

Contents

- Motivation
- Graph drawing by equation
- Graph drawing by sketch
- Graph drawing by search
- Graph editing
- Conclusion

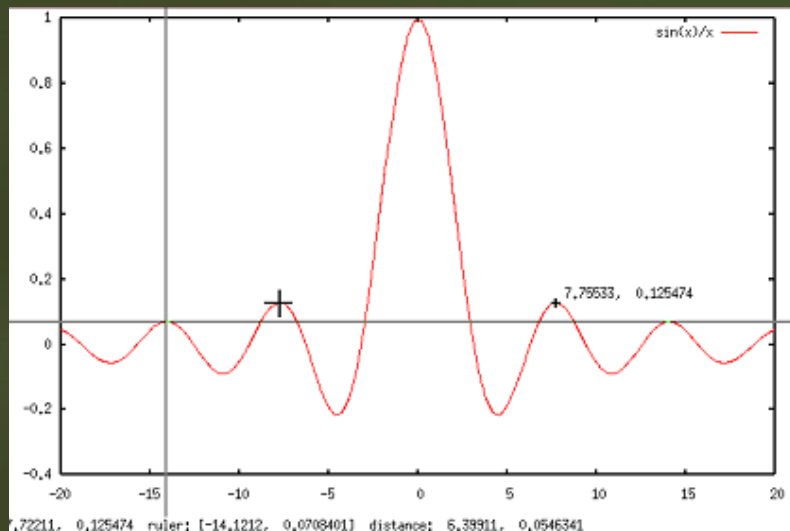
Motivation

- Mathematics education in e-Learning
 - Limited to displaying texts and videos.
 - Mathematical figures
 - Indispensable for conceptual understanding
 - Images? inconvenient for interactive learning
 - Needs for efficient graph drawing
 - Easy, fast, and accurate drawing
 - Natural interface

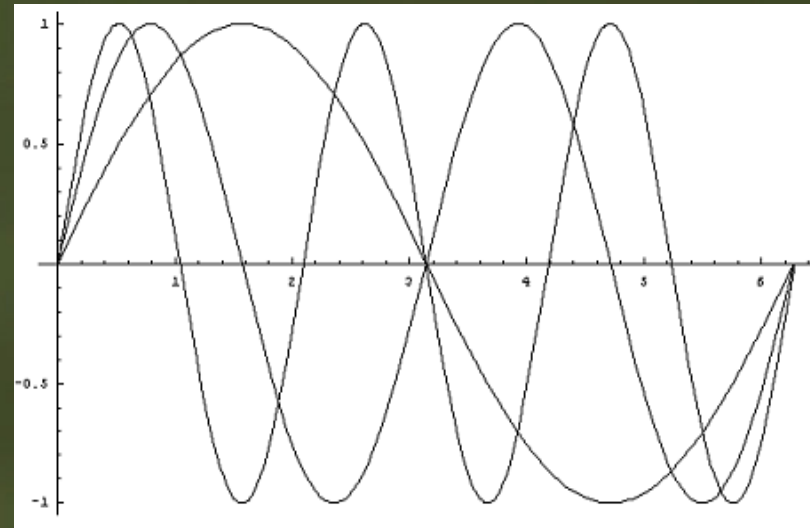
Previous Systems

- Math packages - Mathematica, Maple
 - e.g., `In[1]=plot[sin[x], {x, 0, 2Pi}]`
- Drawing tools - gnuplot, GraphEQ
 - No direct manipulation
- GeoGebra, Cinderella
 - Menu-driven Interface
- MS PPT - mainly for simple diagrams

Graphs in Engineering Textbooks

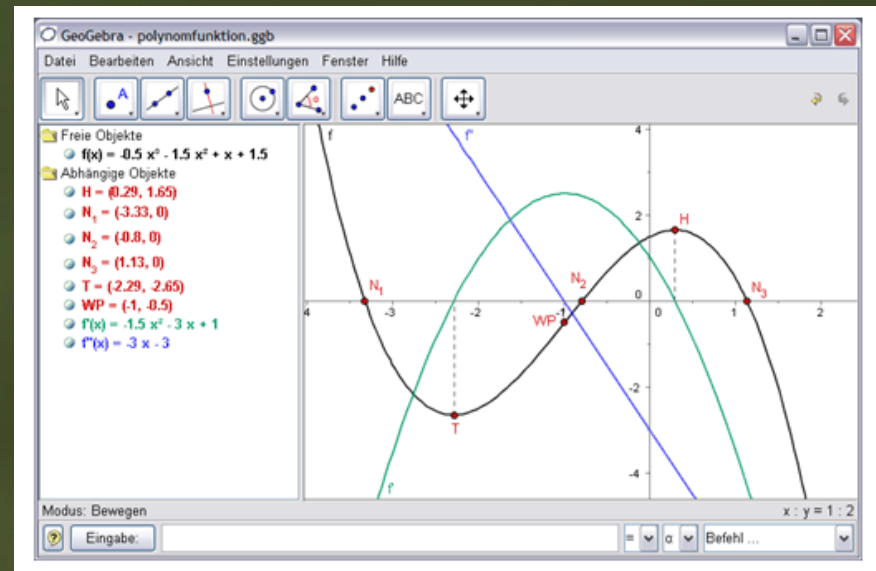
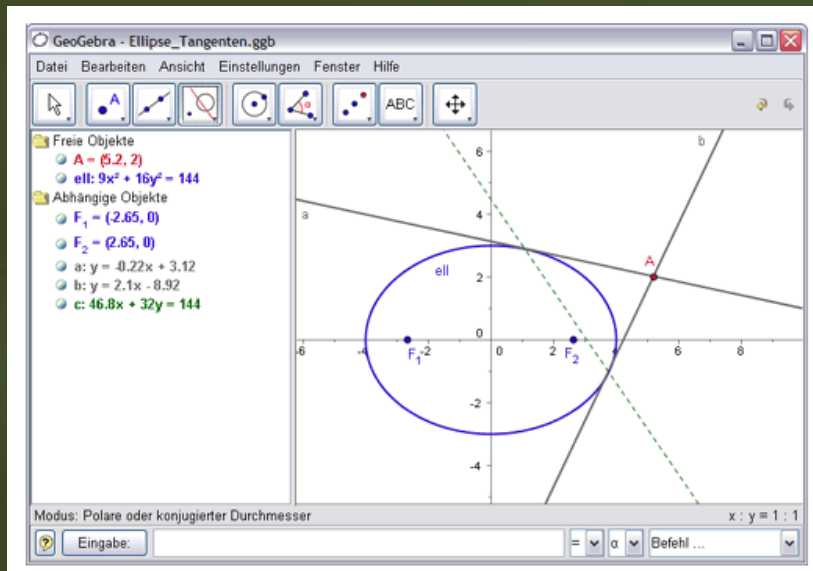


