

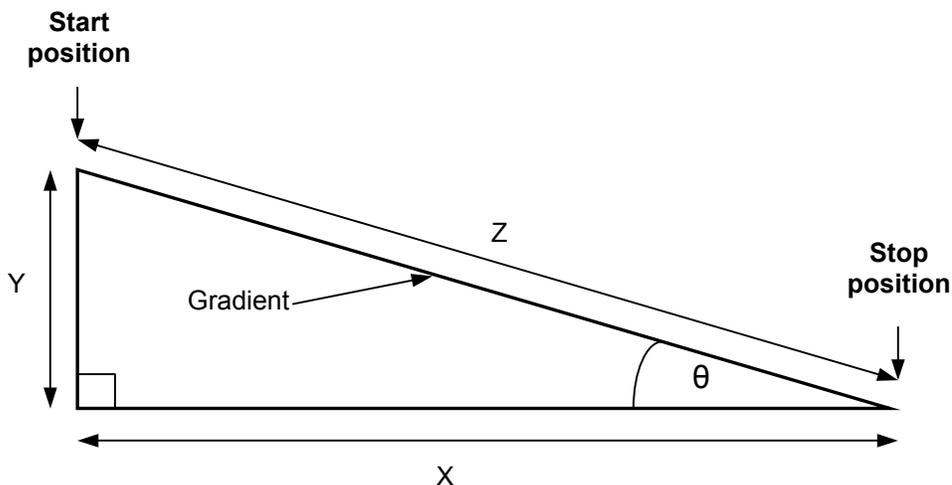
**Determining Braking Distance:**

One of the functions of the VBOX is to measure braking distance and this is explained in the application notes “Brake Testing – Brake testing applications and descriptions” and “Brake Testing – Brake test with CAN wheel speed data”, both of which can be found in the support section of the VBOX website.

Although one of the most accurate measurements systems available, a potential pitfall of the measurement of braking distance is that, due to the nature of GPS satellite positioning, the VBOX measures braking distance assuming a flat surface. This introduces the possibility of slightly erroneous results for braking distance measurements when performed on a gradient.

Referencing the diagram below, the distance Z represents the actual distance travelled, however, the VBOX will see the distance as X. If this were viewed from directly above then the distances X and Z would appear to be the same.

The value of Y is given by selecting relative height in VBOX tools.



Therefore, the actual value of Z can be calculated by applying Pythagoras’s theorem to the known parameters, in that the height change Y will always be vertical and hence at 90° in relation to the theoretical horizontal distance travelled, X.

Thus: 
$$\text{Braking Distance } Z = \sqrt{(X^2)+(Y^2)}$$

For example then, if the distance X is 20m and the relative height Y from the start position to the end position is 1.5m, then the value of the actual distance travelled would be:

$$Z = \sqrt{((20^2)+(1.5^2))}$$

Hence, 
$$Z = \mathbf{20.056m}$$

The value of Z can be displayed live in VBOX tools by simple configuration.

BRAKING DISTANCE ON A GRADIENT

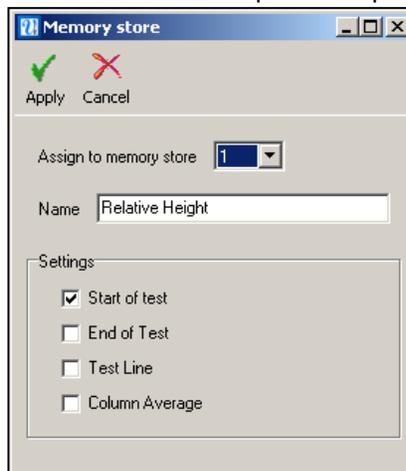
**Creating a Gradient-Corrected Distance Result in Report Generator:**

The Report Generator can be configured using the default Brake Test setup to calculate the braking distance from a speed to 0 assuming a flat surface. The Maths channel and memory store facility within Rep Gen can be used to instantly calculate a gradient-corrected braking distance.

