2)(3x-5) = 12$$
$$3x^2 - 8x - 16 - (3x^2 + x - 10) = 12$$
$$3x^2 - 8x - 16 - 3x^2 - x + 10 = 12$$
$$-9x - 6 = 12$$

$$-9x = 18$$
$$x = -2$$

Solution set = \emptyset

b. Solve $\frac{4}{x-5} = 0.$

Solution: The only way a fraction can equal zero is if the numerator is 0 but its denominator is not. Since the numerator, 4, is never 0, the solution set is \emptyset .

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Radical Equations

A radical equation is one in which an unknown occurs in a radicand. The next two examples illustrate the techniques employed to solve such equations.

EXAMPLE 11 Solving a Radical Equation

Solve $\sqrt{x^2 + 33} - x = 3$.

We begin by isolating the radical on one side.

$$\sqrt{x^2 + 33} = x + 3$$

Then we square both sides and solve using standard techniques. Thus,

$$x^{2} + 33 = (x + 3)^{2}$$
 (squaring both sides
 $x^{2} + 33 = x^{2} + 6x + 9$
 $24 = 6x$
 $4 = x$
Solution set {4}

EXAMPLE 12 Solving a Radical Equation
Solve
$$\sqrt{y-3} - \sqrt{y} = -3$$
.
 $\sqrt{y-3} = \sqrt{y} - 3$
 $y-3 = y - 6\sqrt{y} + 9$ (squaring both sides)
 $6\sqrt{y} = 12$
 $\sqrt{y} = 2$
 $y = 4$ (squaring both sides)

Solution set = \emptyset



Solve:
$$x = \sqrt{6x - x^3}$$

Solution Since $(\sqrt{a})^2 = a$, we raise both sides to power 2. $x^2 = \left(\sqrt{6x - x^3}\right)^2$ $x^2 = 6x - x^3$ $x^{3} + x^{2} - 6x = 0$ $x(x^2 + x - 6) = 0$ x(x+3)(x-2)=0

Solution continued

$$x = 0$$
 or $x + 3 = 0$ or $x - 2 = 0$
 $x = 0$ or $x = -3$ or $x = 2$

Check each solution. $-3 \stackrel{?}{=} \sqrt{6(-3) - (-3)^3}$

$$0 \stackrel{?}{=} \sqrt{6(0) - (0)^3}$$
$$0 = 0 \checkmark$$

$$2 \stackrel{?}{=} \sqrt{6(2) - (2)^3}$$

 $-3 \neq 3$

-3 is an extraneous solution. The solution set is $\{0, 2\}$.

Solve:
$$\sqrt{2x + 1} + 1 = x$$

Solution
Step 1 Isolate the radical on one side.
 $\sqrt{2x + 1} = x - 1$
Step 2 Square both sides and simplify.
 $(\sqrt{2x + 1})^2 = (x - 1)^2$
 $2x + 1 = x^2 - 2x + 1$
 $x^2 - 4x = 0$
 $x(x - 4) = 0$

Solution continued

Step 3 Set each factor = 0. x = 0 or x - 4 = 0x = 0 or x = 4Check. Step 4 $\sqrt{2(0)+1}+1 \stackrel{?}{=} 0$ $\sqrt{2(4)+1}+1 \stackrel{?}{=} 4$ $4 = 4 \checkmark$ $2 \neq 0$

> 0 is an extraneous solution. The solution set is {4}.

Solve:
$$\sqrt{2x-1} - \sqrt{x-1} = 1$$

Solution Step 1 Isolate one of the radicals. $\sqrt{2x-1} = 1 + \sqrt{x-1}$

Step 2 Square both sides and simplify.

$$\left(\sqrt{2x-1}\right)^2 = \left(1 + \sqrt{x-1}\right)^2$$
$$2x - 1 = 1 + 2\sqrt{x-1} + x - 1$$
$$2x - 1 = 2\sqrt{x-1} + x$$

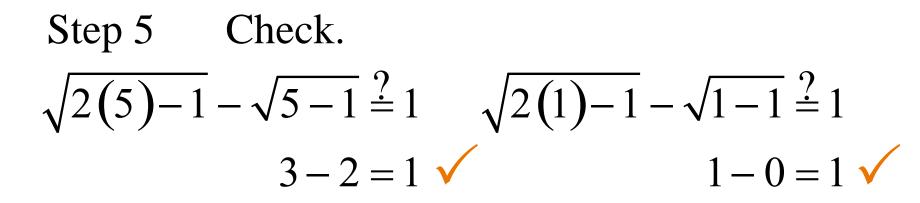
Solution continued

Step 3Repeat the process - isolate the
radical, square both sides, simplify
and factor.

$$x - 1 = 2\sqrt{x - 1}$$
$$(x - 1)^{2} = (2\sqrt{x - 1})^{2}$$
$$x^{2} - 2x + 1 = 4(x - 1)$$
$$x^{2} - 6x + 5 = 0$$
$$(x - 5)(x - 1) = 0$$

Solution continued

Step 4 Set each factor = 0. x-5=0 or x-1=0x=5 or x=1



The solution set is $\{1,5\}$.