gnuplot $\frac{\sin x}{x}$



Mathematica $\sin ax$

GeoGebra Screenshots



Graph Drawing by Equation

Graph Drawing by Equation

• Simple keyboard input

$$y = 2*x^2 + 3$$

$$y = \sin(x), y = 3^x, y = \log(x), y = \sqrt{x}$$

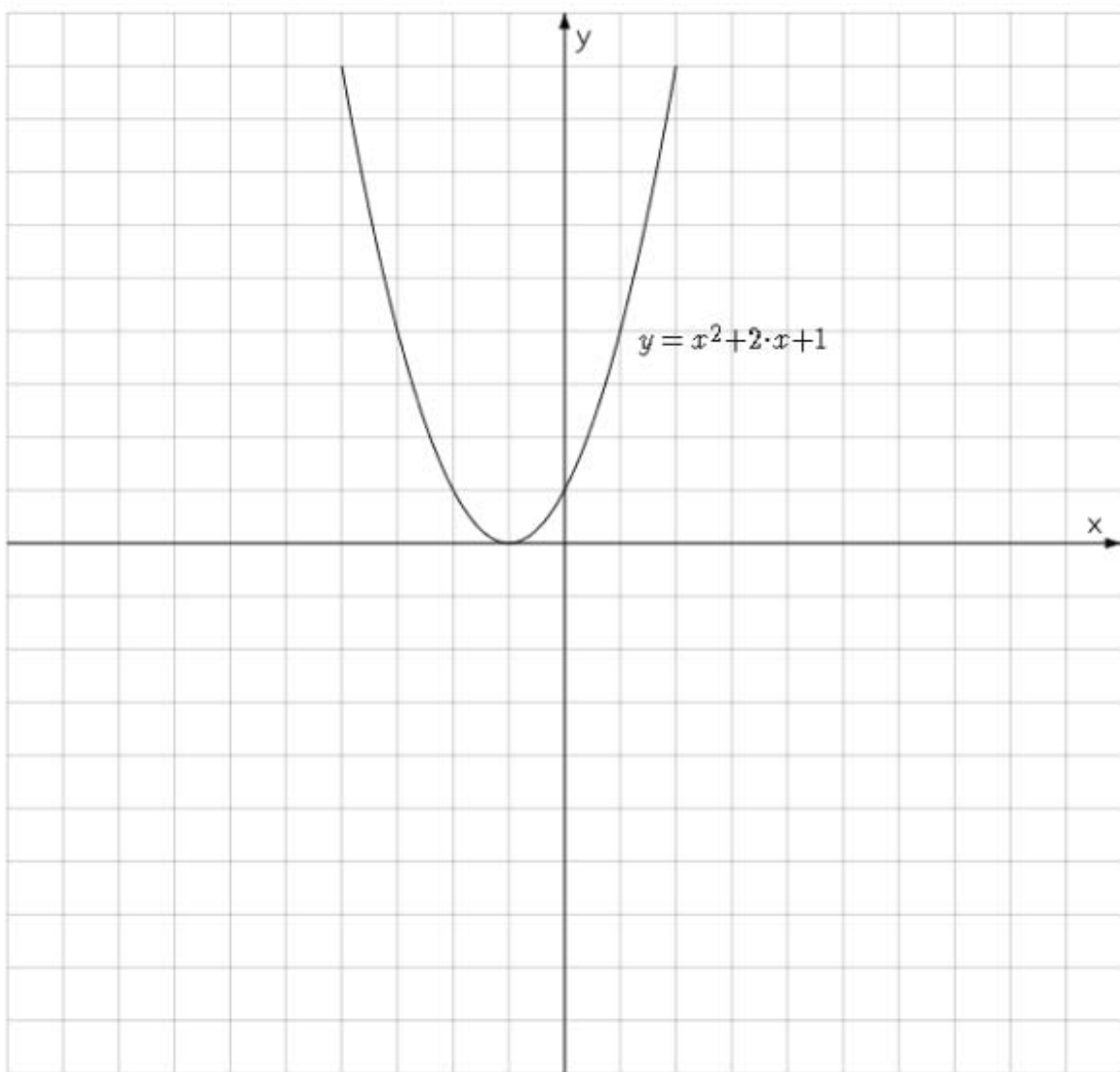
$$x^2 + y^2 - 1 = 0$$

$$y = f(x) + g(x), y = a*x^2 + b*x + c$$

$$a*x + b*y^2 + c = 0$$



y=x^2+2*x+1 Enter



Equation Options Candidates

Type : None
 Primitive Type : None

Primitive Information

a : 1
 b : 2
 c : 1

Equation : Modify

Display Equation Text

Equation Text

Original Equation User Define

Confirm

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To Modify

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections Apply

Omit Intermediate Sections

From To

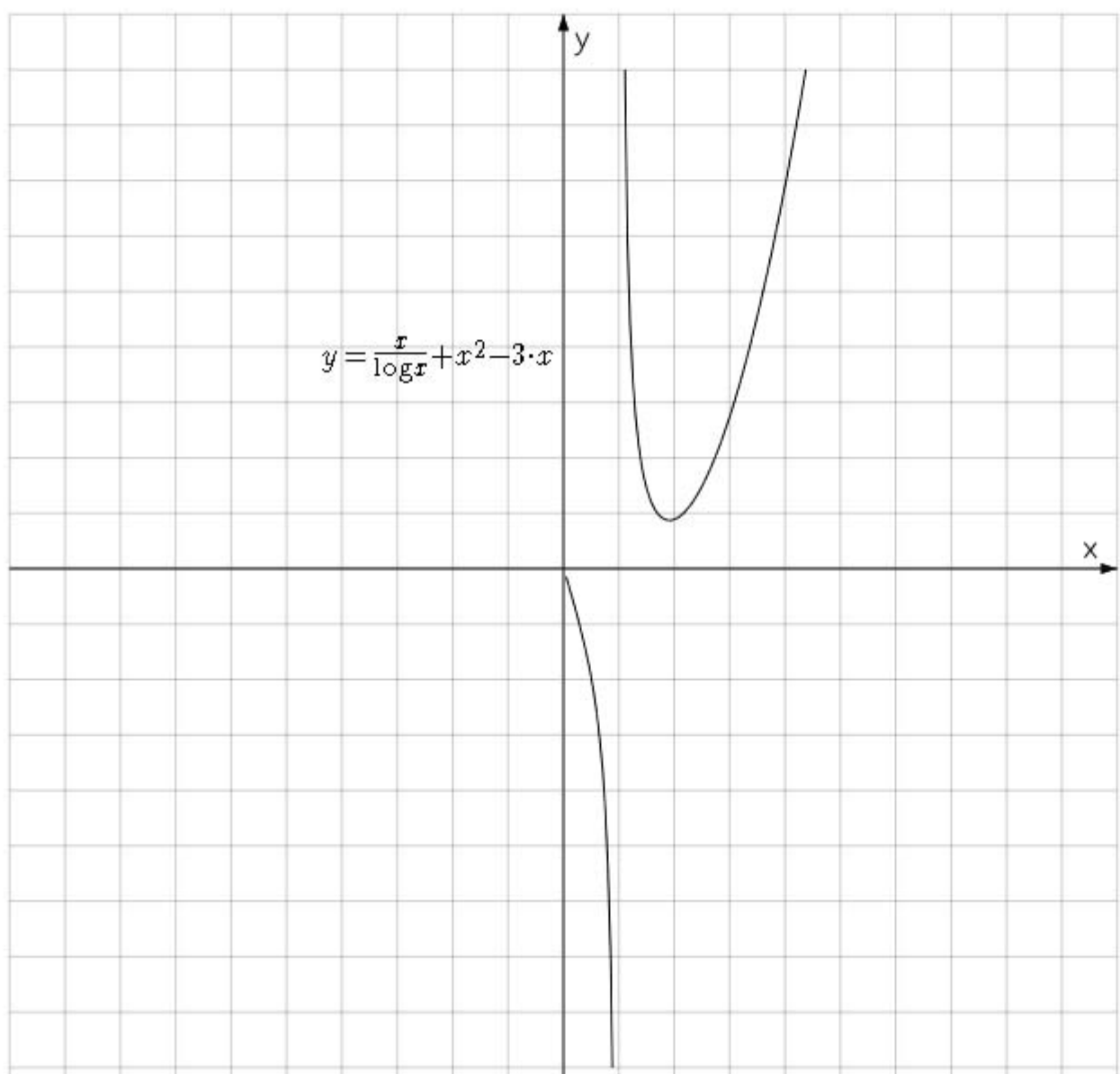
Left Height Right Height Short Height

x zoom 1.0

y zoom 1.0



y=x/log(x)+x^2-3*x Enter



Equation Options Candidates

Type : None
Primitive Type : None
Primitive Information

No Information

Equation :

Display Equation Text

Equation Text

Original Equation User Define

Color

Line Options

- Color - - Stipple - - Width -



Display Extreme Points

Set up Domain

From To Mode

Stippling None Left Right Bottom

Mensuration Options

Enable Mensuration

of Sections 10 Apply

Omit Intermediate Sections

From 0.000000 To 0.000000


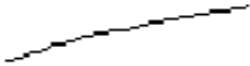




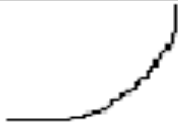



Left Height Right Height Short Height

Graph Drawing by Equation

Graph Drawing by Sketch

Graph Drawing by Sketch

- Pen gesture recognition
 - *Gesture set*
- Fitting to a similar function/curve
 - Common in the middle/high school math
- Modification
 - Changing the equation of a graph
 - Moving the graph or its control points

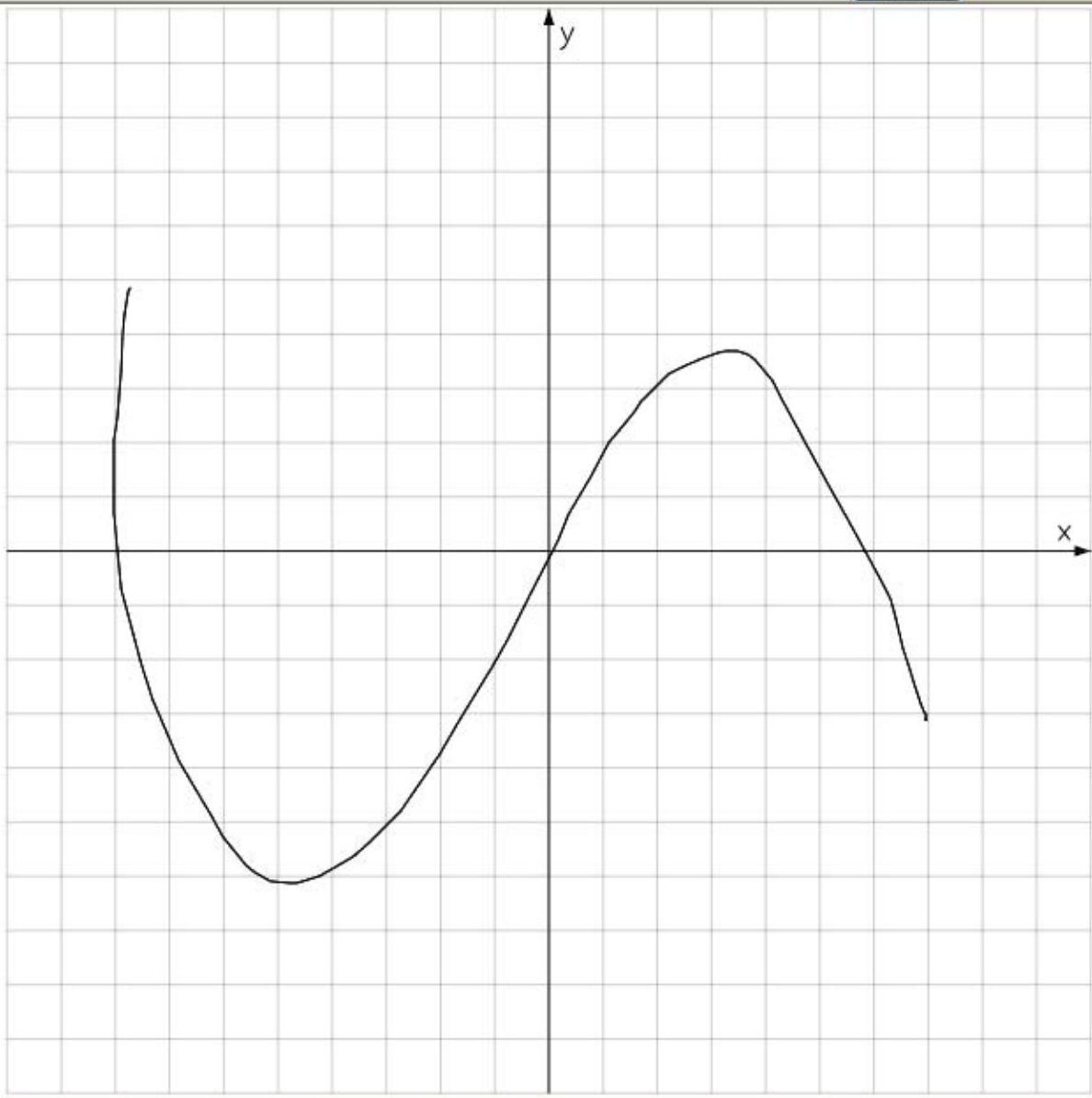
| name of gesture | example | purpose | number of stroke |
|-----------------|---|-----------------------------------|------------------|
| point |  | indicate vertex | 1 |
| solid line |  | generate straight line | 1 |
| delete |  | delete | 2 |
| quadratic |  | generate quadratic <u>func.</u> | 1 |
| cubic |  | generate cubic <u>func.</u> | 1 |
| log |  | generate log. <u>func.</u> | 1 |
| exponential |  | generate exponential <u>func.</u> | 1 |
| ellipse |  | generate ellipse | 1 or 2 |
| hyperbola |  | generate hyperbola | 2 |
| parabola |  | generate parabola | 2 |

Graph Drawing by Sketch

- Pen gesture recognition
 - *Gesture set*
- **Fitting to a similar function/curve**
 - ***Common in the middle/high school math***
- Modification
 - Changing the equation of a graph
 - Moving the graph or its control points