**Theory:**

The value of relative height at the start of the test is assigned to a Memory Store. A Maths channel is created to subtract the Memory Store value from the Relative height value at the end of the test, to calculate the change in Relative height during the test. Another Maths channel is then created to use Brake distance and the Maths Channel value of delta Relative height to create a 'Gradient Corrected Brake Distance'

- Load the file containing the brake stops performed on a gradient.
- Run Report Generator, then click on the default Brake Test setup button
- Open the Test Setup screen and set the Start speed to the correct Start speed for your brake stop. In our example we are using 90Km/h.
- Insert a new column in the RepGen results table between the Distance and the Graph Run columns (to do this, right-click on the Graph Run column and choose Insert Column)
- Left click on the new column title box to open the channel selector box and set this column to Relative height.
- Right click on the Relative height channel title box and select 'Assign column to memory store', then select memory store 1 and tick the 'Start of Test' option and press apply.



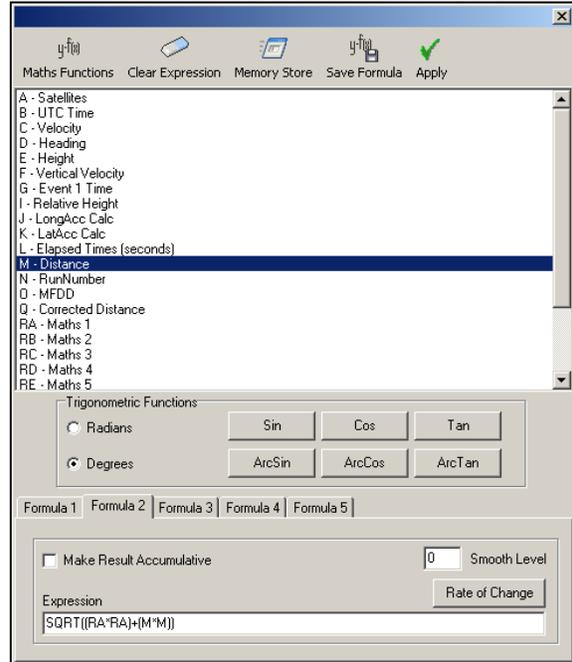
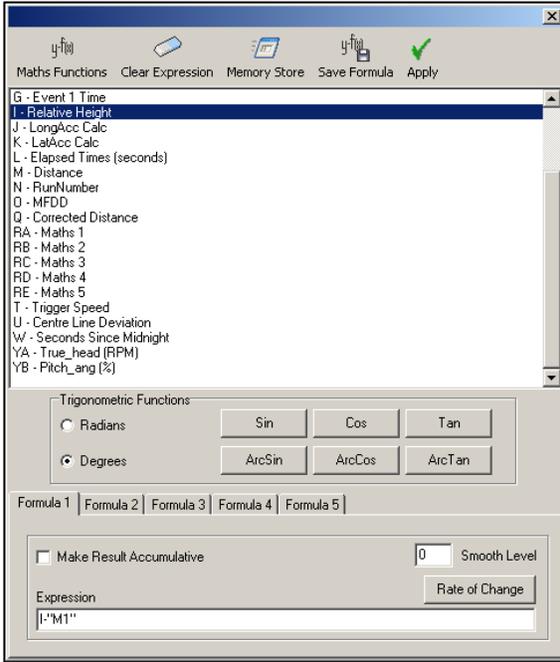
- Insert a new column and set it to be Maths Channel 1, and edit the Column Label to 'Relative Height Diff'
- Insert another new column and set it to be Maths Channel 2, and edit the Column Label to 'Gradient Corrected Brake Dist'
- Now click on the Rep Gen Maths channel button:



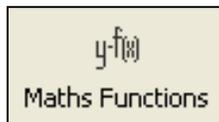
# APPLICATION NOTE

## BRAKING DISTANCE ON A GRADIENT

- This will bring up the following screen to allow you to first create an expression for the relative Height difference in Maths Channel1. Then create a formula for the calculation of the gradient corrected distance in Maths Channel2.