ABSOLUTE VALUE EQUALITY

The absolute value of a real

number x, written $|\mathcal{X}|$, is

 $|x| = \begin{cases} x, & x \ge 0\\ -x, & x < 0 \end{cases}$

defined as

Ex:
$$|3| = 3$$
, $|-8| = 8$, $|-2| = 2$
Ex: Solve $|x-3| = 2$
 $|x-3| = 2$
 $x-3=2$, $x-3=-2$
 $x=5$, $x=1$
 $S = \{1,5\}$

Ex: Solve |7-3x| = 5 |7-3x| = 5 $7-3x = 5, \quad 7-3x = -5$ $-3x = -2, \quad -3x = -12$ $x = \frac{2}{3}, \quad x = 4$

Ex: Solve |x-4| = -3, the absolute value of expression always positive, so $S = \emptyset$

Ex: Solve
$$|x-8|=5$$

 $x = \frac{1}{2}, \quad x = -\frac{1}{2}$

$$|x-8| = 5$$

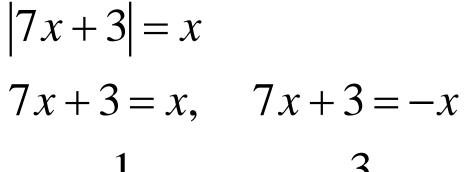
 $x-8 = 5, \quad x-8 = -5$
 $x = 13, \quad x = 3$

$$S = \{3, 13\}$$

Ex: Solve
$$\left|\frac{4}{x}\right| = 8$$

 $\left|\frac{4}{x}\right| = 8$
 $\frac{4}{x} = 8, \quad \frac{4}{x} = -8$
 $S = \{-1/2, 1/2\}$

Ex: Solve
$$|7x+3| = x$$



$$x = -\frac{1}{2}, \qquad x = -\frac{3}{8}$$

$$S = \emptyset$$

QUADRATIC EQUATION

A quadratic equation in the variable *x* is an equation equivalent to the equation

$$ax^2 + bx + c = 0,$$

where *a*, *b*, and *c* are real numbers and $a \neq 0$. A quadratic equation is also called a second- degree equation.

THE ZERO-PRODUCT PROPERTY

Let *A* and *B* be two algebraic expressions. Then AB = 0 if and only if A = 0 or B = 0.

SOLVING A QUADRATIC EQUATION BY FACTORING

- **Step 1** Write the given equation in standard form so that one side is 0.
- **Step 2** Factor the nonzero side of the equation from Step 1.
- **Step 3** Set each factor obtained in Step 2 equal to 0.
- **Step 4** Solve the resulting equations in Step 3.
- **Step 5** Check the solutions obtained in Step 4 in the original equation.

Solve by factoring:
$$2x^2 + 5x = 3$$
.
Solution
 $2x^2 + 5x = 3$
 $2x^2 + 5x - 3 = 0$
 $(2x-1)(x+3) = 0$
 $2x-1=0$
 $2x=1$
 $x=\frac{1}{2}$
The solutions
check in the
original equation.
The solution set is
 $\left\{\frac{1}{2}, -3\right\}.$