Enter



Equation Options **Candidates**

Type : None
Primitive Type : None

Primitive Information

No Information

Equation : **Modify**

Display Equation Text

Equation Text

Original Equation User Define

Confirm

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To **Modify**

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections **Apply**

Omit Intermediate Sections

From To

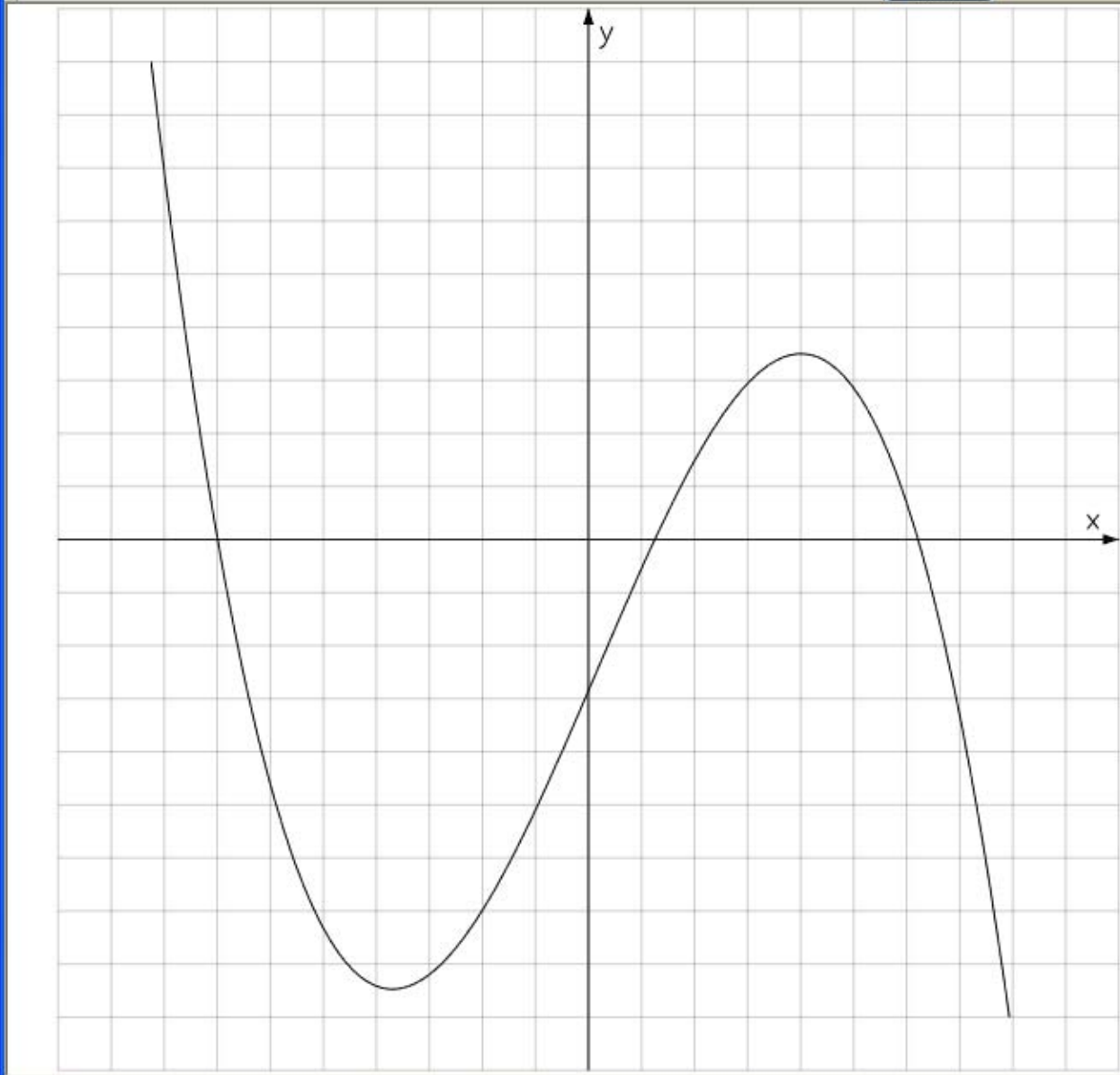
Left Height Right Height Short Height

x zoom 1.0

y zoom 1.0



Enter



Equation Options **Candidates**

Type : None
Primitive Type : None

Primitive Information

No Information

Equation : **Modify**

Display Equation Text

Equation Text

Original Equation User Define

Confirm

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To **Modify**

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections **Apply**

Omit Intermediate Sections

From To

Left Height Right Height Short Height

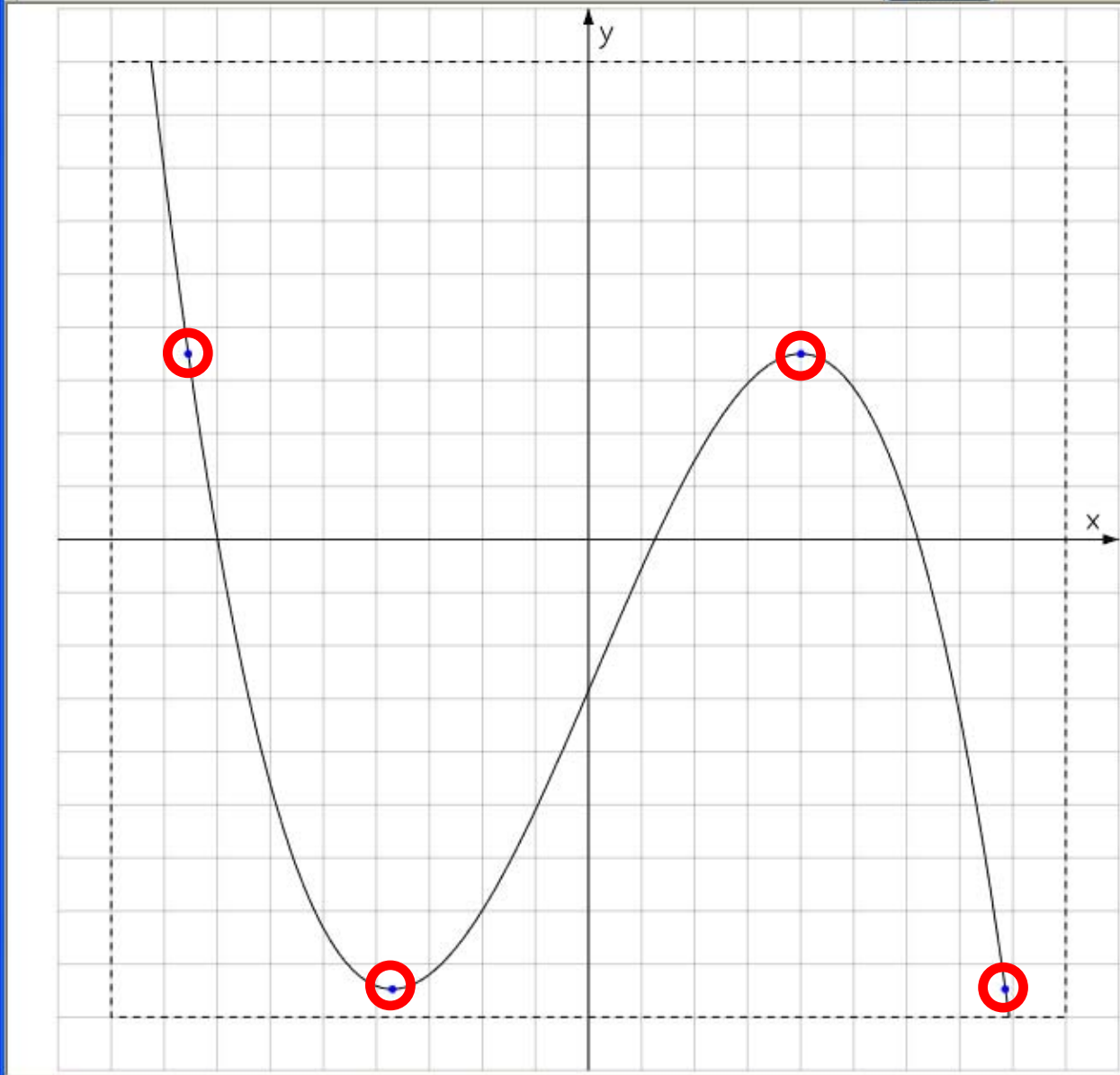
x zoom 1.0

Graph Drawing by Sketch

- Pen gesture recognition
 - *Gesture set*
- Fitting to a similar function/curve
 - *Common in the middle/high school math*
- **Modification**
 - ***Changing the equation of a graph***
 - ***Moving the graph or its control points***



Enter



Equation Options Candidates

Type : Explicit
Primitive Type : Cubic
Primitive Information

a : -0.052386
b : 0.024534
c : 2.3272
d : -2.851941

Equation : $y = -0.052386x^3 + 0.024534x^2 + 2$ Modify

Display Equation Text

Equation Text

Original Equation User Define

Confirm

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To Modify

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections Apply

Omit Intermediate Sections

From To

Left Height Right Height Short Height

Graph Drawing by Sketch

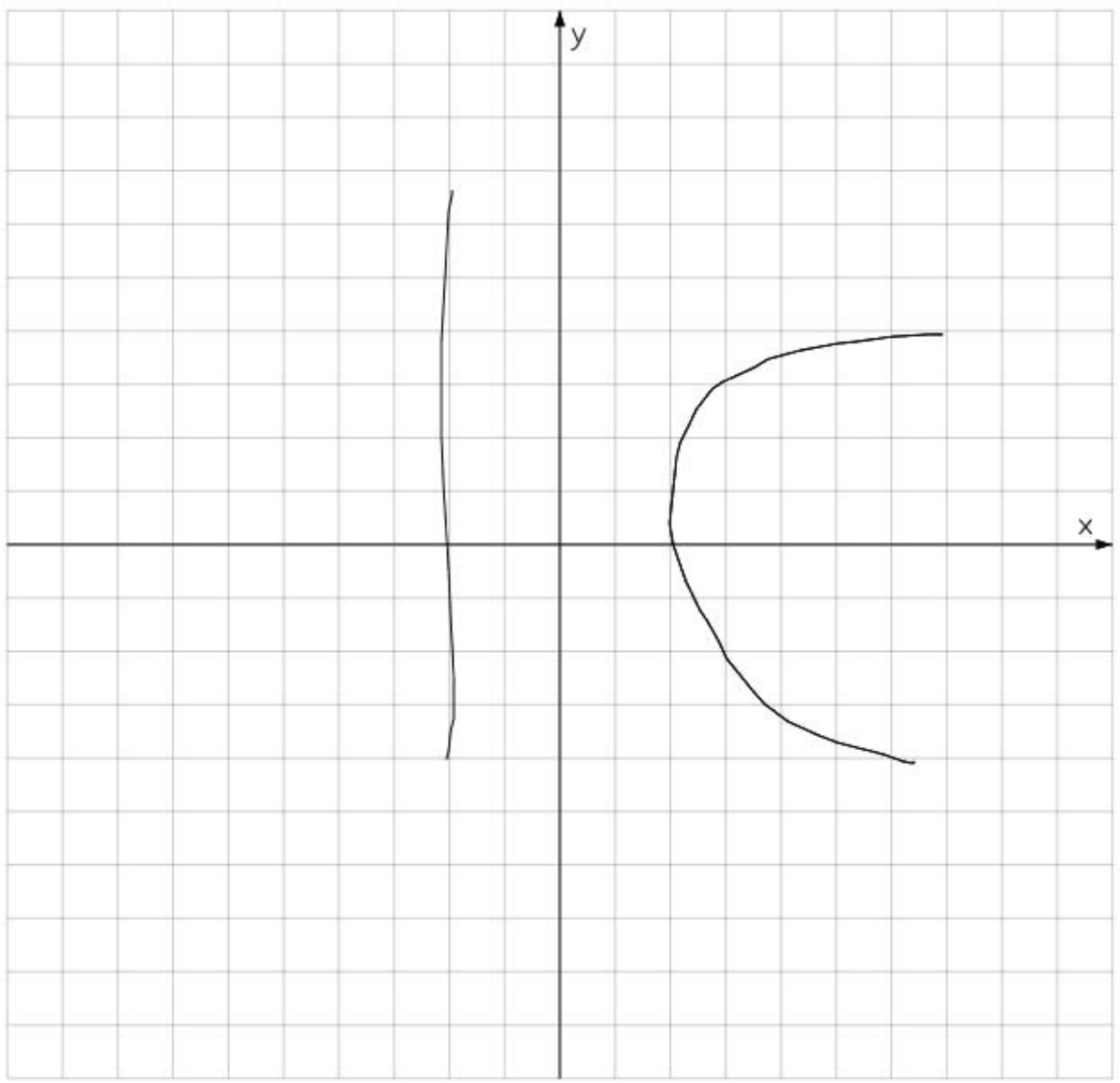
Graph Drawing by Search

Graph Drawing by Search

- Search in a DB of pre-drawn graphs
 - Query by sketch
 - Selection among candidates
 - Modification
 - Updating the DB with the new graph
 - Similarity matching
 - Types of graphs, coefficients of equations, etc



