

Framework reference: Page 173

Strand: Algebra
Topic: Graphs of functions
Pupils should be taught to: Construct functions arising from real-life problems and plot their corresponding graphs.
Year group: 9
Objectives: Use a motion detector and graphical calculator to plot the distance-time graph of a bouncing ball.
Key Vocabulary: Function, graph, distance-time graph
Resources required: A Calculator-based ranger (CBR) connected to a demonstration calculator (Viewscreenor TI-SmartView emulator)

Summary

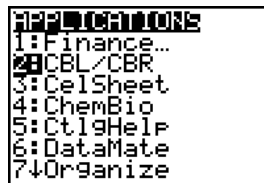
This activity uses the CBR as a distance sensor. The software uses an application called **ball bounce** to take a series of distance measurements very quickly over a 4-second period. The user can then look at distance-time, velocity-time and acceleration-time graphs of the motion.

The instructions below show how to set up the calculator and CBR unit and how to navigate the software. There are also some suggestions for data to collect. There are no handouts associated with this activity.

Instructions for the teacher

(1) Loading the software

Press [APPS] Select **CBL/CBR** – it may not be number 2 on your machine.



When you see this screen press any key to continue.



From the menu below choose **3:RANGER** and press [ENTER]



This is the main menu. Choose **3:APPLICATIONS** and then choose **1:METERS**

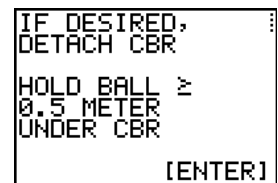


From the next menu choose **3:BALL BOUNCE**. At this point the calculator will prompt you if the CBR is not connected.

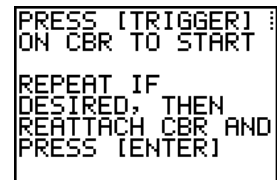


(2) Arranging the kit

Using the longest lead you have, plug the CBR firmly into the calculator. The screen prompts you to prepare the experiment by holding the moving object in a suitable place. It is not necessary to be ready quite yet. Just press [ENTER].



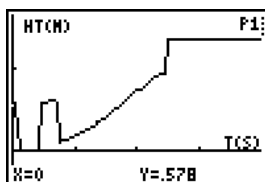
Now get everything ready. It is easiest to use the TRIGGER button on the CBR unit. The unit will start clicking and at every click it will take a measurement. Remember that it will carry on taking readings for 4 seconds, so you will have to act quickly!



(3) A first look at the data

Press the trigger and drop the object. Hopefully it will fall and bounce, remaining in line with the motion sensor.

When the CBR unit has finished clicking, press **ENTER** on the calculator. A graph showing distance against time will be shown.

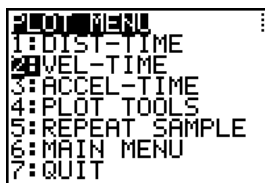


How can you interpret this representation of the motion that occurred? When did the motion start? Where are the bounces shown? What is the straight line for the last two seconds representing? What do the tick marks on the axes represent? How do you know?

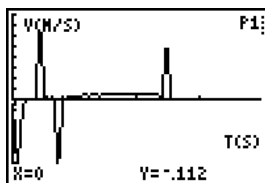
Take your time over this part of the activity—it is essential that the students are very clear in their understanding of how the graph relates to the motion that they saw.

You can use the left **←** and right **→** cursor keys to trace the points on the graph and the coordinates at the bottom of the screen indicate the time elapsed and the height of the object.

Press **ENTER** to see the plot menu. If your data has not worked out well, you can choose **5** to repeat the sample.



Choose **2:VEL-TIME** to display the corresponding velocity-time graph.



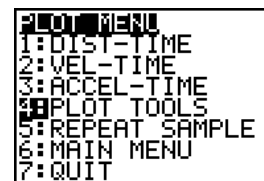
Again it is important to interpret the graph in relation to the motion. Ask questions such as “what does a negative velocity represent?” or “why is the velocity zero in the middle of this bounce?”

(4) Smoothing the data set

Press **ENTER** to see the plot menu again. Once again look at the distance-time graph. Much of it is not relevant because it shows data before and after the motion you are interested in.

Press **ENTER** to return to the plot menu again.

This time choose **4:PLOT TOOLS** to view your graph differently.



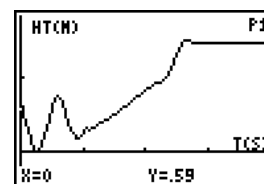
This Plot Tools menu allows you to improve the graph's appearance with smoothing and you can also choose to select just part of the graph (to get rid of the parts before and after the actual motion took place).

Choose **2: SMOOTH DATA**.

There are four options. Choose **2:MEDIUM**. This is appropriate for most experiments.



This is the graph lightly smoothed. (Compare it with the actual data plotted previously)



Discuss what smoothing actually does to the data set. What values are no longer shown? Why is this a good idea? What are the disadvantages?

Try light and heavy smoothing and see their effect too.

(4) Removing irrelevant data

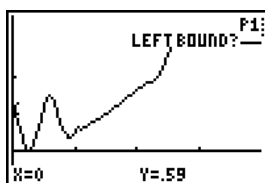
Press **ENTER** and again choose **4:PLOT TOOLS**.

This time choose option **1** to select the domain.



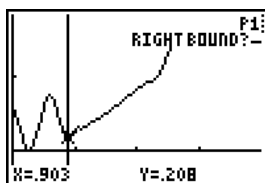
Discuss which parts of the graph are showing irrelevant data. The calculator will allow you to select a relevant part of the graph and look at it more closely.

Select the left bound of the domain you want using the left **◀** and right **▶** cursor keys. Keep an eye on the X and Y values at the bottom of the screen too.

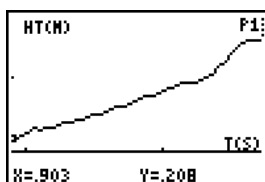


When you have decided press **ENTER**.

Now in a similar way you need to select the right bound of the domain you want and press **ENTER**.



A new re-scaled graph is automatically displayed between the points you chose. (Note: choose your bounds with care, you cannot recover the original graph).



Press **ENTER** to return to the Plot Menu. You can now look at the three different graphs and discuss their interpretation again



(5) Suggestions about data collection

It can be difficult to control the line of motion of the object. It must remain in line with the sensor throughout its motion.

The simplest situation to consider is an object such as a heavy book falling under gravity. Clamp the sensor to an overhanging shelf or some high place. Hold the book underneath it and let it fall. Remember that the sensor is only reliable for distances more than 50cm and less than 6m.

What difference does it make to the graph if the sensor is placed below the object?

Does a heavy book fall faster than a light one? (Many students will think that it must.)

Investigate the effects of air resistance with a light object (but not so light it will float out of line!)

To record the bouncing of a ball it is best to use a large one, such as a football or basketball with the CBR clamped above it. For more than one bounce it can be difficult to control the line of motion of the ball. It must remain in line with the sensor throughout its motion and, unless the floor is perfectly even the ball will often bounce out of line.

Another possibility for investigation is vertical oscillation on a spring: for example, attach the object to a piece of elastic fixed below or above the CBR. Pull the object gently down and release it.

The **Ranger** software can also be used to create distance-time graphs of students moving at different speeds towards and away from the CBR, clamped horizontally. There are teacher notes and handouts to support such an activity in Lesson 28 of **30 Calculator Lessons for Key Stage 3 (A+B Books)**.