Chapter 10 / **Example 21**

Application of differentiation to kinematics

The height (m) of a rocket projected vertically into the air until it returns to the ground is represented by the function $h(t) = -0.11t^2 + 1.32t + 1.5, t \geq 0$ where t is the number of seconds after the rocket was launched.

a State the height at which the rocket was launched.

b Find the maximum height reached by the rocket.

c Calculate the velocity of the rocket at $t = 7.5$ s and state whether it is ascending or descending at this time.

d Find the other time at which the rocket is travelling at the same speed as when. $t = 7.5$ s

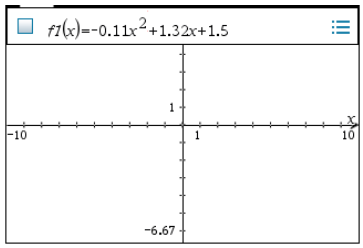
Open a new document and add a Graphs page.

The entry line is displayed at the top of the work area.

The default graph type is function, so '$f1(x)=$' is displayed.

The default axes are $-10 \leq x \leq 10$ and $-6.67 \leq y \leq 6.67$.

Type $-0.11x^2 + 1.32x + 1.5$ and press enter.

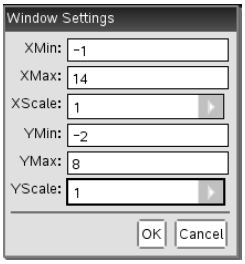


Choose appropriate axes to show the graph.

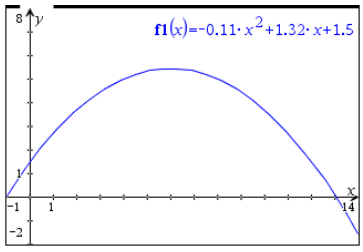
Press menu 4:Window/Zoom | 1:Window Settings…

Set the axes to show $-1 \leq x \leq 14$ and $-2 \leq y \leq 8$ with a scales of 1.

Press enter when you have finished.



The GDC displays the graph $f1\ x = -0.11x^2 + 1.32x + 1.5$



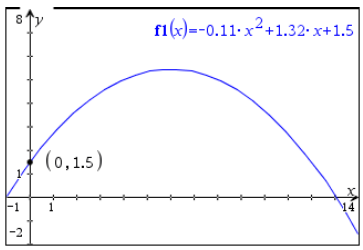
To find the y-intercept press menu 5:Trace | 1:Graph Trace

Press 0 enter to change the x coordinate to 0.

Press enter again and then press esc to leave the graph trace mode.

The y-intercept is at $0,1.5$.

The rocket was launched from a height of 1.5 m.



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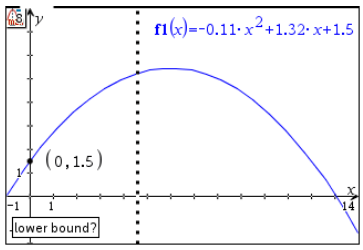
To find the vertex press menu 6:Analyse Graph | 3:Maximum

You will need to give the lower and upper bounds of the region that includes the vertex.

The GDC shows a line and asks you to set the lower bound. Move the line using the touchpad and choose a position to the left of the vertex.

Click the touchpad.

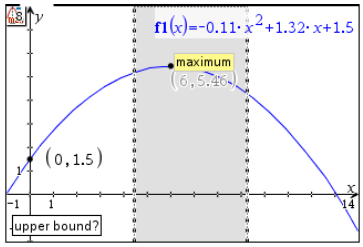


The GDC shows another line and asks you to set the upper bound.

Use the touchpad to move the line so that the region between the lower and upper bounds contains the vertex.

When the region contains the zero, the calculator will display the word 'maximum' in a box.

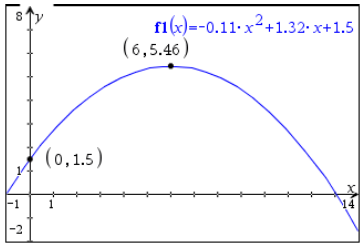
Click the touchpad.



The GDC displays the vertex.

The vertex of the quadratic function is at $6, 5.46$.

The maximum height is 5.46 m.



To find the velocity of the rocket with a GDC, use the first derivative.

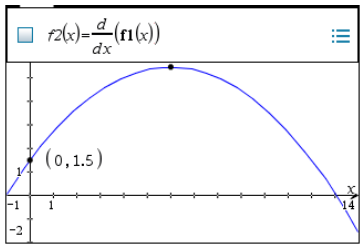
To graph the derivative function

Press tab to display the entry line '$f2(x)=$' is displayed.

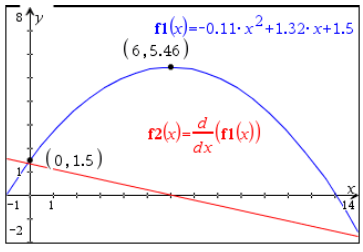
Press ⌨ and select $\frac{d}{d\square}\square$

Type X in the denominator and the function $f1(x)$.

Press enter.



The GDC displays the graphs $f1(x)$ and its first derivative.



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To find the velocity at $t = 7.5$ press menu 5:Trace | 1:Graph Trace.

Select the graph $f2(x)$ using the touchpad.

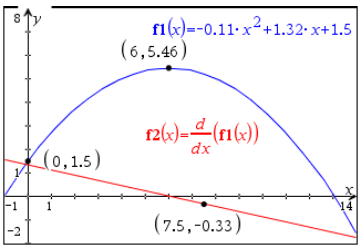
Type 7.5 and press enter to change the x coordinate to 7.5.

Press enter again and then press esc to leave the graph trace mode.

The point is $7.5, -0.33$.

The velocity is -0.33 ms^{-1}.

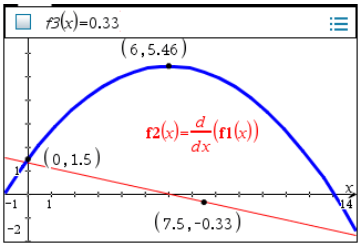
Because the velocity is negative, the height is decreasing and so the rocket is descending.



To find another point where $v = +0.33$ ms^{-1} draw the line $y = 0.33$ and find the point of intersection.

Press tab to display the entry line '$f3(x)=$' is displayed.

Type 0.33 and press enter.



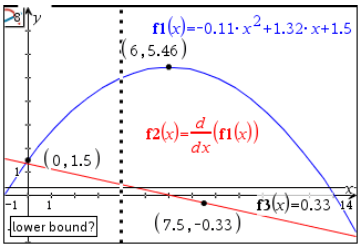
Press menu 6:Analyse Graph | 4:Intersection

Use the touchpad to choose $f2$ and $f3$.

To find the intersection you need to give the lower and upper bounds of the region that includes the intersection.

The GDC shows a line and asks you to set the lower bound. Move the line using the touchpad and choose a position to the left of the intersection.

Click the touchpad.

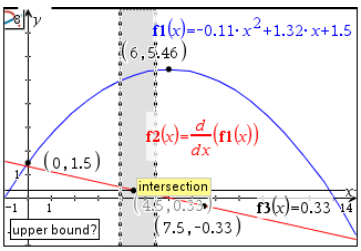


The GDC shows another line and asks you to set the upper bound.

Use the touchpad to move the line so that the region between the lower and upper bounds contains the intersection.

When the region contains the intersection, the calculator will display the word 'intersection' in a box.

Click the touchpad.



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The GDC displays the intersection of the two straight lines at the point $4.5, 0.33$

The rocket has the same speed at t = 4.5 s.