Enter

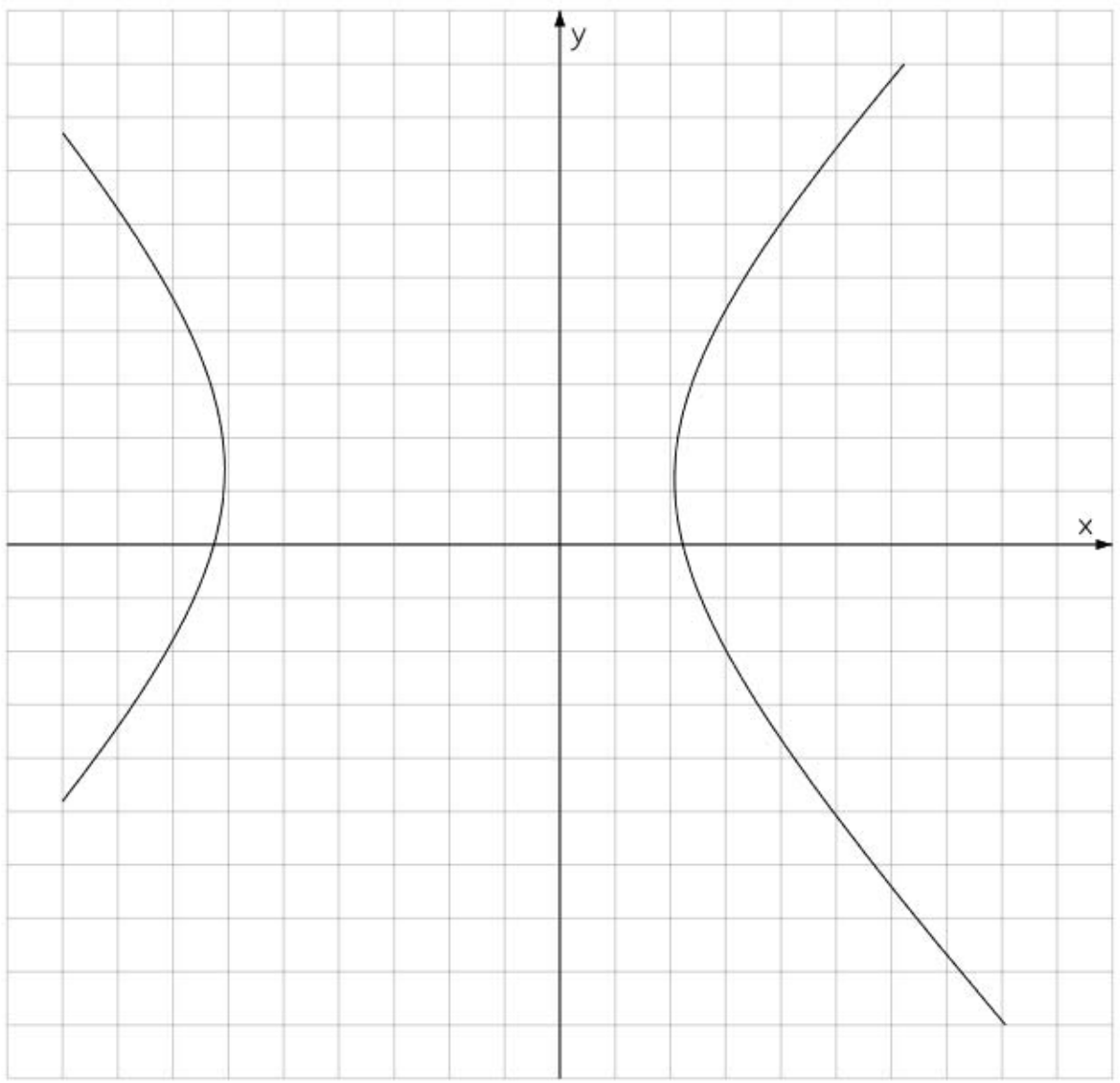


Equation Options Candidates

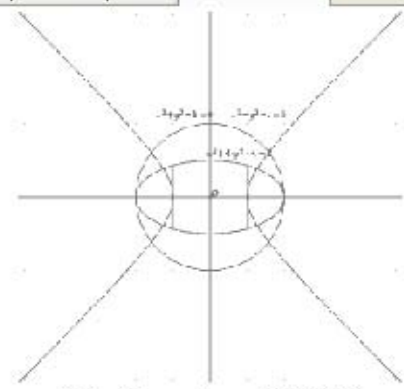
x zoom 1.0
y zoom 1.0



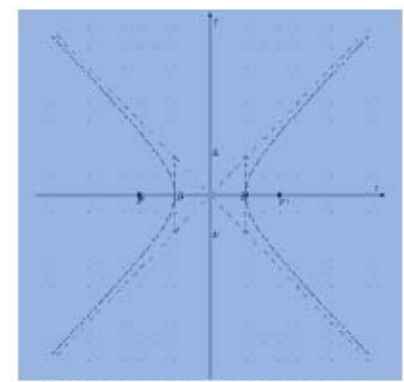
Enter



Equation Options Candidates



[1] implicit.gse [score: 9.000000]



[2] hyper.gse [score: 81.000000]

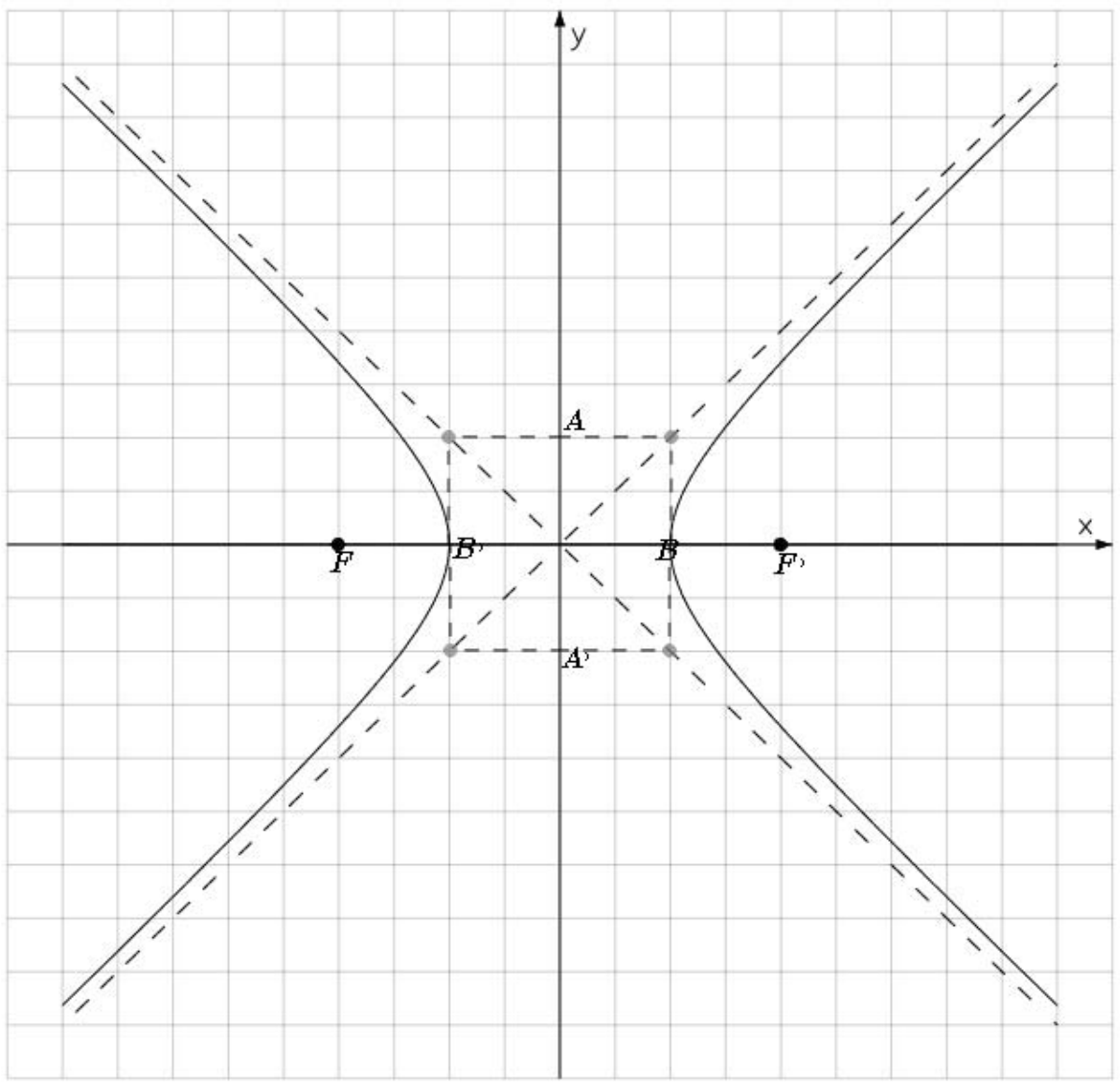


x zoom 1.0

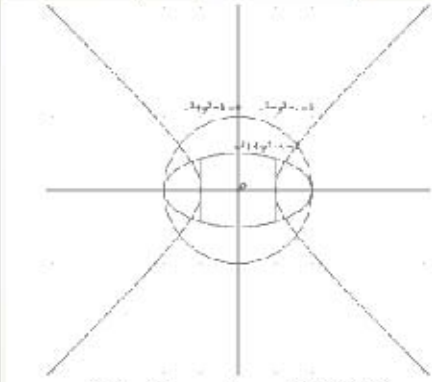
y zoom 1.0



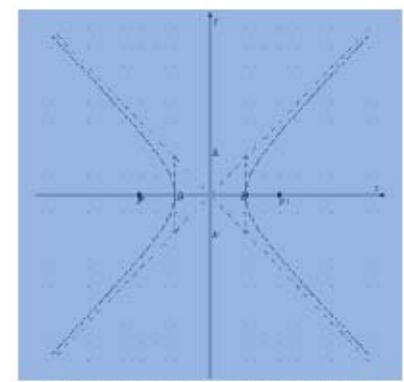
Enter



Equation Options Candidates



[1] implicit.gse [score: 9.000000]