- The expression used in Formula 2 is Pythagoras' theorem applied to the Maths Channel1 (identified with the characters RA in the list) and the Distance (identified with the character M in the list). **Note: the Square Root function can be inserted from the available options in the "Maths Functions" menu:**



- Click Apply – this will apply the settings and close the Maths Channel window.
- Click Scan to produce the brake results now including the Gradient Corrected distance.:

Report Generator - Brake Test (modified)							
use	Run num	Time(s)	Dist(m)	Relative Height	Relative Height Diff	Gradient Corrected Brake Dist	Graph run
	1	0	0.00	-2.62	0.00	0.00	
<input checked="" type="checkbox"/>	1	4.44	49.08	-5.96	-3.34	49.20	

BRAKING DISTANCE ON A GRADIENT

**SUMMARY:**

As is evident from the results above, the brake stop has a change in height of **-3.34m**, indicating a downhill gradient.

Standard Brake distance = **49.08M**

Applying Pythagoras Theorem

$$\begin{aligned} \text{Gradient Corrected distance} &= \sqrt{(3.34^2)+(49.08^2)} \\ \text{Gradient Corrected distance} &= \mathbf{49.20M} \end{aligned}$$

When this gradient is taken into account the resulting 'gradient-corrected' brake stop distance is 49.20m, which is 12cm longer than the brake stop distance, which assumes a flat surface.

**Note: This RepGen test setup can also be used in VBOX Tools live mode, to give real-time gradient corrected brake distances.**

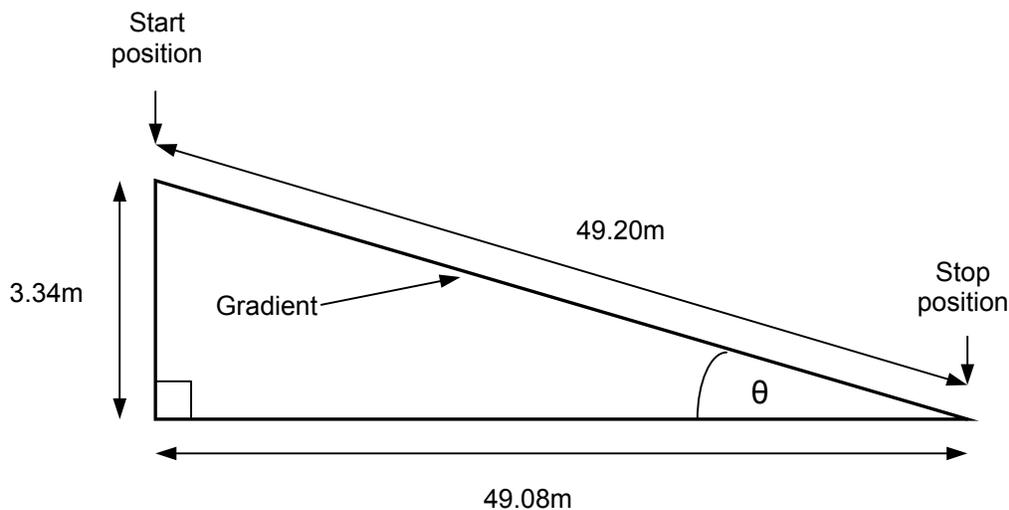
**Determining Gradient angle:**

It may also be desirable for the user to know the actual angle of the gradient. This can be calculated with simple trigonometry. Referring back to the brake test recorded in VBOX tools on the previous pages, we can calculate the angle  $\theta$  as follows:

$$\cos \theta = 49.08 / 49.20$$

Thus,  $\theta = \cos^{-1} (49.08 / 49.20)$

Hence,  $\theta = \mathbf{4.00^\circ}$





# APPLICATION NOTE

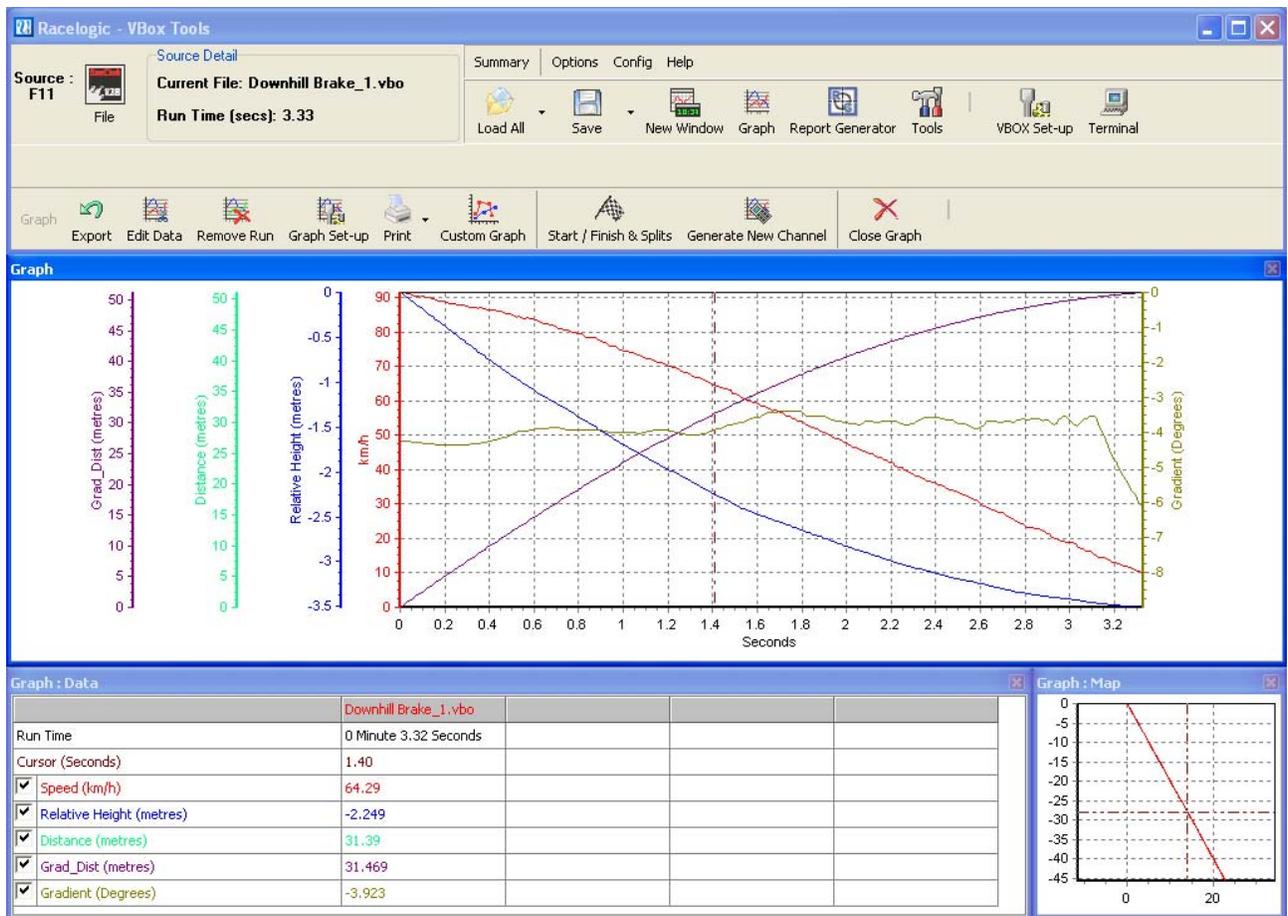
## BRAKING DISTANCE ON A GRADIENT

This is true for a constant gradient, but in reality this gradient is likely to be varying a little along its length. Real time indication of gradient may be required to qualify a surface as suitable in instances of testing where a known gradient is required to be within specified limits, for example  $5^\circ \pm 1^\circ$

In these instances, the easiest way to give a real time indication of the gradient is to calculate this as a function of velocity and vertical velocity.

Using VBOX Tools, a formula can be created in much the same way as given in the previous example for distance. To give gradient angle, the formula  $\text{ArcTan}(\text{Vertical velocity} / \text{Velocity})$  should be used. This will return a value of gradient for each GPS sample taken.

**Note: Road Gradient is very low dynamically, so to improve the accuracy of the gradient, a high level of smoothing can be applied.**



In the above screen capture, the value of the gradient is plotted from the start of the file to the end of the brake stop. At the selected cursor point, this is  $3.92^\circ$ , slightly less than  $4.00^\circ$  calculated for just the 90-0km/h section of the file.

The small variations in gradient due to surface undulations can clearly be seen.