To Measure a Constant Velocity

Apparatus

calculator, black lead, calculator based ranger (cbr, shown), Physics application

Method

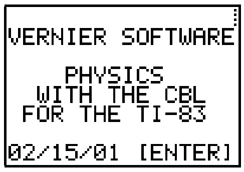
Press **APPS** (blue key, second from the left hand side on the calculator keyboard) and from the menu select the application **Physics** by either scrolling down (blue keys with arrows up down left and right) and pressing **Enter** or entering the number beside the name **Physics**: 5 in this case.

screen 1

Enter the following, taking care to read the instructions presented by the calculator. If things go wrong at first then simply exit the program (press **On** to exit or follow exits in menus) and start again. **Enter** will move the program on to the next stage. You cannot damage the calculator and each trial takes only seconds so you have lots of time to experiment. With constant use, as recommended in this text, the use of the program becomes second nature.

At the Vernier Software title screen

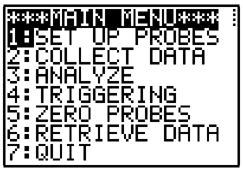
Enter.



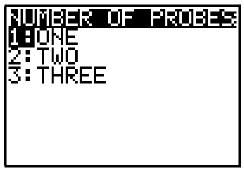
screen 2

The probe or sensor used must be specified.

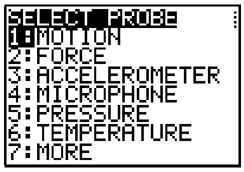
Set up One Motion probe



screen 3



screen 4

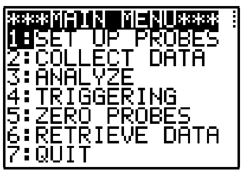


screen 5

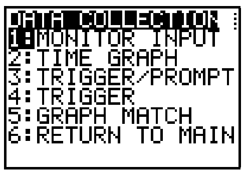
Measurements can then be collected at given time intervals and plots displayed. Following the calculator menu options carefully, choose 0.1 seconds and 80 measurements as follows:

Collect data Time graph 0.1 80

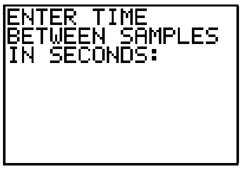
Enter



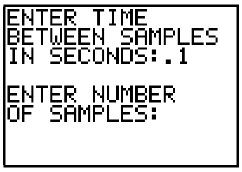
screen 6



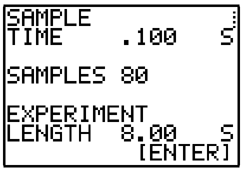
screen 7



screen 8



screen 9

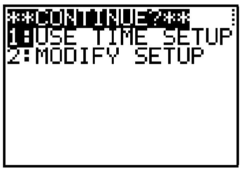


screen 10

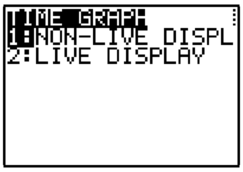
Since this is a live display, the calculator asks for an initial estimate of the range of distances involved, here 0 to 5 m, and the scale, here 1 m, so that it will scale the graph appropriately on screen. The graph is auto re-scaled at the end.

Use time setup ∨

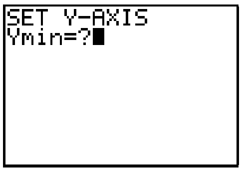
Live display 0 5 1



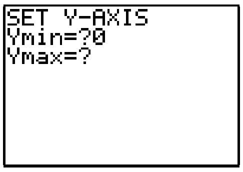
screen 11



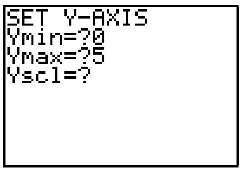
screen 12



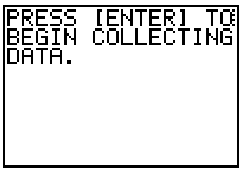
screen 13



screen 14



screen 15



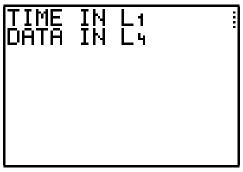
screen 16

Point the detector towards a hard surface such as a wall and press **Enter** to begin data collection while walking to and fro.

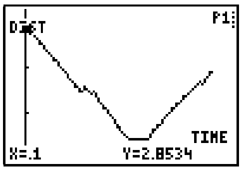
Note on the use of the motion detector

The motion detector cannot measure within 30 cm of itself but can measure up to 6 m away. It sends out a cone of ultrasound and detects the reflected waves. Experiments should therefore be done in an open space in the lab or outside it to avoid extraneous reflections which will show as noise on the graph and perhaps distort the graph completely. If this happens, then remove the other objects or move to a more open area. Similarly, reflection is best from a hard surface such as a wall or sheet of cardboard although human bodies can be quite good reflectors. Once you are used to the behaviour of the detector, none of this is a problem. The distance measured is directly in front of the detector - it will not measure sideways movements.