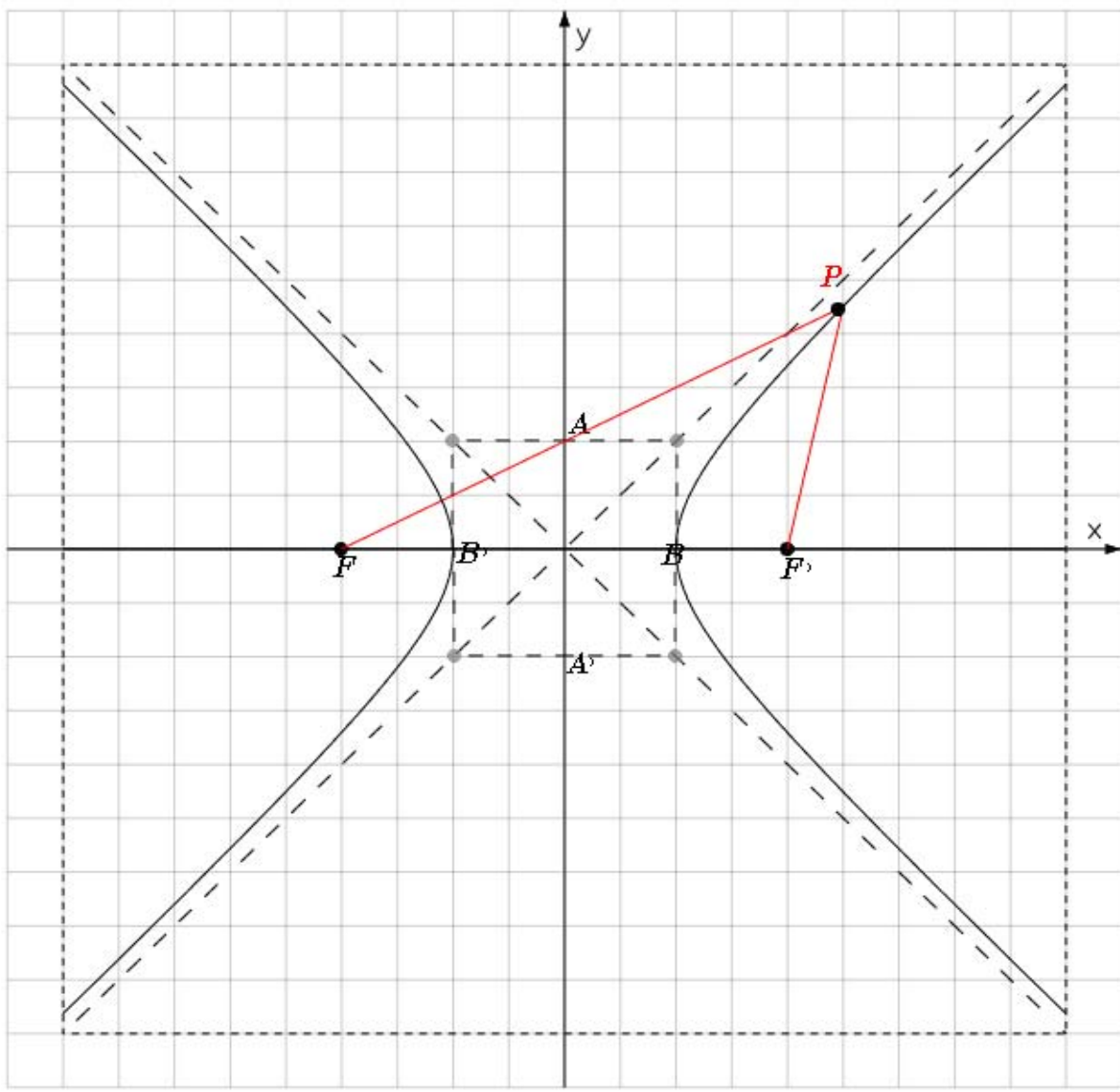
[2] hyper.gse [score: 81.000000]



x zoom 1.0
y zoom 1.0



P Enter



Equation Options **Candidates**

Type : Explicit
 Primitive Type : None
 Primitive Information
 a : 4.5
 b : -18.000001

Equation : P Modify

Display Equation Text

Equation Text
 Original Equation User Define
Confirm


Line Options
 - Color - - Stipple - - Width -

Display Extreme Points
 Set up Domain
 From 4 To 5 Modify
 Stippling None Left Right Both

Mensuration Options
 Enable Mensuration
 # of Sections 10 Apply
 Omit Intermediate Sections
 From 0.000000 To 0.000000
 Left Height Right Height Short Height

x zoom 1.0
 y zoom 1.0

Graph Drawing by Searching

A chalkboard with a wooden border and a horizontal chalk line. The text "Graph Editing" is written in white on the dark green chalkboard surface.

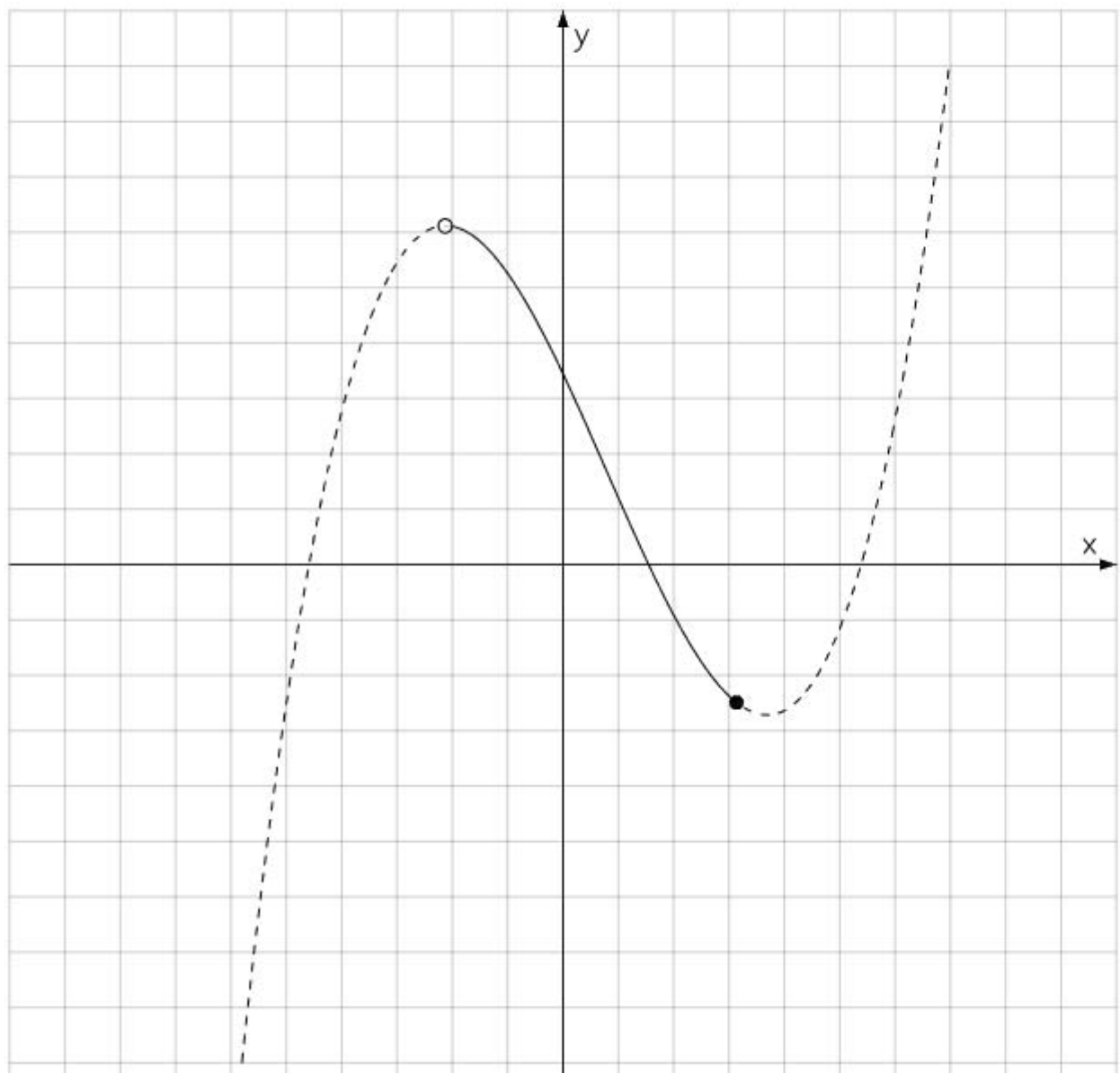
Graph Editing

Graph Editing

- Graph drawing in restricted domains
 - Different equations in different intervals
- Useful features in graph drawing
 - Drawing intersection points and tangent lines
 - Filling some bounded regions
 - Visualizing mensuration
- Additional features
 - Points on a graph, coordinate values, etc



Enter



Equation Options Candidates

Type : None
 Primitive Type : None
 Primitive Information
 a : 0.090089
 b : -0.211362
 c : -2.115352
 d : 3.438835

Equation :

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color - - Stipple -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration
 # of Sections

