

## Problem 9.4.7

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## Question

**Question:** Find the roots of the following quadratic equation graphically:

$$16x^2 - 8x + 1 = 0$$

## Solution

First, the equation is already in standard quadratic form:

$$16x^2 - 8x + 1 = 0$$

### **Input Variables:**

The given quadratic can be written in the conic form:

$$\mathbf{x}^T \mathbf{V} \mathbf{x} + 2\mathbf{u}^T \mathbf{x} + f = 0$$

where

$$\mathbf{V} = \begin{pmatrix} 16 & 0 \\ 0 & 0 \end{pmatrix}, \quad \mathbf{u} = \begin{pmatrix} -4 \\ 0 \end{pmatrix}, \quad f = 1$$

## Solution

Since the roots correspond to intersections with the x-axis, we represent the line:

$$L : \mathbf{x} = \mathbf{h} + \kappa \mathbf{m}$$

with

$$\mathbf{h} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \quad \mathbf{m} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

# Input Parameters

Symbol	Value
<b>v</b>	$\begin{pmatrix} 16 & 0 \\ 0 & 0 \end{pmatrix}$
<b>u</b>	$\begin{pmatrix} -4 \\ 0 \end{pmatrix}$
<i>f</i>	1
<b>h</b>	$\begin{pmatrix} 0 \\ 0 \end{pmatrix}$
<b>m</b>	$\begin{pmatrix} 1 \\ 0 \end{pmatrix}$

Table: Input Parameters

## Solution

The points of intersection of a line with a conic are:

$$\kappa = \frac{1}{\mathbf{m}^T \mathbf{V} \mathbf{m}} \left[ -\mathbf{m}^T (\mathbf{V} \mathbf{h} + \mathbf{u}) \pm \sqrt{[\mathbf{m}^T (\mathbf{V} \mathbf{h} + \mathbf{u})]^2 - g(\mathbf{h}) \mathbf{m}^T \mathbf{V} \mathbf{m}} \right]$$

where

$$g(\mathbf{h}) = \mathbf{h}^T \mathbf{V} \mathbf{h} + 2\mathbf{u}^T \mathbf{h} + f$$

# Step-by-Step Evaluation

**Step 1:** Compute  $\mathbf{m}^T \mathbf{V} \mathbf{m}$

$$\mathbf{m}^T \mathbf{V} \mathbf{m} = 16$$

**Step 2:** Compute  $\mathbf{V} \mathbf{h} + \mathbf{u}$

$$\mathbf{V} \mathbf{h} + \mathbf{u} = \begin{pmatrix} -4 \\ 0 \end{pmatrix}$$

**Step 3:** Compute  $\mathbf{m}^T (\mathbf{V} \mathbf{h} + \mathbf{u})$

$$\mathbf{m}^T (\mathbf{V} \mathbf{h} + \mathbf{u}) = -4$$

**Step 4:** Compute  $g(\mathbf{h})$

$$g(\mathbf{h}) = 1$$

## Final Roots

**Step 5:** Substitute into  $\kappa$ :

$$\kappa = \frac{4 \pm \sqrt{16 - 16}}{16} = \frac{4}{16} = 0.25$$

**Step 6:** Intersection point:

$$x = h + \kappa m = (0, 0) + (0.25)(1, 0) = (0.25, 0)$$

Thus, the quadratic  $16x^2 - 8x + 1 = 0$  intersects the x-axis at

$x = 0.25$



Parabola and Root of the Quadratic Equation