Once the graph is complete the screen clears and shows that time data is in list 1 and distance data in list 4. Data here include to and fro movement.



screen 17



screen 18

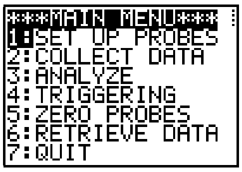
Enter will move the program on at this point and in general. When the graph is displayed the arrow or cursor keys step along the graph and the measurements at each point selected are shown on the screen. Screen 18 shows motion to (down slope) and then from (up slope) a wall.

Try a few different examples of time interval and number of measurements - each trial can be completed in a few seconds. Only if a time interval greater than or equal to 0.1 s is specified is it possible to obtain a live display of the motion as it is being measured. Once the calculator has been set up for the motion probe, only the timing and number of measurements need be specified until a different probe is used with the calculator.

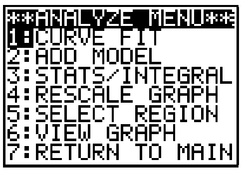
I Stand about 2 m from a wall and using a time interval which gives a live display (0.1 s or more), move towards the wall slowly and steadily in a straight line while the detector measures the motion. The motion should be seen graphing on the screen as it happens. The time and distance measurements are loaded into lists L1 and L4 of the calculator respectively. Sketch the graph you have made in your copy. Include label and unit information on each axis as usual.

To exit from the graph **Enter Next**
and for repeat **No**.
From the main menu **Analyse**

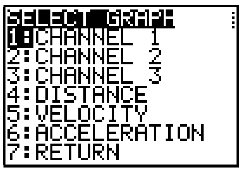
screen 19



screen20

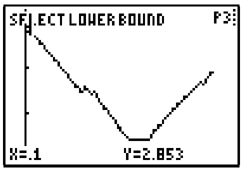


screen 21

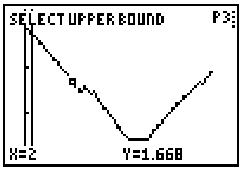


screen 22

Select select a region of the graph of **distance** against time which looks straight! This can eliminate sections of noise, especially at either end of the measurements. Move the flashing cursor along the graph using
> > and
Enter to select left and then right boundaries for the data selection. Once the graph is shown, **Enter** to move on to the next menu.

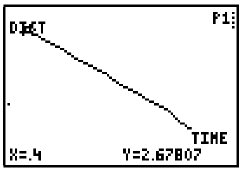


screen 23



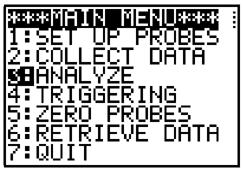
screen 24

While the data is being reorganised by the calculator there is a short delay during which a moving line is displayed at the top right hand side of the screen. The selected data is then displayed. NB 23 and 24 show to **and** fro motion

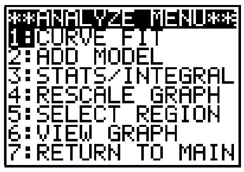


screen 25

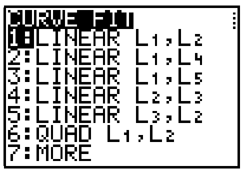
Analyse Curve fit Linear L1, L4



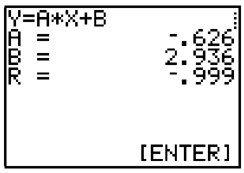
screen 26



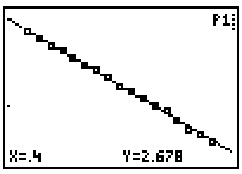
screen 27



screen 28



screen 29



screen 30

Results

The calculator uses a mathematical procedure to determine the line which is the best fit to the data. The method is that of least squares - calculus allows the minimisation of the sum of the squares of the differences between measured and calculated points. We need not understand the method to use the results.

The data display shows

$$\mathbf{y = ax + b}$$

which is the same equation as **y = mx + c** and so a is the slope of the graph. Since the graph is of displacement (the motion is in a straight line) against time, the slope is the velocity. The straight line means that the velocity is constant

b is the intercept for the graph - where it crosses the y axis and so means where the motion began.

r is a number which describes how well the calculated equation correlates with (matches) the data. If r is 1.00 the points lie in a perfect scatter about the fitted line. r is called the correlation coefficient.

So, **y = ax + b** represents the physics $\mathbf{s = vt + s_o}$ (what does $\mathbf{s_o}$ represent?) in this case. Make a table in your lab book big enough for four examples and enter the values for a, b and r as **v, $\mathbf{s_o}$ and r.** Give the appropriate units. Make another table for four graphs and sketch the graph in one section. Ensure the axes are labeled with quantities and units.

Repeat the above for

II Stand 0.5 m away from the wall and walk away from it. Enter v so and r into the table and sketch the graph.