Omit Intermediate Sections

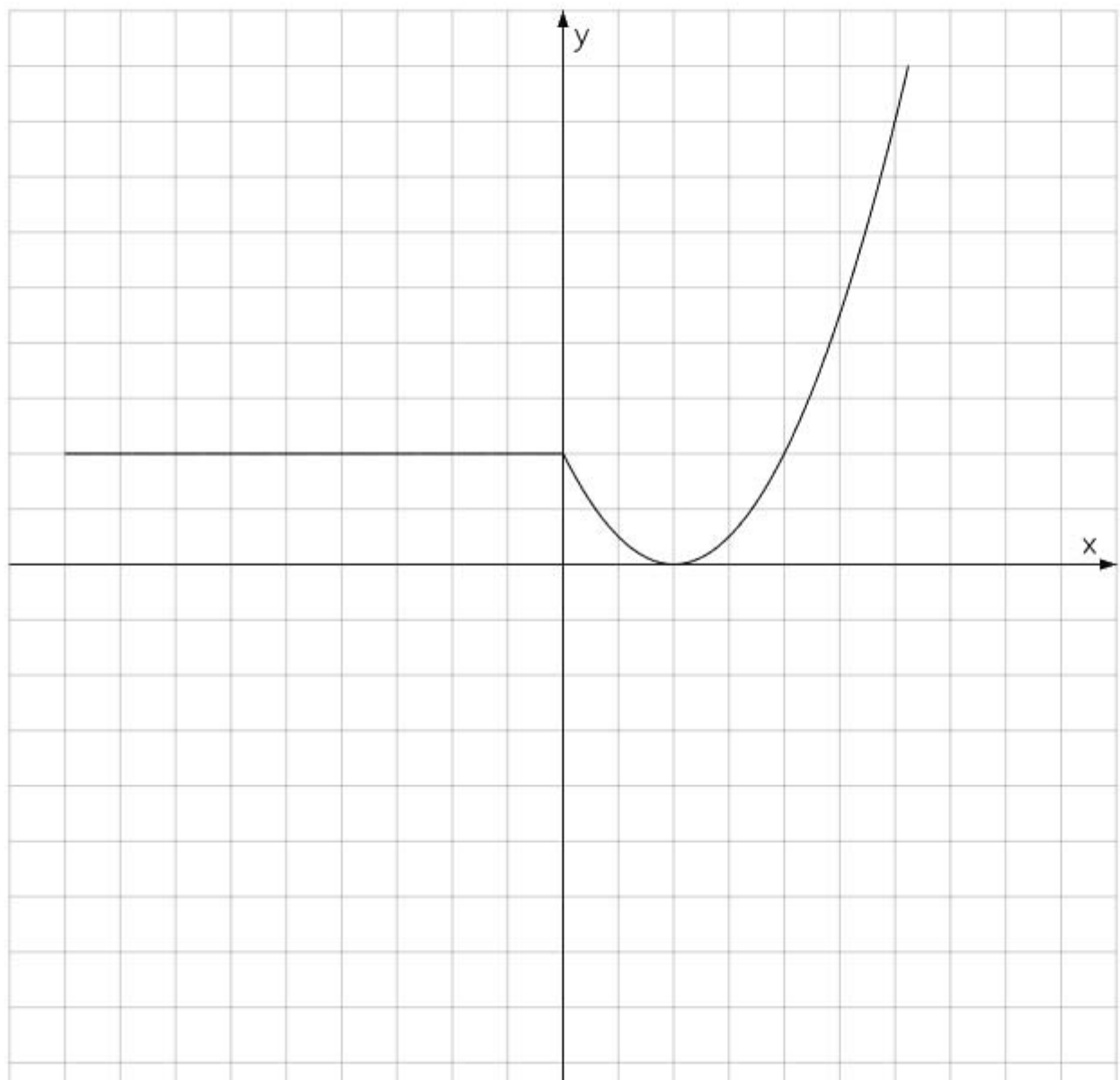
From To

Left Height Right Height



$y=0.5*x^2-2*x+2$

Enter



Equation Options Candidates

Type : None
 Primitive Type : None
 Primitive Information
 a : 0.5
 b : -2
 c : 2

Equation :

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color - - Stipple -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration

of Sections

Omit Intermediate Sections

From To

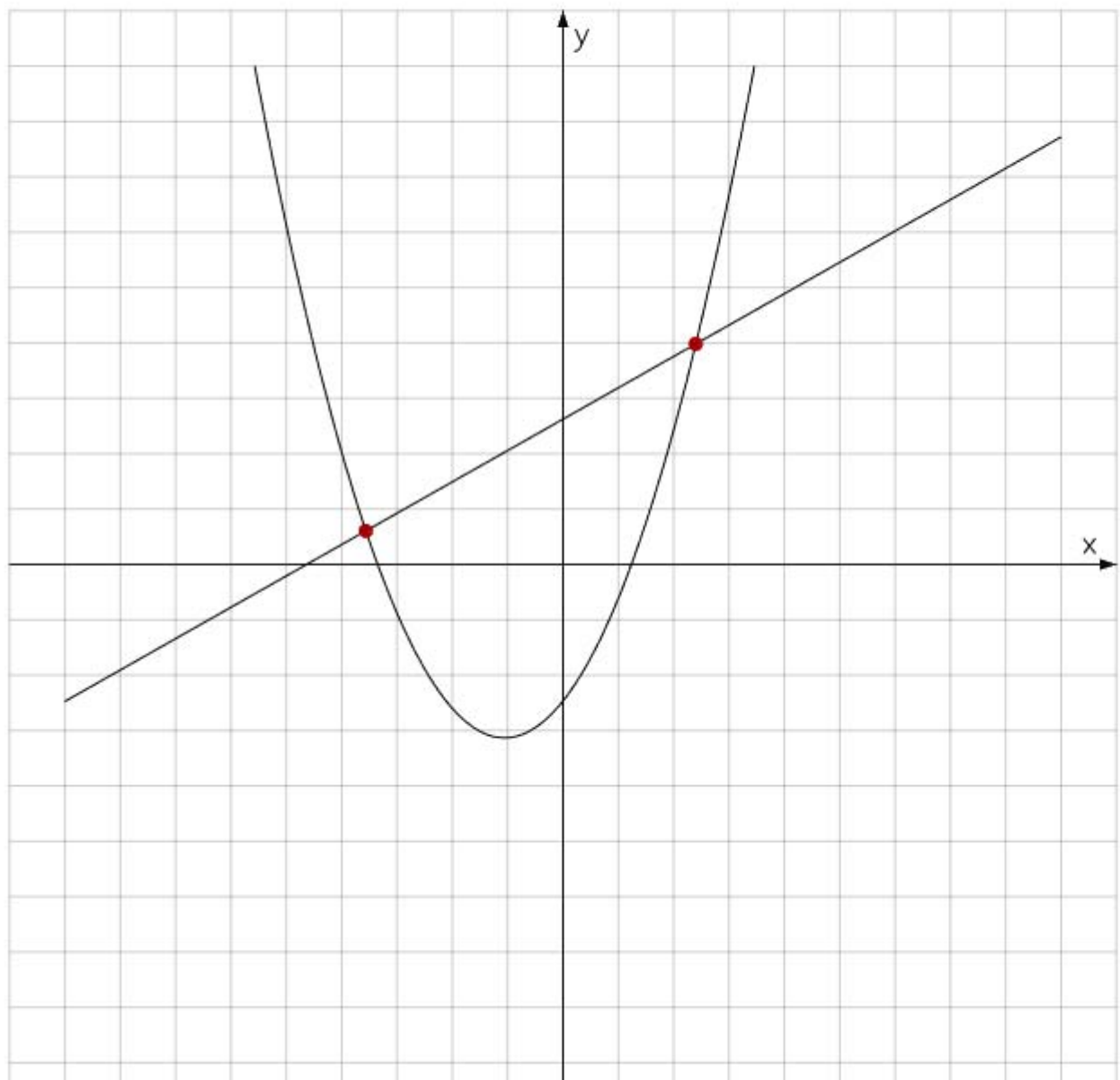
Left Height Right Height

x zoom



$y=0.5*x^2-2*x+2$

Enter



Equation Options Candidates

Type : None
 Primitive Type : None
 Primitive Information
 a : 0.5
 b : -2
 c : 2

Equation :

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color - - Stipple -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration