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Solve by factoring: 3t^2 = 2t.
Solution
             3t^2 = 2t
       3t^2 - 2t = 0
      t(3t-2)=0
     t = 0 | 3t - 2 = 0
3t = 2
                                              \left\{0,\frac{2}{3}\right\}.
```

The solutions check in the original equation.

The solution set is

Solve by factoring $x^2 + x - 12 = 0$

Solution: The left side factors easily:

(x-3)(x+4) = 0

Whenever the product of two or more quantities is zero, at least one of the quantities must be zero. This means that either

$$x - 3 = 0$$
 or $x + 4 = 0$

Solving these gives x = 3 and x = -4. Thus, the roots of the original equation are 3 and -4, and the solution set is $\{3, -4\}$.

b. *Solve* $6w^2 = 5w$.

Solution: We write the equation as

 $6w^2 - 5w = 0$

so that one side is 0. Factoring gives

w(6w-5)=0

Setting each factor equal to 0, we have

$$w = 0 \quad \text{or} \quad 6w - 5 = 0$$
$$w = 0 \quad \text{or} \quad 6w = 5$$

Solution set $\{0,5\}$

EXAMPLE 3 Solving a Higher Degree Equation by Factoring

a. Solve $4x - 4x^3 = 0$.

Solution: This is called a *third-degree equation*. We proceed to solve it as follows:

$$4x - 4x^{3} = 0$$

$$4x(1 - x^{2}) = 0$$
 (factoring)

$$4x(1 - x)(1 + x) = 0$$
 (factoring)

Setting each factor equal to 0 gives 4 = 0 (impossible), x = 0, 1 - x = 0, or 1 + x = 0. Thus,

Solution set
$$\{0,1,-1\}$$

Solve by factoring:
$$x^2 + 16 = 8x$$
.
Solution
Step 1 $x^2 + 16 = 8x$
 $x^2 - 8x + 16 = 0$
Step 2 $(x-4)(x-4)=0$
Step 3 $x-4=0$ $x-4=0$
Step 4 $x=4$ $x=4$
Step 5 Check the solution in original equation.
 $(4)^2 + 16 = 8(4)$
 $32 = 32$ The solution set is $\{4\}$

EXAMPLE 2 Solving a Quadratic Equation by Factoring Solve (3x - 4)(x + 1) = -2.

Solution: We first multiply the factors on the left side:

$$3x^2 - x - 4 = -2$$

Rewriting this equation so that 0 appears on one side, we have

$$3x^{2} - x - 2 = 0$$

(3x + 2)(x - 1) = 0
Solution set $\left\{\frac{-2}{3}, 1\right\}$

THE SQUARE ROOT PROPERTY

Suppose *u* is any algebraic expression and $d \ge 0$.

If
$$u^2 = d$$
, then $u = \pm \sqrt{d}$.

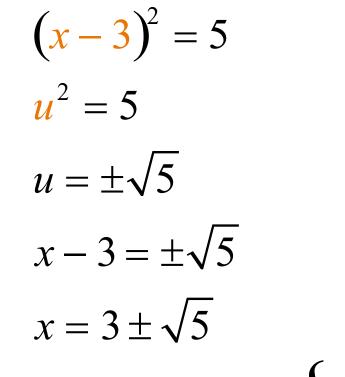
EXAMPLE 5 Solution by Factoring Solve $x^2 = 3$.

$$x = \mp \sqrt{3}$$

Solution set $\{\sqrt{3}, -\sqrt{3}\}$

Solve:
$$(x-3)^2 = 5$$
.

Solution



The solution set is $\{3+\sqrt{5}, 3-\sqrt{5}\}$.

Quadratic Formula

Solving quadratic equations by factoring can be quite difficult, as is evident by trying that method on $0.7x^2 - \sqrt{2}x - 8\sqrt{5} = 0$. However, there is a formula called the *quadratic formula* that gives the roots of any quadratic equation.

Quadratic Formula

The roots of the quadratic equation $ax^2 + bx + c = 0$, where a, b, and c are constants and $a \neq 0$, are given by

$$\Delta = b^2 - 4ac$$

if $\Delta > 0$ then there are two roots $x_1 = \frac{-b + \sqrt{\Delta}}{2a}$ and $x_1 = \frac{-b - \sqrt{\Delta}}{2a}$

if $\Delta = 0$ then there are two equal roots $x_1 = x_1 = \frac{-b}{2a}$

if $\Delta < 0$ then there are no real roots in \Re

EXAMPLE 6 A Quadratic Equation with Two Real Roots Solve $4x^2 - 17x + 15 = 0$ by the quadratic formula.

$$\Delta = b^2 - 4ac = (-17)^2 - 4.4.15 = 49 > 0$$

$$x_1 = \frac{-b + \sqrt{\Delta}}{2a} = \frac{-(-17) + \sqrt{49}}{2.4} = \frac{24}{8} = 3$$

$$x_1 = \frac{-b - \sqrt{\Delta}}{2a} = \frac{-(-17) - \sqrt{49}}{2.4} = \frac{10}{8} = \frac{5}{4}$$

Solution set
$$\left\{3, \frac{5}{4}\right\}$$

A Quadratic Equation with One Real Root EXAMPLE 7 Solve $2 + 6\sqrt{2}y + 9y^2 = 0$ by the quadratic formula. Solution $\Delta = b^2 - 4ac = (6\sqrt{2})^2 - 4.9.2 = 0$ $x_1 = x_1 = \frac{-b}{2a} = \frac{-6\sqrt{2}}{29} = -\frac{\sqrt{2}}{3}$ Solution set $\left\{-\frac{\sqrt{2}}{3}\right\}$

EXAMPLE 8 A Quadratic Equation with No Real Solution Solve $z^2 + z + 1 = 0$ by the quadratic formula.

Solution $\Delta = b^2 - 4ac = (1)^2 - 4.1.1 = -3 < 0$

The equation has no roots