For the next two motions use a time interval less than 0.1 seconds. This will give a non live display (because it happens so fast) which has some advantages: there is no need to give initial values for Ymin, Ymax and Yscl.

III Measure the motion of a ball pushed along the ground and let go away from the detector. Enter v s_o and r into the table and sketch the graph.

IV Measure the motion of a ball pushed along the ground and let go towards the detector. Ensure that the detector is protected but the ultrasound beam is unimpeded. Enter v so and r into the table and sketch the graph.

Examine the table. What is clear about motions towards and motions away from the detector?

Conclusion

From speedometers in cars we are familiar with the idea that there will be an "instantaneous" velocity which may vary from moment to moment. To accommodate this observation we redefine velocity as the rate of change of displacement with time as time approaches zero (gets very small). This is written as

$$\mathbf{v = ds / dt}$$

Where v is velocity, s is displacement, t is time and ds and dt mean the instantaneous change in displacement and time. As a vector it may be positive, zero or negative.

Aim To Measure a Constant Acceleration

Apparatus

calculator, black lead, cbr, Physics application, basketball, ramp.

Method

Set up a ramp. Measure the height and (sloping) length of the ramp. Set out a table for height, length, u (initial velocity), a (acceleration) and r.

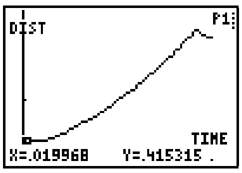
Give appropriate units in each case. Let a basketball roll down the ramp under gravity. Note the approximate time it takes. Set up the motion detector as before for this sort of timescale - perhaps one second in total. As before, connect the calculator firmly to the cbr and measure the motion. Ensure the conic zone of the ultrasound is kept clear of reflective objects. The time scale is very short so a non live display will automatically be given. The time and distance measurements are loaded into List 1 and List 4 but velocity is calculated from these and stored in List 5. (How is the velocity calculated ?).

App Physics Enter

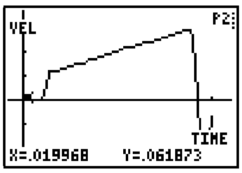
Collect data Time Graph 0.03 50

Enter Use time setup Enter

Examine the distance against time graph. Sketch it with correct labeling of the axes.



screen 1 (distance time)



screen 2 (velocity time)

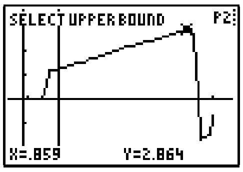
Enter (Velocity)

Examine the velocity against time graph. Sketch it and note if a section approximates to a straight line. If not, repeat until such a graph is obtained. If a good straight line plot is displayed then go to the main menu of the program:

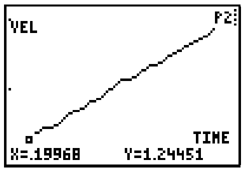
Enter Next No

Analyse

Select > Enter > Enter on the velocity against time graph to eliminate unwanted data: only the straight line section is required.

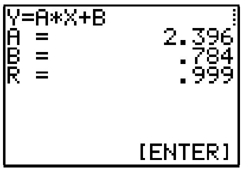


screen 3

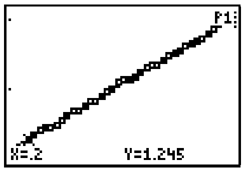


screen 4

Enter Analyse Curve fit Linear L1, L5



screen 5



screen 6

to fit line to **velocity** against time graph

A straight line is fitted to the selected velocity against time data points.

Results

The calculator displays the equation:

y = ax + b. This represents v = at + u (work this out - it is the same equation as a = (v - u) / t). Write down the values displayed for a, b and r in your table entering the data as a, u and r. Enter the measured height and (sloping) length of the ramp. Change the height and perform the experiment again. Repeat for at least six different heights. Measure the height (opposite) and length (hypoteneuse) of the ramp. a is the slope of the graph of velocity against time so the slope is the acceleration and the straight line means that the acceleration is constant.

b is the intercept of the graph on the y axis and so is the initial velocity, u.

r is a number which describes how well the equation matches (correlates with) the data. A value of 1.00 means a perfect scatter about the line.

Conclusion

The velocity of the ball increases at a steady rate with time so a falling ball moves with constant acceleration due to the pull of gravity. The acceleration of the ball increases with angle.

Definition of Acceleration

Following the same argument as before for velocity, we can say that there will be an "instantaneous acceleration" which may change from moment to moment. Hence:

$$\mathbf{a = dv / dt}$$

where a is acceleration and dv and dt mean the change in velocity and time as the time interval approaches zero. Thus the slope of velocity against time gives the acceleration at each point along the line. If the acceleration is constant then a straight-line plot is obtained. The slope of the line is the acceleration.

Option

Calculate the sine of the angle of the ramp from the horizontal. How could this information be used to calculate a value for g, the acceleration due to gravity? Why would this value be lower than the known value? What other information could be derived from this?