of Sections

Omit Intermediate Sections

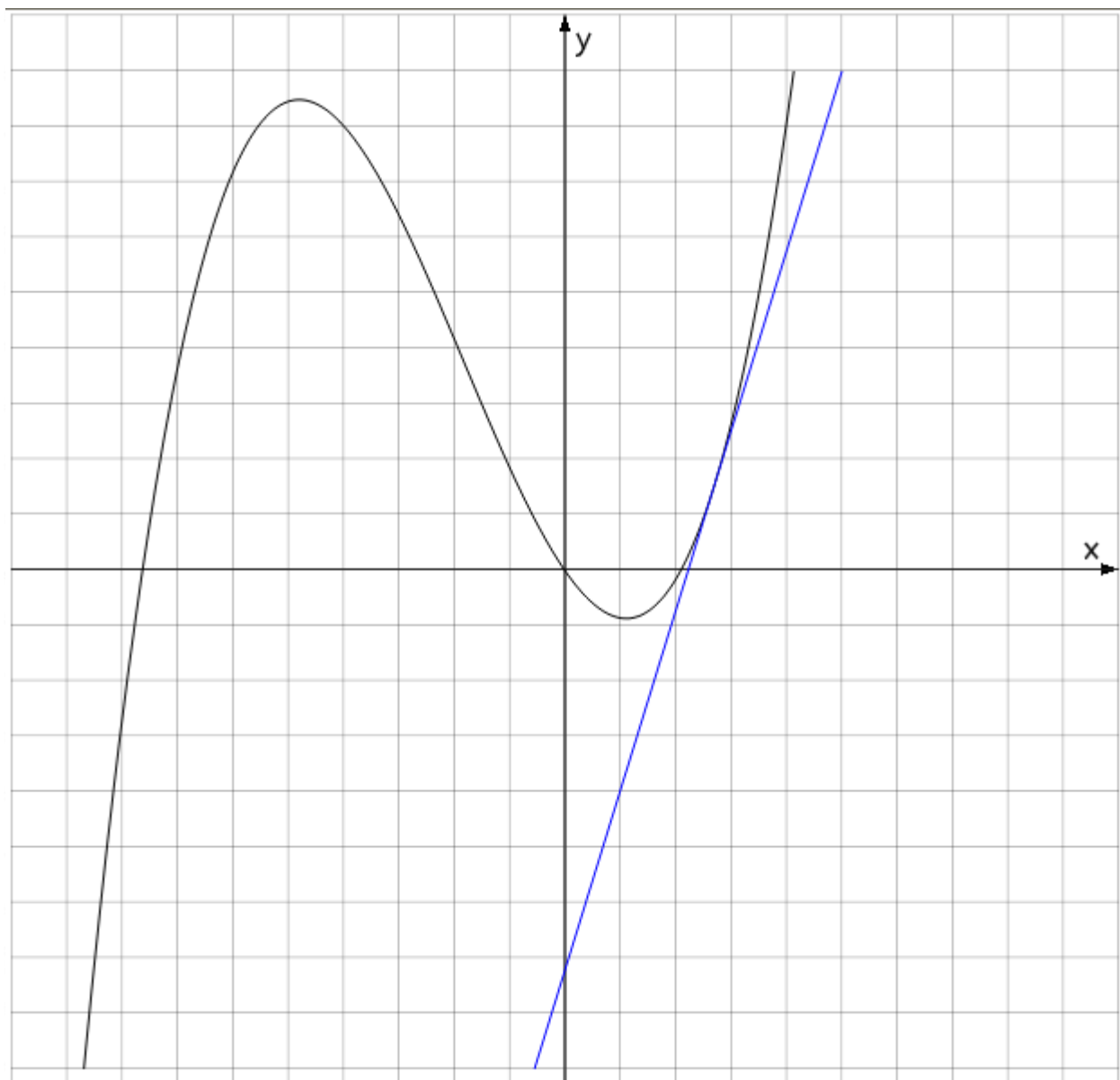
From To

Left Height Right Height



$y=0.5*x^2-2*x+2$

Enter



Equation Options Candidates

Type : Explicit

Primitive Type : Cubic

Primitive Information

a : 0.047336
 b : 0.047872
 c : -1.647233
 d : 0.016277

Equation : $y=0.04734*x^3+0.04787*x^2-$

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color -



- Stipple -



Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration

of Sections

Omit Intermediate Sections

From To

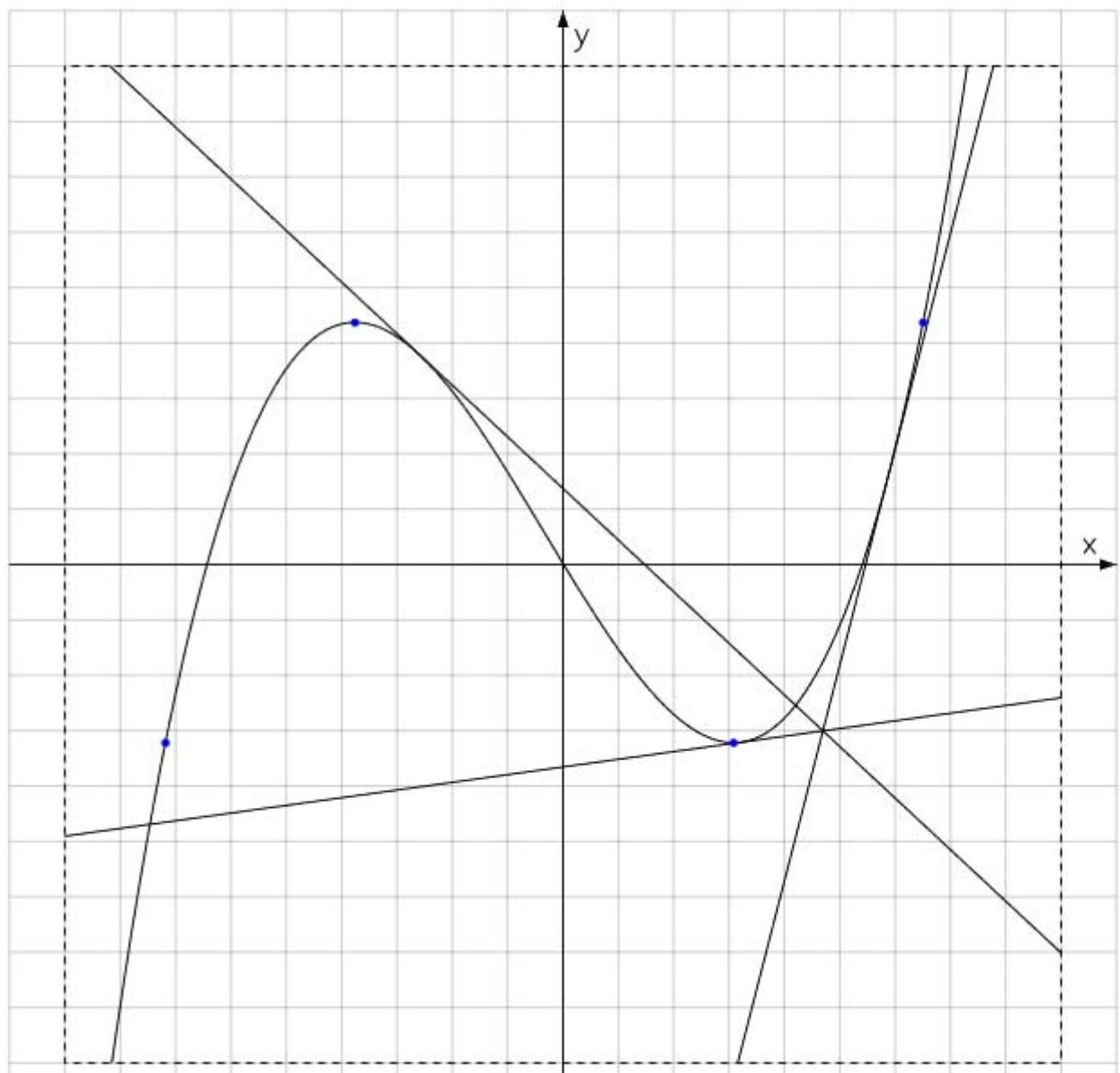
Left Height Right Height

x zoom



$y=0.5*x^2-2*x+2$

Enter



Equation Options Candidates

Type : Explicit
 Primitive Type : Cubic
 Primitive Information
 a : 0.047336
 b : 0.047872
 c : -1.647233
 d : 0.016277

Equation : $y=0.04734*x^3+0.04787*x^2-$

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color - - Stipple -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration

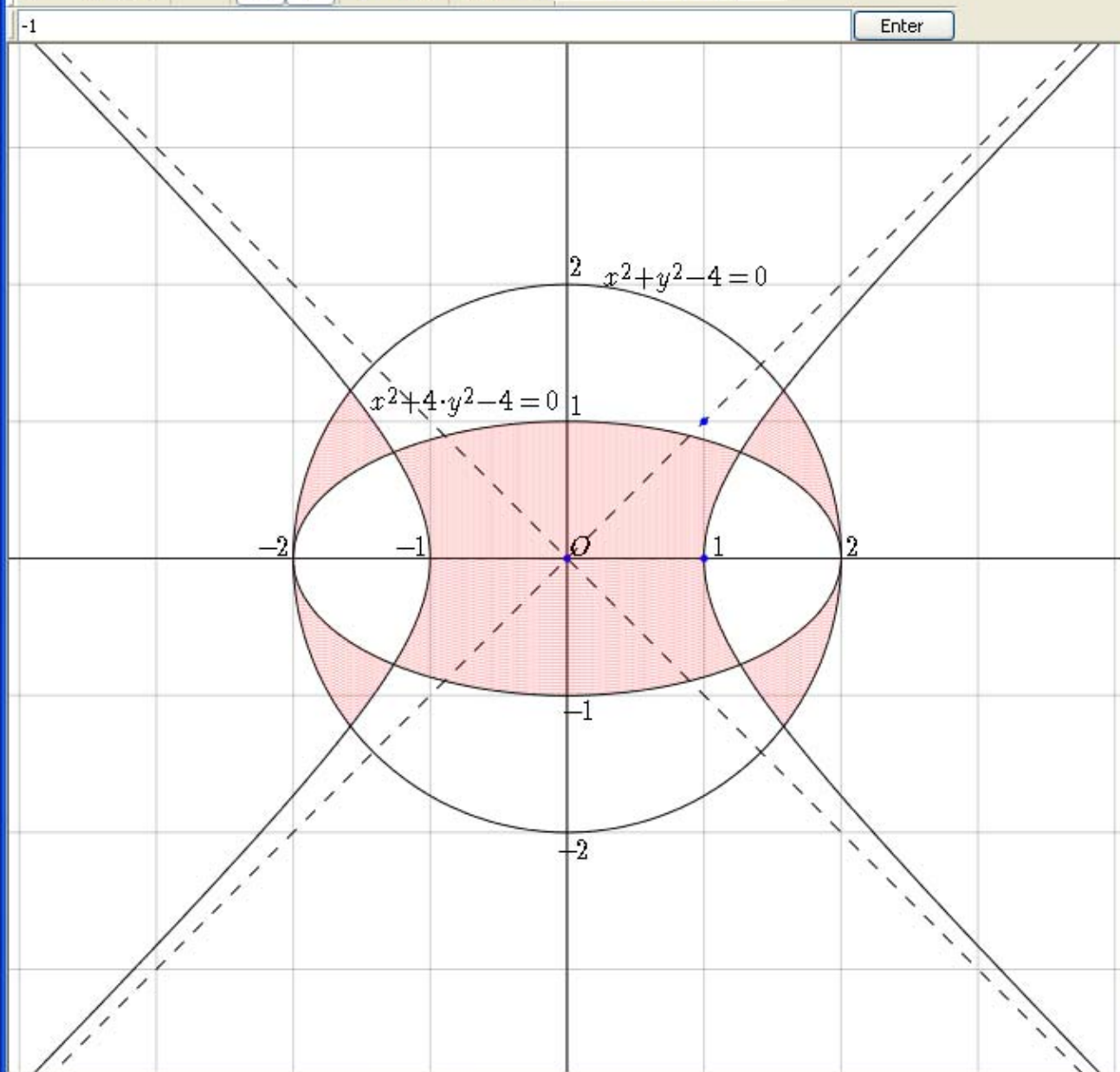
of Sections

Omit Intermediate Sections

From To

Left Height Right Height

x zoom



Equation Options Candidates

Type : Implicit
 Primitive Type : Hyperbola

Primitive Information

center : 0 0
 a : 1
 b : 1
 theta : 0

Equation :

Display Equation Text

Equation Text

Original Equation User Define

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections

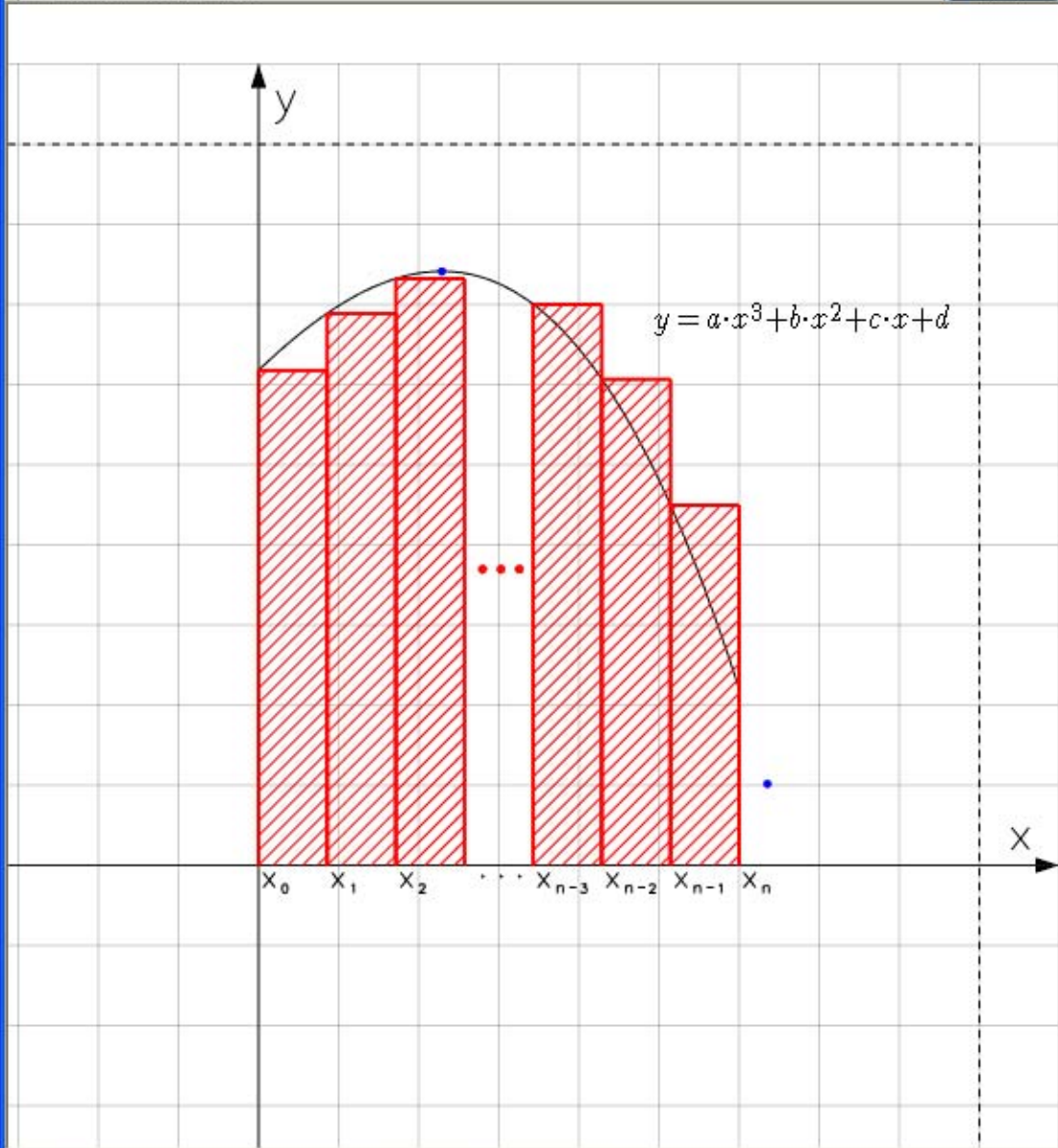
Omit Intermediate Sections

From To

Left Height Right Height Short Height



y=a*x^3+b*x^2+c*x+d Enter



Equation Options Candidates

Type : Explicit
Primitive Type : None

Primitive Information

a : -0.023827
b : -0.12685
c : 0.955489
d : 6.176475

Equation : $y = a \cdot x^3 + b \cdot x^2 + c \cdot x + d$

Display Equation Text

Equation Text

Original Equation User Define

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections

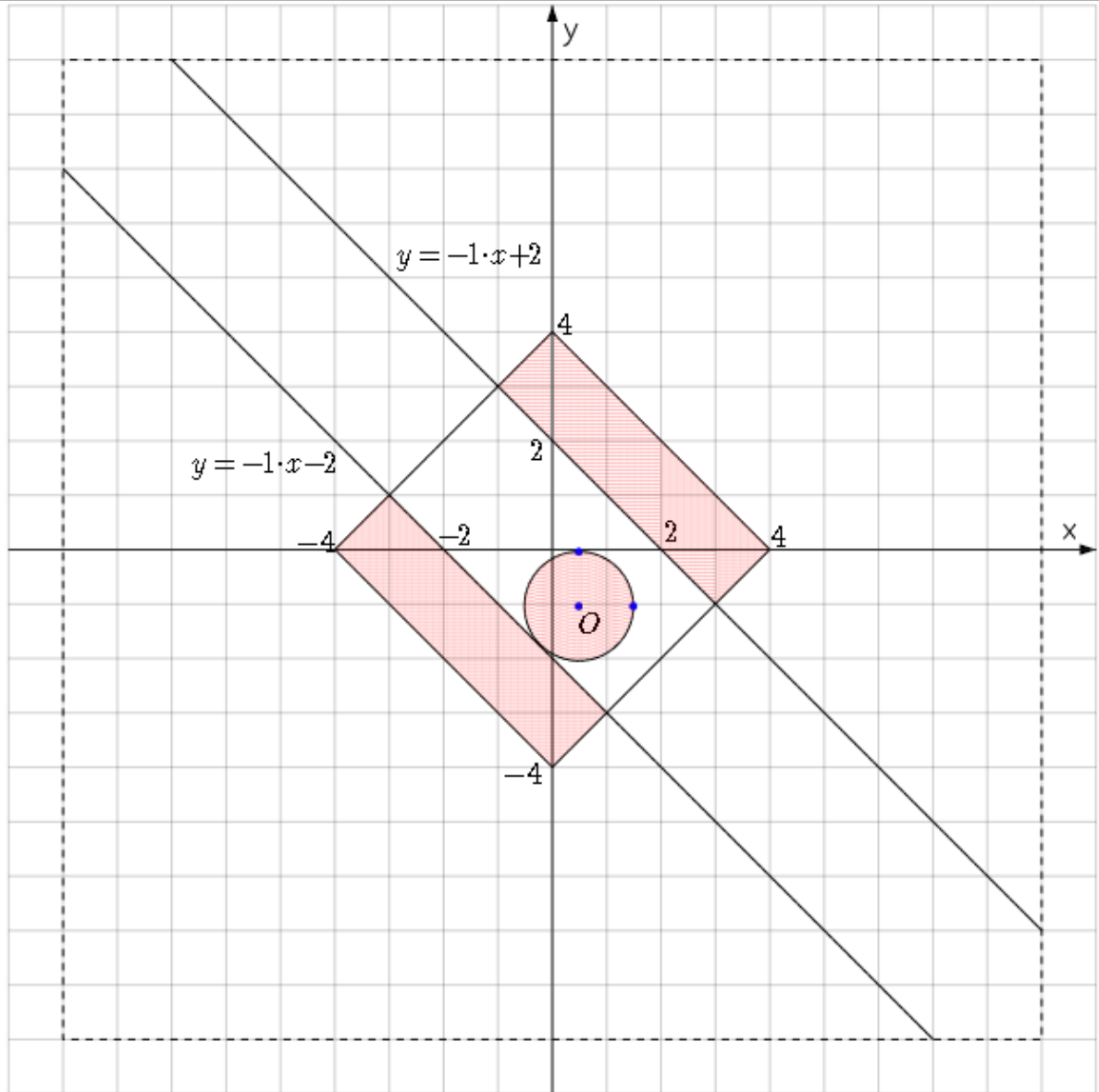
Omit Intermediate Sections

From To

Left Height Right Height Short Height



-4 Enter



Equation Options Candidates

Type : Implicit
 Primitive Type : None
 Primitive Information
 center : 0.4875 -1.04
 a : 1
 b : 1
 theta : 0

Equation : -4 Modify

Display Equation Text

Equation Text

Original Equation User Define

Confirm

Line Options

- Color - - Stipple - - Width -

Display Extreme Points

Set up Domain

From To Modify

Stippling None Left Right Both

Mensuration Options

Enable Mensuration

of Sections Apply

Omit Intermediate Sections

From To

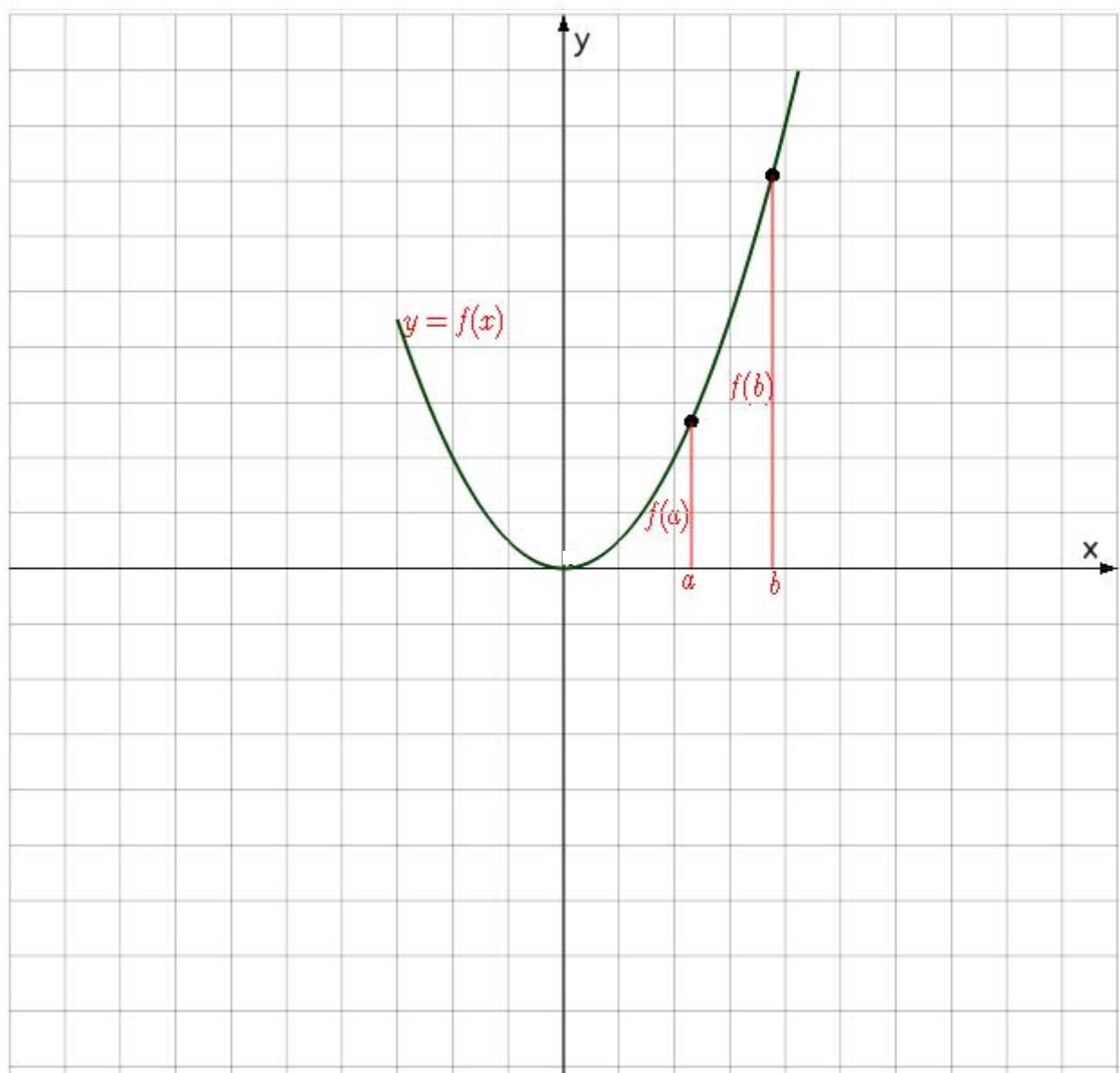
Left Height Right Height Short Height

x zoom

y zoom



$y=x^2-2*x+3$ Enter



Equation Options Candidates

Type : Explicit
 Primitive Type : Quadratic
 Primitive Information
 a : 0.419677
 b : 1.377591
 c : -0.349145

Equation : $y=0.41968*x^2+1.37759*x-0.349145$

Display Equation Text

Equation Text

Original Equation User D

Line Options

- Color - - Stipple -

Display Extreme Points

Set up Domain

From To

Stippling None Left Right

Mensuration Options

Enable Mensuration

of Sections

Omit Intermediate Sections

From To

Left Height Right Height

Graph Editing

Conclusion

• Contributions

- Efficient graph drawing for mathematics education in e-Learning
- Easy and fast generation of complicated math figures

• Future work

- Presentation of graph construction
- Animation of graph generation